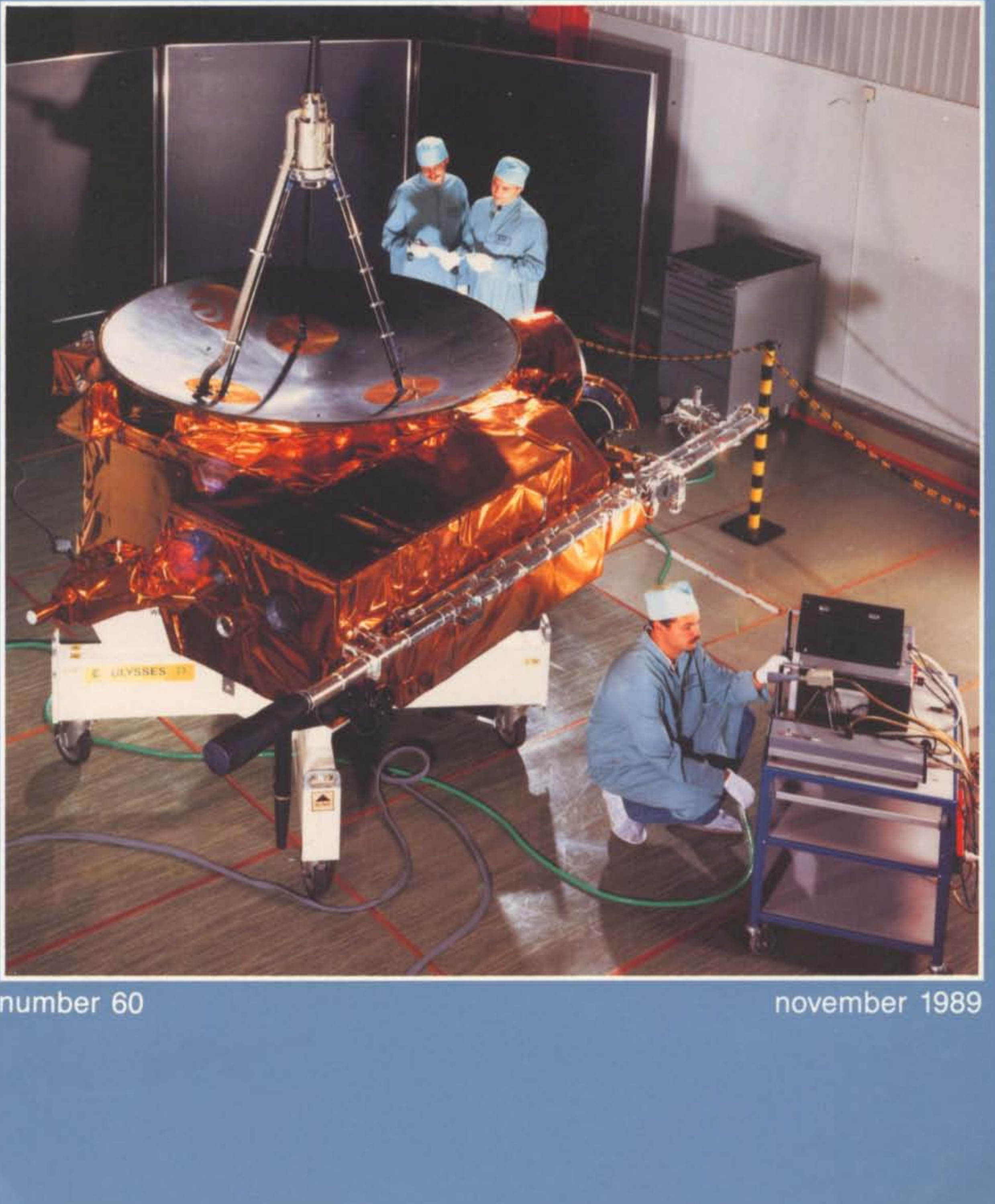
european space agency

esa bulletin

agence spatiale européenne



number 60

november 1989

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.

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The major establishments of ESA are:

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr H. Grage.

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agence spatiale européenne

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

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(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;
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(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.
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esa bulletin

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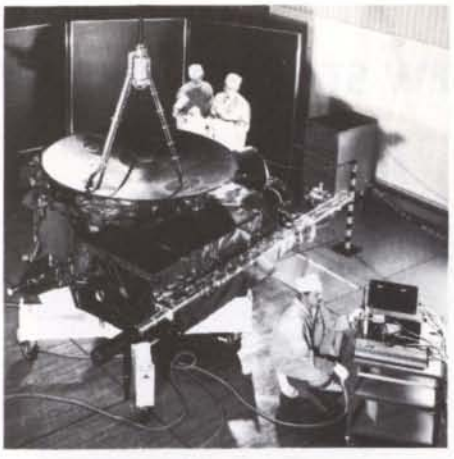

Front cover: Ulysses spacecraft under test at ESTEC (see page 8)

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

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Bruce Battrick, Duc Guyenne

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Layout
Carel Haakman

Montage
Keith Briddon, Paul Berkhout

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Printed in The Netherlands
ISSN 0376-4265

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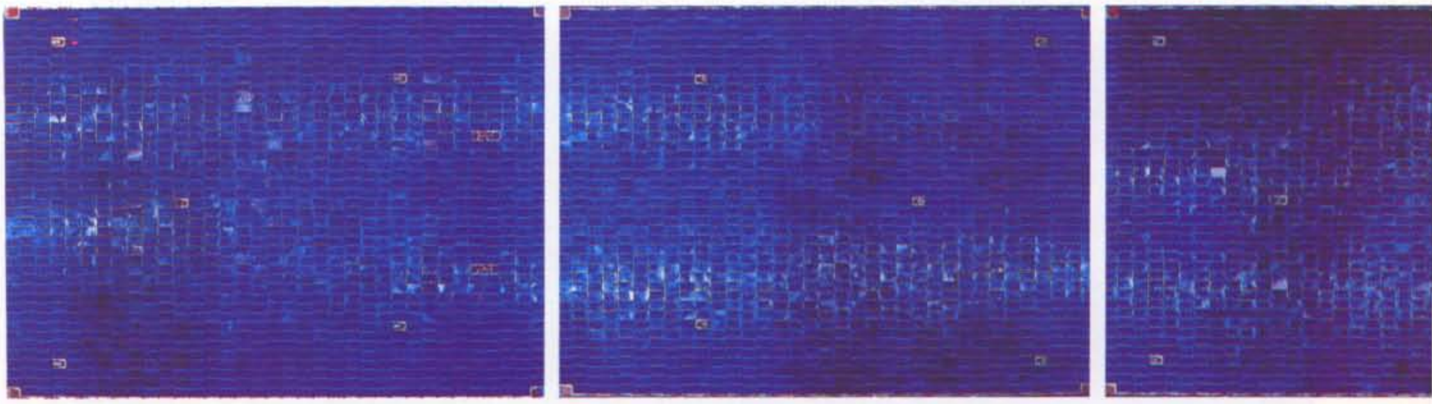

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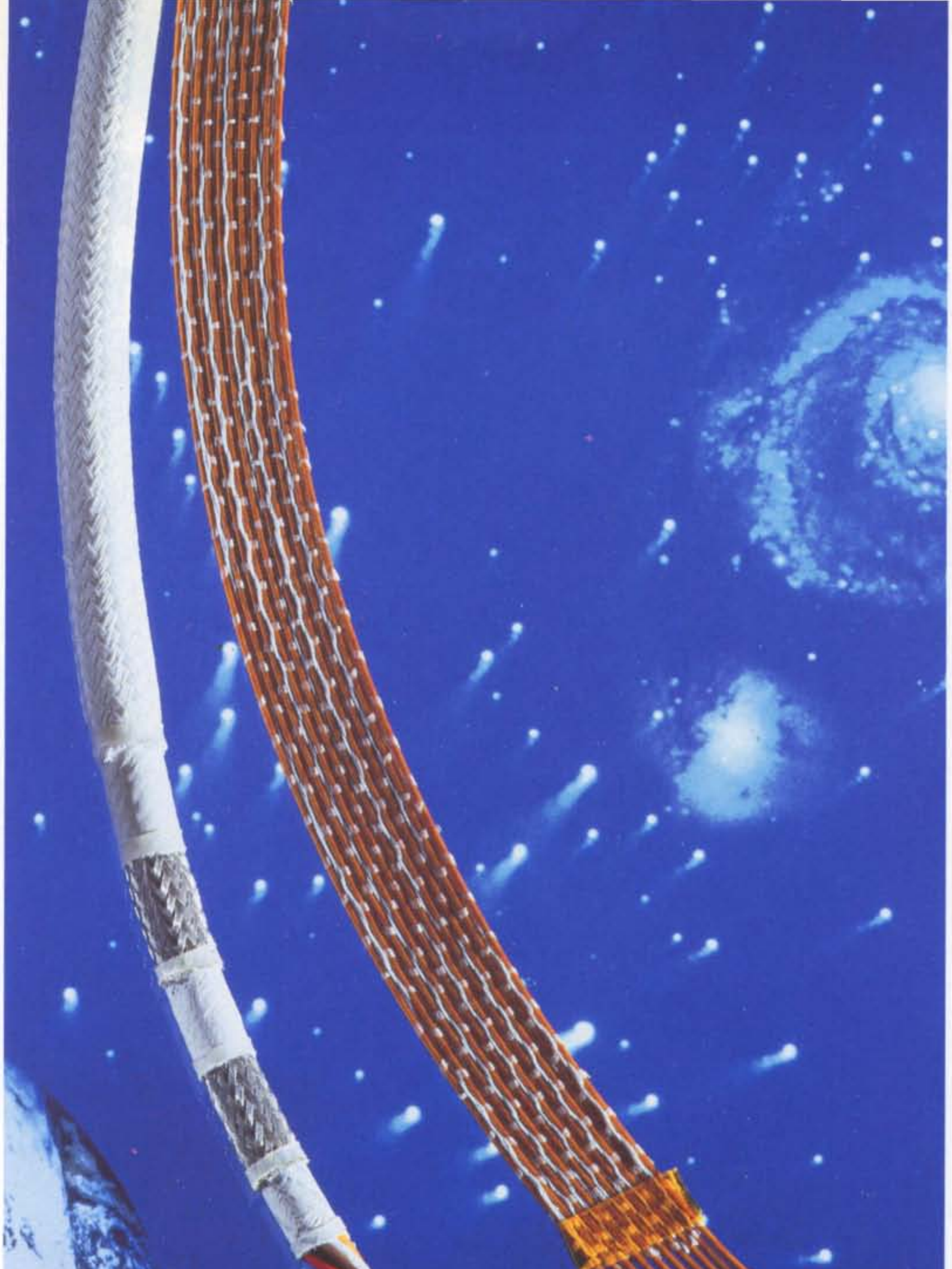

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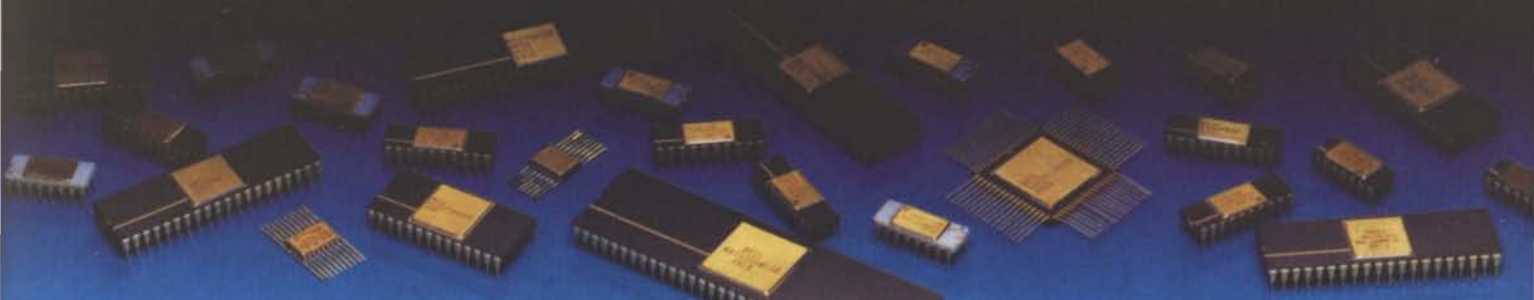

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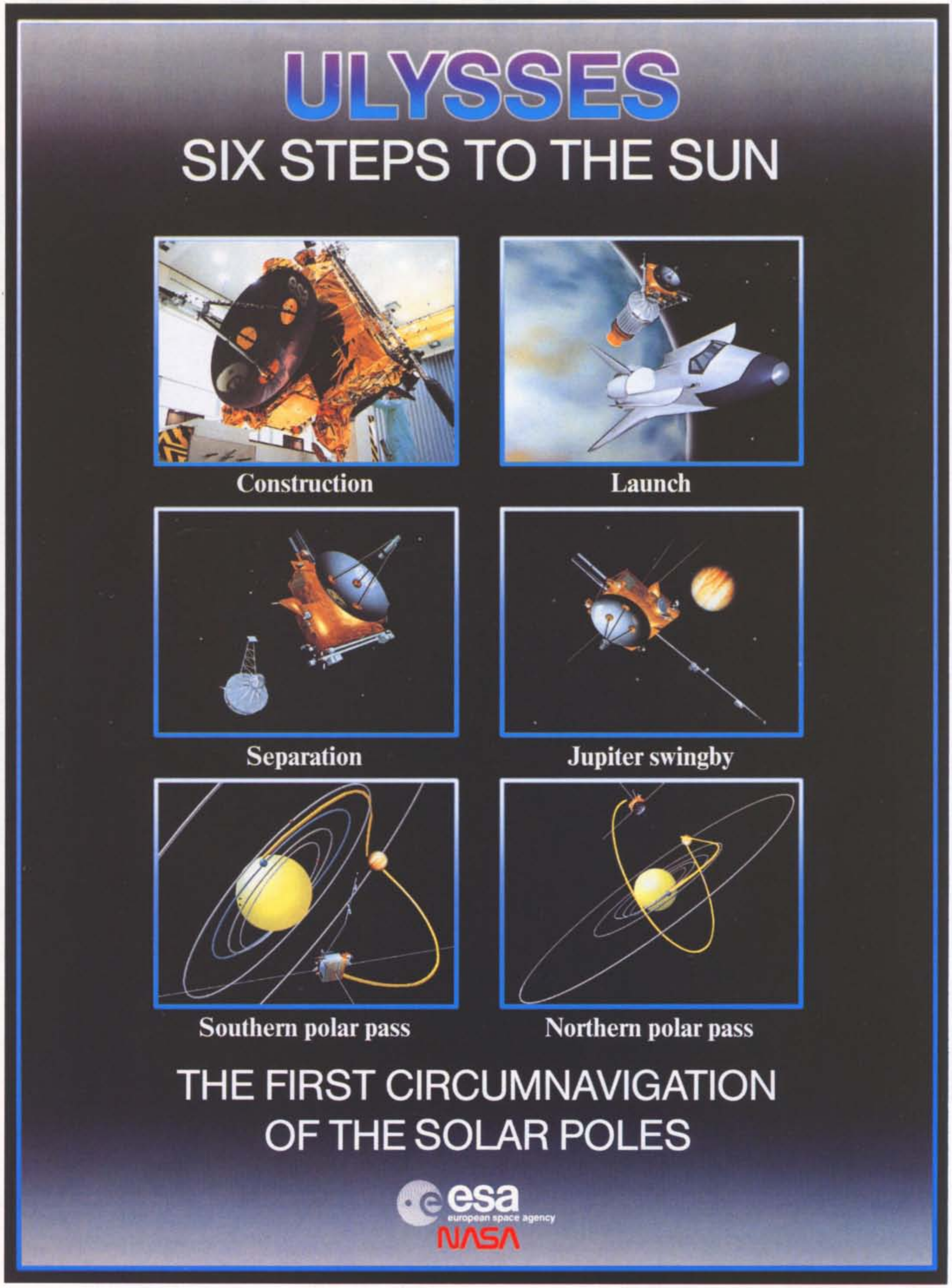
ULYSSES
SIX STEPS TO THE SUN
Construction
Launch
Separation
Jupiter swingby
Southern polar pass
Northern polar pass
THE FIRST CIRCUMNAVIGATION
OF THE SOLAR POLES
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Ulysses — Preparations for the Voyage over the Solar Poles Resumed

K.-P. Wenzel & R.G. Marsden
Solar and Heliospheric Science Division, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

The joint ESA-NASA Ulysses mission is finally scheduled to start its long-awaited interplanetary voyage in October next year. This will make Ulysses the first spacecraft to perform an exploration of the inner heliosphere covering the full range of heliographic latitudes, including the solar-polar regions. Following a period of storage after the Shuttle 'Challenger' accident, activities were resumed this year to recertify the spacecraft and its scientific payload for flight.

Introduction

The past year has seen a number of positive developments affecting the much-delayed Ulysses project. Among these, the resumption of NASA's Shuttle operations in the autumn of 1988, and the successful launches of the Magellan and Galileo planetary missions earlier this year, were perhaps the most significant external factors.

On ESA's side, reintegration of the scientific payload and spacecraft recertification was started in early 1989, after a spacecraft storage period lasting nearly three years (the second such period in the history of the Ulysses programme). These activities will continue until the beginning of 1990, when the spacecraft should be ready for shipment to the launch site.

The launch campaign at Cape Canaveral will start in May 1990, leading up to the Shuttle launch in early October 1990.

Within the overall programme, ESA is responsible for the development of the spacecraft and its in-orbit operation. NASA is responsible for the provision of the launcher and all launch services, for provision of the spacecraft's electrical power source (a Radioisotope Thermoelectric Generator, or RTG), for tracking and data acquisition support by the Deep-Space Network, and for processing and distribution of the scientific data.

Six steps on the way to the first circumnavigation of the solar poles

The Mission Operations Centre, which is to be staffed by a joint team of ESA and NASA personnel, will be located at the Jet Propulsion Laboratory (JPL), in Pasadena, California.

Ulysses' scientific payload consists of nine instruments that are provided by institutes from both ESA Member States and the United States. In addition, the spacecraft's telecommunications system will be used to conduct radio-science investigations.

The Ulysses mission

The primary scientific objective of the Ulysses mission is to explore the inner heliosphere over the full range of solar latitudes. The heliosphere is the vast region of space extending outwards from the solar corona. It is dominated by the magnetised stream of ionised gas, or plasma, that flows radially away in all directions from our star. This flow, which is called the 'solar wind', is the only large-scale astrophysical plasma that is available for in-situ study, just as the Sun is the only star close enough for its surface structure to be resolved. Observations of the Sun and the heliosphere are used as a basis for deciding what is possible in other astrophysical settings.

Our knowledge of the heliospheric plasma environment to date is based largely on the vast number of observations made during the past three decades by spacecraft operating close to the plane of the ecliptic (the plane in which the Earth orbits the Sun). If further progress is to be made in understanding the physics of the heliosphere, a comprehensive database of in-situ measurements made at all solar latitudes is required.

To obtain such a database is the fundamental goal of Ulysses' unique exploratory mission. Specific topics to be addressed are (Fig. 1):

- the three-dimensional structure of the solar wind and heliospheric magnetic field
- solar radio bursts and heliospheric plasma waves
- solar hard X-rays
- the propagation and acceleration of solar energetic particles
- the propagation and deceleration of galactic cosmic rays
- the distribution of interplanetary/interstellar neutral gas and cosmic dust
- the origin of cosmic gamma-ray bursts.

Direct ballistic injection of a spacecraft into a solar polar orbit requires a launch energy far in excess of the capabilities of currently-available launch vehicles. In order to achieve such an orbit, Ulysses will first make a close flyby of Jupiter, during which the planet's immense gravitational pull will act as a sling-shot to propel the spacecraft out of the ecliptic plane and send it arcing back towards the Sun (Fig. 2).

After the encounter, Ulysses will be travelling in an elliptical orbit in a plane almost at right-angles to the ecliptic, climbing slowly in solar latitude. The first high-latitude pass will be over the Sun's southern pole, followed one year later by the second (northern) polar pass.

Although enabling the spacecraft to get what amounts to a free ride on a natural booster, the Jupiter swing-by manoeuvre places a major constraint on the mission, namely that launch opportunities occur only once every 13 months.

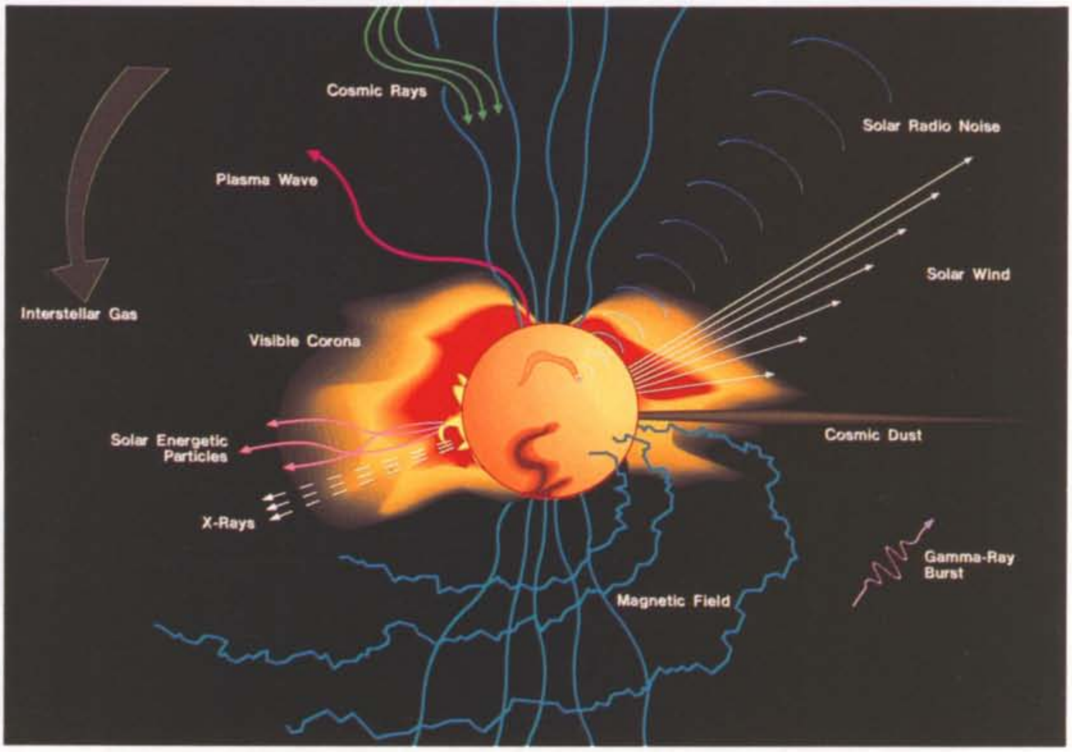

Figure 1. Schematic of various solar-, interplanetary- and galactic-science topics that will be investigated by the Ulysses mission

The Ulysses launch vehicle

Since the start of the Ulysses project in 1977, there have been many versions of the launch vehicle. Although NASA's Space Transportation System (STS) has remained as the baseline for achieving a circular orbit around the Earth, there have been many variants of the Upper Stage needed to propel the spacecraft towards Jupiter.

Following the Challenger accident in 1986 and the resulting delay in the launch of Ulysses until 1990, NASA made a major review of Shuttle safety policy. One outcome was that a liquid-fuelled Centaur Upper Stage was considered to be too dangerous to be carried by the Shuttle. It was therefore decided to revert once again to a US Air Force Inertial Upper Stage (IUS). This two-stage solid motor will be augmented by the PAM-S boost motor, which is a variant of the well-proven PAM-D Payload Assist Module (Fig. 3).

Although the IUS and PAM have both been flown previously with the STS, they have never been used in combination. Their main role has been for the injection of fairly heavy payloads into geostationary orbit. Consequently, although the combined weight of the spacecraft and the PAM-S is such that the IUS sees a normal load, the situation for PAM-S is very different. Instead of the 1 ton of a typical PAM payload, the Ulysses spacecraft weighs only 370 kg. As a result, the PAM-S imparts an acceleration in excess of 11 g, rather than the usual 4—5 g experienced by other payloads. Since the low payload weight and high acceleration are both outside the existing PAM database, considerable analysis and some testing has been needed to prove this motor's suitability for the Ulysses mission.

Project status and plans
As a consequence of the delay resulting

The FM recertification programme includes a rigorous series of system-level electrical tests and a number of mechanical checks. The first Integrated System Test (IST) was successfully completed at Friedrichshafen in mid-September.

Thereafter, the complete spacecraft started what it is hoped will be its last series of Earth-bound journeys. From Dornier, Ulysses was transported to IABG near Munich, where it was successfully demonstrated that the spacecraft's low magnetic levels have remained unchanged since its initial integration in 1983.

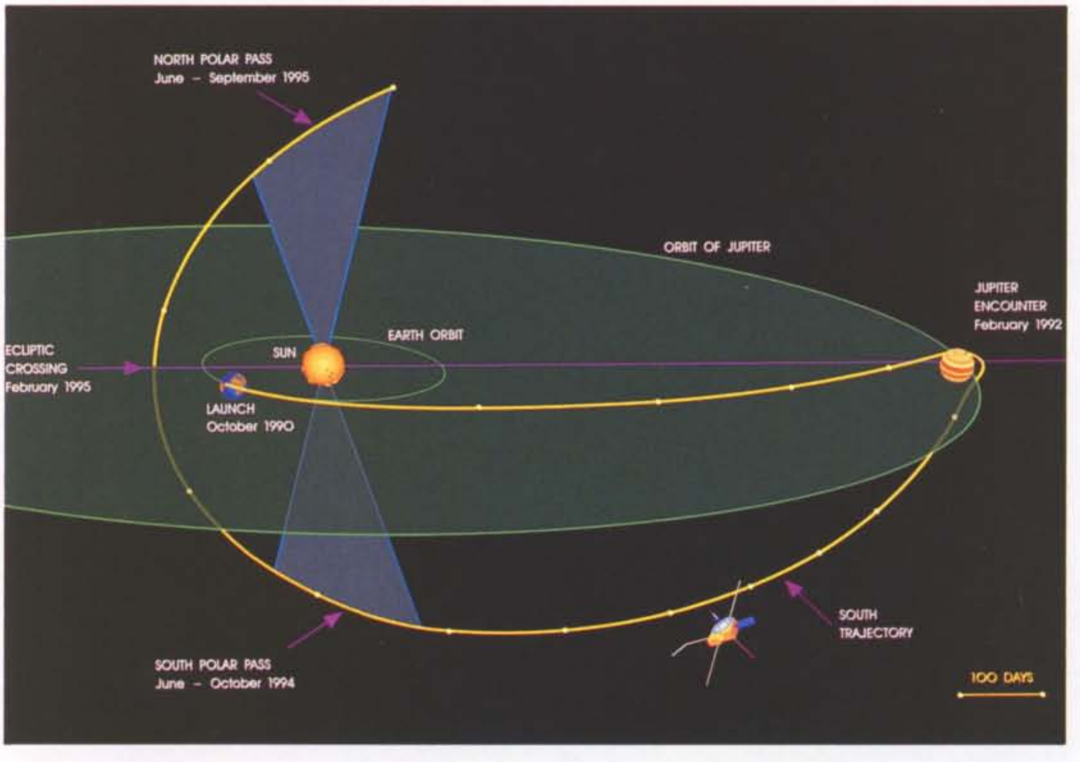

Figure 2. Ulysses trajectory viewed from 15° above the ecliptic plane. The blue segments show regions in which the heliographic latitude of the spacecraft exceeds 70°. Dots are plotted along the Ulysses trajectory at 100 d intervals

from the Challenger accident, the Ulysses spacecraft was put into storage at the Prime Contractor's site (Dornier) in Friedrichshafen (W. Germany). The majority of the scientific instruments were returned to the investigator teams. This year has seen a significant increase in hardware-related activities.

Starting in January, following the refurbishment of memory modules in the spacecraft's data-handling subsystem and a number of experiments, the Qualification Model (QM) spacecraft was built up using flight-spare units. It was then subjected to system-level electrical tests. These tests, conducted at Dornier, served to check out the flight-spare hardware, while at the same time providing training for the (largely new) assembly, integration and test team, prior to starting Flight Model (FM) spacecraft integration.

On 5 October, the spacecraft arrived at ESTEC in Noordwijk (NL), where it will undergo its final recertification tests, including cold thermal-vacuum exposure, a second IST, spin balance testing, and a number of other mechanical tests. Between these activities, Mission Operation System (MOS) tests will be slotted in, designed to demonstrate the readiness of the ground system for the in-orbit operation, and to train the (totally new) spacecraft operations team.

The ESOC (Darmstadt) Spacecraft Operations Team that was dissolved in 1986 has been reformed, and will transfer to JPL in early 1990 to take its place as part of the joint ESA-NASA Mission Operations Team. This will include a Ulysses Science Coordination Office.

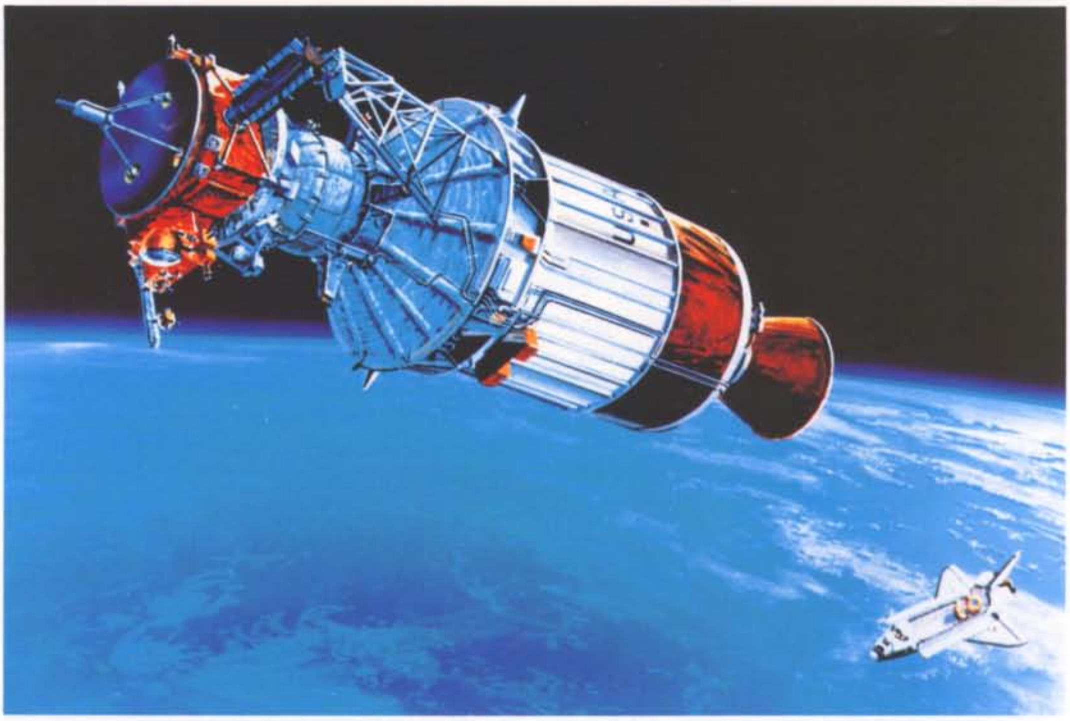

Figure 3. Artist's impression of Ulysses and the large Upper Stage after deployment from the Space Shuttle. The Upper Stage consists of the two-stage IUS (large diameter) coupled to the PAM-S boost motor (small diameter). Prominent features of the spacecraft are the parabolic high-gain antenna and the RTG. The launch support structure, which is attached to the IUS adapter, carries RTG cooling lines

Some adjustments in mission operations planning have been necessary due to the long launch delay. The flight-control computer system has had to be replaced, for example, necessitating the conversion of spacecraft and payload control software.

A Spacecraft Pre-Shipment Review will be held in February 1990, followed by a buffer period, which will lead to resumption of the launch campaign at Cape Canaveral in May 1990.

Acknowledgement
The authors acknowledge the contribution provided by D. Eaton, Ulysses ESA Project Manager.

Further Reading

Other articles on the Ulysses mission that have appeared in earlier ESA publications include:

— The International Solar-Polar Mission – Its Scientific Investigations, K.-P. Wenzel, R.G. Marsden & B. Battrick, ESA Publication SP-1050, July 1983.

— The ISPM Mission: Science Objectives and Mission Overview, K.-P. Wenzel & R.G. Marsden, ESA Journal No. 2, 1983.

— Ulysses — The Voyage Must Wait, R.G. Marsden & K.-P. Wenzel, ESA Bulletin No. 48, November 1986.

Why 'Ulysses'?

Why is the first space mission to circumnavigate the poles of the Sun called 'Ulysses'?

When the project was started in the mid-1970s, it was called the 'Out-of-Ecliptic' mission, and later became the 'International Solar Polar Mission' (ISPM). It was renamed 'Ulysses' in 1984, at the suggestion of one of the Scientific Investigators, Prof. B. Bertotti of the University of Pavia (Italy).

The story is told in Dante's 'Inferno' that Ulysses, the Greek hero of the Trojan War and King of Ithaca, becoming restless for further adventure, wanted to set off for another voyage to explore beyond the known world, which at that time ended at Gibraltar,

'to venture the uncharted distances .... of the uninhabited world behind the Sun .... to follow after knowledge and excellence.'

'Ulysses' therefore seems to be an apt name for man's first adventure over the solar poles.


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Marconi technology has played a key role in both ESA and national space programmes. From prime contractor in the UK X-ray astronomy satellites, the supplier of UV Cameras for the International Ultra-Violet Explorer, to providing the propulsion system for ESA's Infrared Space Observatory, the experience continues to grow.
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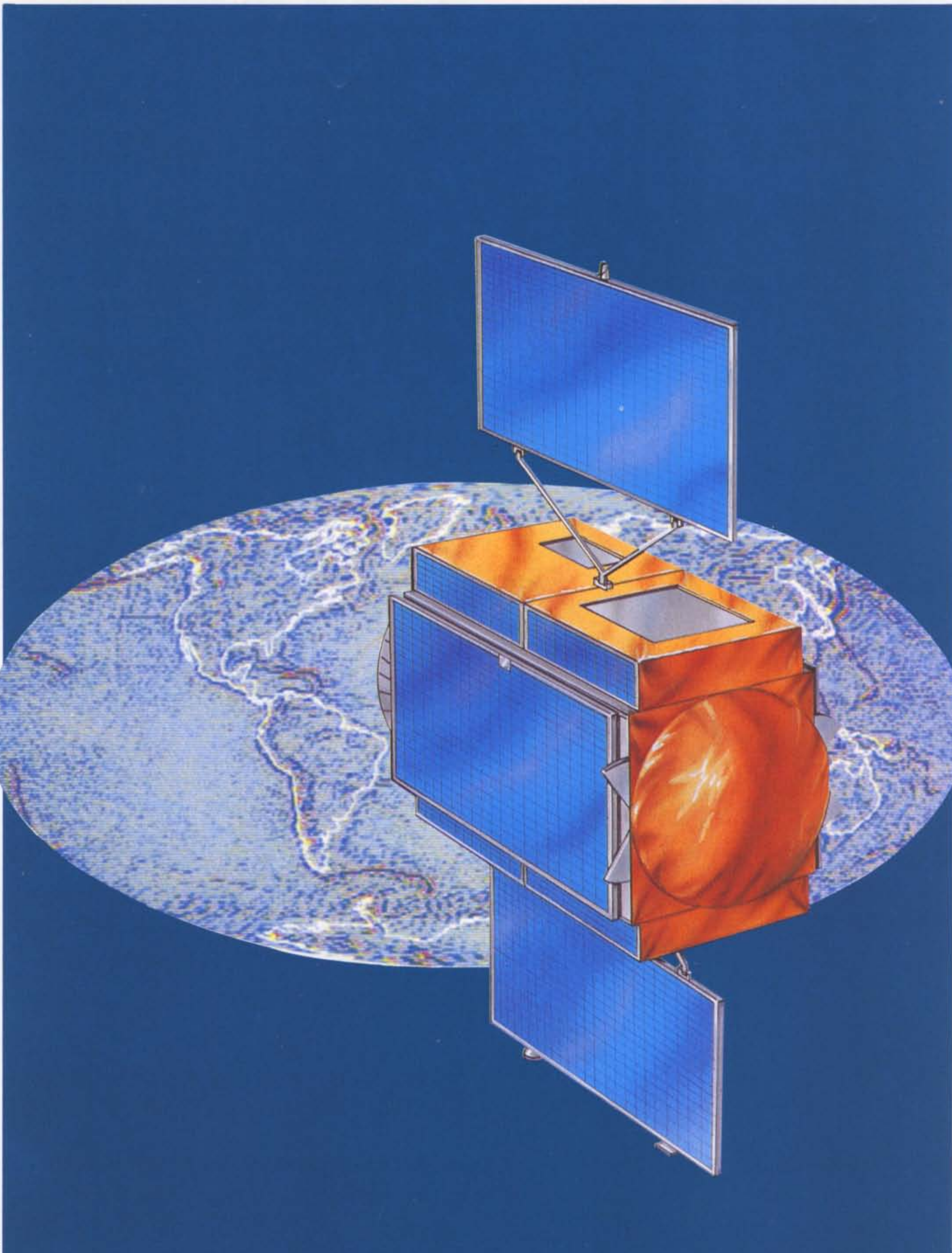


photo: Dornier

Aristoteles — A European Solid-Earth Mission

G.Mecke
Earth-Observation Preparatory Programme, ESA Directorate of Earth Observation and Microgravity Programmes, ESTEC, Noordwijk, The Netherlands

The Aristoteles mission is a European solid-Earth-sciences programme dedicated to precise global measurement of the Earth's gravity field with unprecedented accuracy. As part of ESA's Earth-Observation Programme, this satellite mission will be an ideal tool for gathering gravity-field, magnetic-field and other data on a global scale, quickly and at reasonable cost. It will contribute both directly and indirectly to a significant improvement not only in our geophysical, geodetic, and oceanographic knowledge, but also that in many other disciplines and applications (Fig. 1).

Contacts with the scientific community and bilateral discussions with ESA Delegations have shown considerable interest in the Aristoteles Programme in Europe and in the United States, as well as in other countries. Discussions with NASA on possible American participation in the mission are currently in progress.

Scientific rationale and objectives

Progress in the Earth-sciences over the past two decades has, as in many other areas of science, been considerable. Since the mid-1960s, for instance, geology has been revolutionised by the theory of plate tectonics. Most of today's knowledge about the structure and dynamics of the Earth has been obtained by interpreting data from measurements of its geopotential fields, of seismic activity and of the irregularities observed in its rotation parameters. These observations will also be used in the coming years to develop a strategy for solving the many unanswered questions in the interdisciplinary science of 'geodynamics'.

Geodynamics is concerned with the physical forces and processes that affect the Earth's core, mantle and crust; it also embraces the interactions of the solid Earth with the atmosphere and the oceans. Until recently, such processes were treated as independent from each other, and the close connection between topographic features, geological structures and natural-resource distribution on the Earth's surface and its structure and dynamics at great depths was not fully recognised.

* Applications and Research Involving Space Techniques Observing The Earth fields from Low Earth orbit Spacecraft.

In the past two decades, however, the concept of and evidence for plate tectonics and sea-floor spreading has revolutionised our understanding of how the Earth works. It is now commonly accepted that many of the processes that shape the Earth's surface are related to processes very deep in its interior. Geodynamics is therefore now a highly interdisciplinary and complex research field, involving increasingly refined studies of the Earth's lithospheric dynamics, rotation (polar motion, length-of-day), surface geometry, gravity field, magnetic field, and sea level.

Space techniques provide a powerful means of studying the links between these quantities on a global scale, and can therefore contribute substantially to our achieving a better knowledge as to how this complex system works.

Geopotential field research

Possibly the most essential prerequisite for our understanding of the structure, dynamics and evolution of planet Earth is precise determination of its gravity and magnetic fields. Both have been measured and mapped in the past in a general way, but not in sufficient detail and, more importantly, not homogeneously on a global scale.

The primary needs for improved high-resolution geopotential data (down to about 100 km) are in:
— solid-Earth geophysics
— physical oceanography
— climatology and global change.

Solid-Earth geophysics
The structure of the gravity field, as measured on the Earth's surface or in near-Earth space, directly reflects irregularities in the mass distribution within the planet's interior. Any changes in this mass distribution

due to internal and external forces become apparent as time variations in the gravity field. Since all geodetic observations, from levelling to inertial navigation systems, are affected by motions of matter on the Earth's surface, detailed knowledge of the gravity field is of fundamental importance for such discipines as geodesy, geophysics, and oceanography.

Physical oceanography
The sea surface differs from the classical reference surface, the geoid, because of currents, wind stress, and salinity and temperature variations. In physical oceanography, an understanding of the departure of the actual sea surface (as measured, for example, by a satellite altimeter) from a unique zero reference level, provides the basis for observing ocean-circulation features down to the very small scales of interest.

The global homogeneous determination of the Earth's gravity field by Aristoteles will provide data of sufficient quality to permit the World Ocean Circulation Experiment (WOCE) to measure all the components of ocean circulation, to substantially refine the models, and to infer the nature of ocean/atmosphere interaction.

The temporal variations in ocean-surface topography are an important aspect of physical oceanography. In particular, changes in the ocean surface's shape relate directly to different driving forces and to changes in the ocean/atmosphere environment. The El Nino Southern Oscillation phenomenon is a good example of the interrelation between oceanic variables and climate.

Climatology and global change
Another example of the need for establishing a high-accuracy reference surface for the World's ceans is the study of secular sea-level rise. The monitoring of sea-level change is an integral part of the study of global change, particularly if combined with surface-temperature and ocean water-body temperature surveys, and monitoring of the ice volumes of the World's glaciers and ice sheets.

Positioning geodesy
In view of the dynamic nature of planet Earth, we can no longer maintain the traditional assumption of regarding the shape of the Earth as constant. In fact, observed phenomena, such as tectonic plate motion, internal heat convection, polar motion and climatic changes are all providing evidence that the Earth is far from a static system. Powerful energy sources in its interior continually manifest themselves through major catastrophic events on its surface.

The list of scientific objectives would be incomplete if it were not to include the study of lithospheric dynamics by means of precise measurements of points on the Earth's surface and their motions. Aristoteles, though primarily a geopotential field mission, has the ability to conduct such studies as a secondary mission objective, which would be of benefit in:

— geodesy: connection of dynamic and inertial reference systems

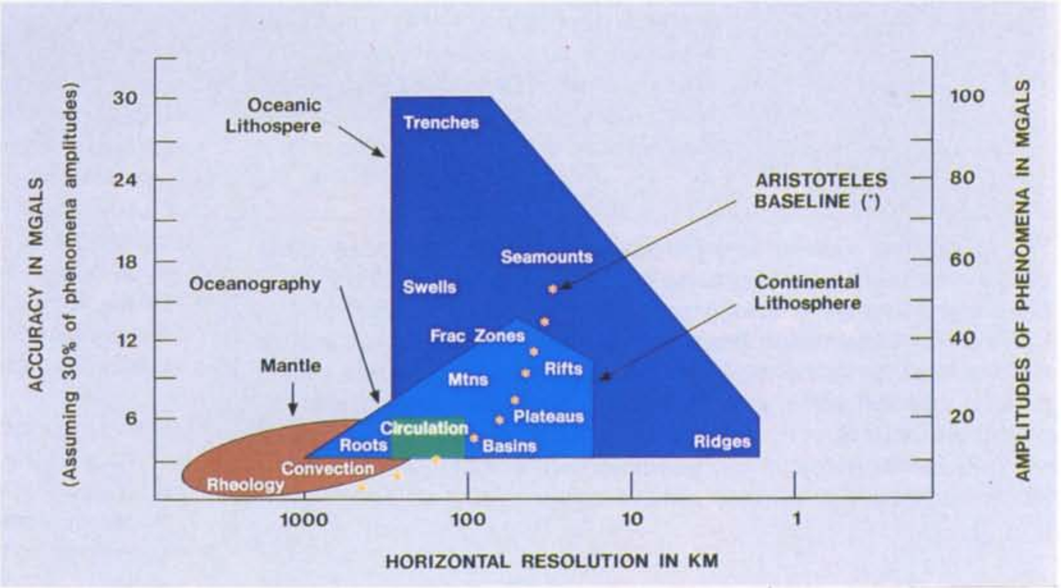


Figure 1. Gravity-measurement accuracy requirements and Aristoteles' capabilities

— geodynamics: monitoring of deformations in seismic areas and monitoring of volcanic activity
— offshore operations: positioning of exploration sites and oil platforms.

Programme background
ESA has been working with industry and the scientific community since the mid-eighties on developing a number of conceptual mission designs in preparation for Aristoteles. As part of the Agency's Earth-Observation Preparatory Programme (EOPP), a system concept for the measurement of anomalies in the Earth's gravity field has been developed that confirms the basic technical feasibility of the approach. A first laboratory model of the highly sensitive accelerometer required for the gravity-gradient determination has been manufactured and tested, and software simulators modelling the data processing that will be needed have already been developed and are now being used for system studies.

The ESA 'SESAME' (Solid-Earth Science and Application Mission for Europe) Workshop in 1986 resulted in a recommendation, based on a single-satellite or a dual-satellite concept, for a mission that would combine gravity-gradiometer and magnetometer measurements at low orbital altitude (about 200 km) with a high-altitude (about 7000 km) Point-Positioning Mission (PPM). The use of satellite-to-satellite tracking systems was recommended for both concepts, and it was also suggested that ESA should explore the possibility of a joint venture with NASA for the two-satellite concept.

Following these recommendations, studies were performed on the possible flight of instruments like 'PRARE' (Precise Range And Range-rate Equipment) for precise tracking, and 'GRADIO' (a gradiometer consisting of a set of accelerometers for gravity-gradient measurements) on the American GRM satellites. These studies showed a clear preference for the single-satellite concept for both scientific and cost reasons.

A subsequent joint ESA/NASA Workshop held in Matera, Italy, in 1987 also recommended the single-satellite concept, with a gradiometer as the baseline payload. Secondary objectives included magnetic-field measurements and a Global Point Positioning System (GPS) as desirable extensions of that baseline. The Matera Workshop also welcomed any possible ESA/NASA cooperation and recommended the setting up of an international data-user team.

It was at this point that the ESA Member States approved preparatory activities for a mission called 'Aristoteles' as part of the Agency's Earth-Observation Preparatory Programme (EOPP). These activities were to be based on the conclusions of the Matera Workshop and included both system-level studies and complementary technology and data (pre)-processing tasks.

Scientific Working Groups were created in 1988 to provide ESA with advice on both the gravity- and magnetic-field mission aspects. The data-processing needs have also been carefully considered.

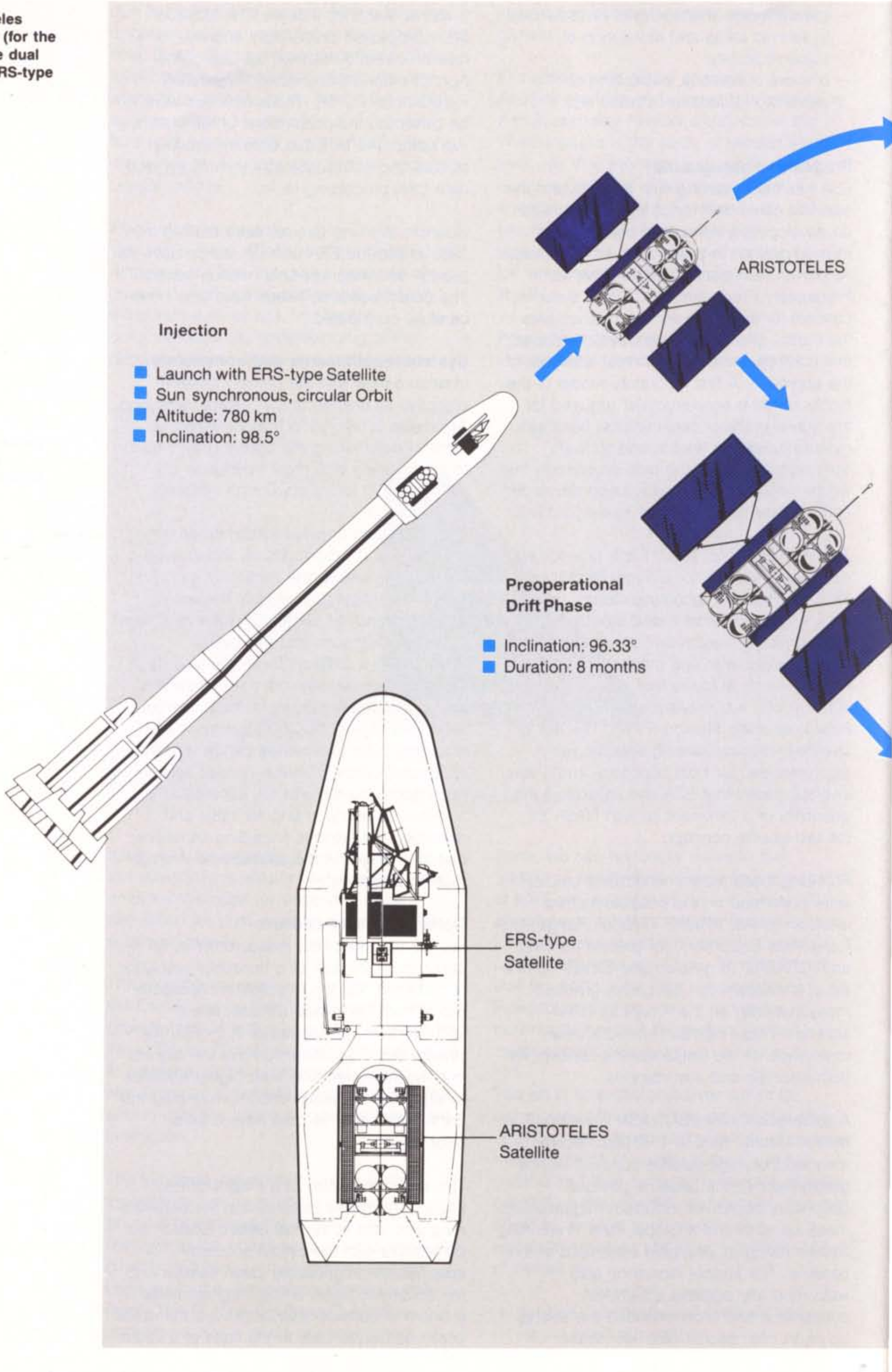
System requirements and constraints
In accordance with the primary mission objective as defined at the Matera Workshop, Aristoteles is tailored to the prime requirement of determining the Earth's gravity field to an accuracy of 5 mgal (resolution of 100 km x 100 km at the Earth's surface).

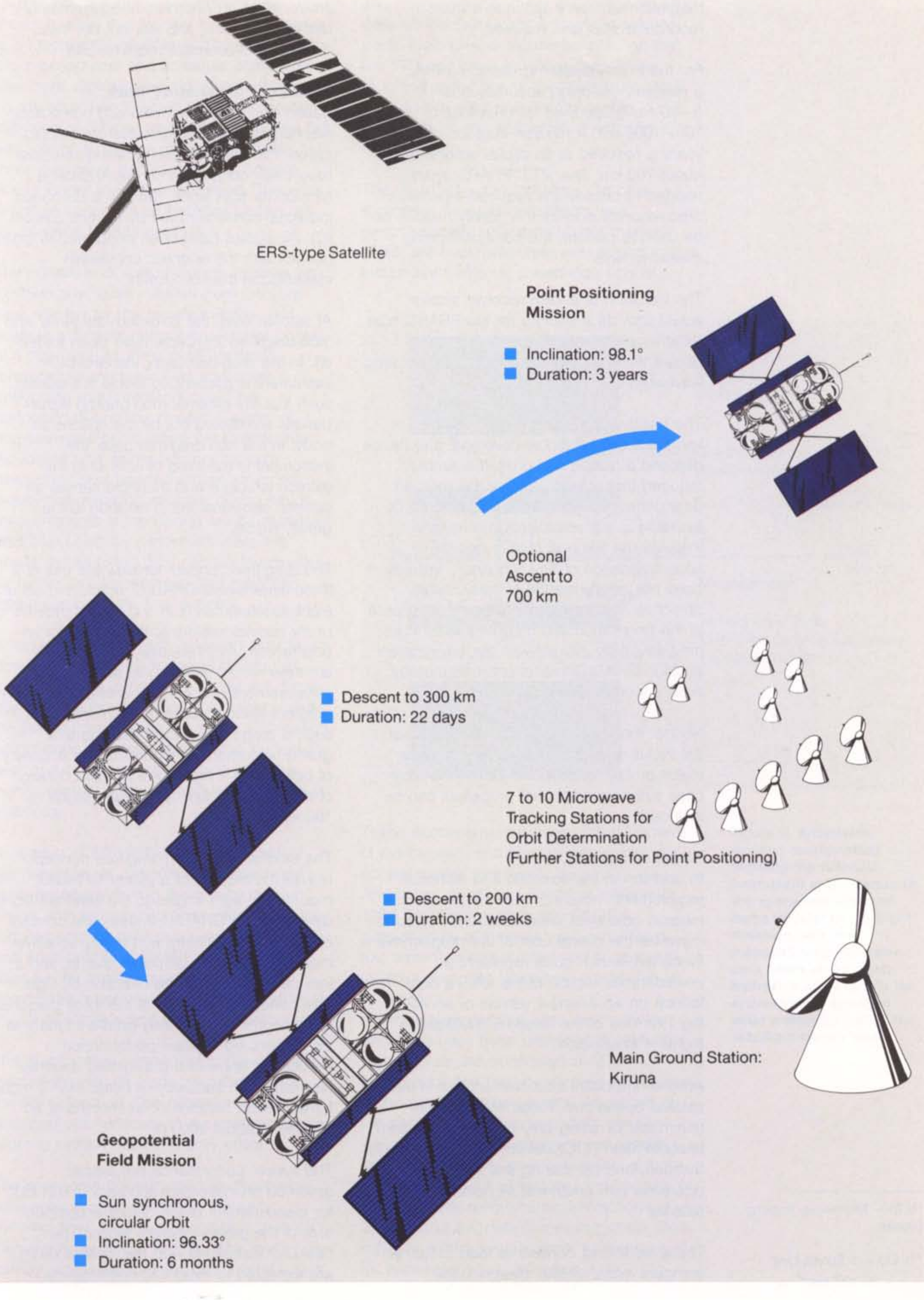
The spacecraft concept (drag-free or non-drag-free) and orbital altitude, the mission duration, as well as the sensitivity, sampling rate and configuration of both the accelerometers and the GRADIO instrument, have to be selected such that this overall requirement is fulfilled. There are also stringent requirements on: the matching of the accelerometers (scale-factors); internal alignment of the GRADIO instrument and matching of its geometrical centre with the spacecraft centre of mass; precise attitude knowledge; low-disturbance accelerations; and low variations in angular rates and parasitic accelerations (including variations due to changes in the spacecraft's internal mass distribution).

Optional mission elements
For the magnetic-field measurements, an accuracy of 2—5 nT at a horizontal resolution of 100 km x 100 km is projected. Measurements from low orbital altitude (about 200 km) to study anomalies in the Earth's lithospheric magnetic field have the highest priority; measurements from higher altitudes to study the magnetic fields surrounding the Earth and that of its core have a lower priority.

The accommodation of a magnetometer aboard Aristoteles requires that the satellite's magnetic field at the instrument location be compatible with the overall accuracy specified. A magnetically clean satellite and the accommodation of the magnetometer on a boom of considerable length are the rather costly consequences. In the case of a vector

Figure 2. Aristoteles mission scenario (for the case of an Ariane dual launch with an ERS-type satellite)




ERS-type Satellite
Point Positioning Mission
Inclination: 98.1°
Duration: 3 years
Optional Ascent to 700 km
Descent to 300 km
Duration: 22 days
7 to 10 Microwave Tracking Stations for Orbit Determination (Further Stations for Point Positioning)
Descent to 200 km
Duration: 2 weeks
Main Ground Station: Kiruna
Geopotential Field Mission
Sun synchronous, circular Orbit
Inclination: 96.33°
Duration: 6 months

magnetometer, very accurate attitude reconstitution is also required.

For the Point-Positioning Mission (PPM), a relative positioning accuracy goal of 5—10 cm is specified for baselines of 100—1000 km. A mission duration of three years is required at an orbital altitude of about 700 km. The MTS*/PRARE system needed to provide the required a-posteriori orbit reconstitution for the gravity mission can be used to perform the point-positioning measurements.

The inclusion of a GPS receiver system would provide a backup for the PRARE orbit-determination system, and would complement the gravity-field measurements at long wavelengths.

The baseline and all optional mission variations call for global coverage, and hence demand a quasi-polar orbit. It is further required that at least 90% of the payload data generated onboard the spacecraft be available to the scientists. Care must therefore be taken to ensure that the accommodation of any secondary instrument does not jeopardise the primary mission objective. This may prove difficult in the case of the boom-mounted magnetometer, which may adversely interact with the environment and the GRADIO instrument, and thereby pose accommodation problems.

Neither the accommodation of a GPS, nor the inclusion of the PPM appear to pose major problems, provided that in the latter case sufficient additional propellant can be included.

Financial aspects

In addition to the scientific and technical requirements resulting from the pre-defined mission objectives, there is also the need to minimise the overall cost of the programme. Since the launch costs represent a considerable fraction of the total, a dual launch on an Ariane-4 vehicle or an APEX flight on one of the Ariane-5 qualification flights is anticipated.

Another important cost element lies in the satellite operations. These costs will be minimised by using only one telemetry and telecommand (TTC) station, namely Kiruna in Sweden, and by sharing this station's operation with another ESA polar-orbiting satellite.

These additional constraints lead to further stringent mass/volume, design load/environment, flight-profile, onboard-memory, satellite-autonomy, and last but not least, development-schedule requirements.

Results of preparatory work

Based on the requirements and constraints mentioned above, system-level studies (so-called 'Pre-Phase-A' and 'Phase-A' studies) have been conducted on the Aristoteles mission for ESA since 1987 by a European industrial consortium led by Dornier System (D). All studies have been performed in close contact with the scientific community interested in the solid Earth.

At satellite level, the so-called 'drag-free' and 'non-drag-free' concepts have been traded-off. In the drag-free case, the GRADIO instrument is suspended inside the satellite such that the external (non-gravity) disturbances are filtered out by the spacecraft body. In the non-drag-free case, the instrument is mounted directly onto the satellite structure and therefore senses all external accelerations in addition to the gravity signal.

The drag-free concept foresaw the use of a three-dimensional GRADIO, employing either eight accelerometers in a cubic arrangement, or six accelerometers at the corners of an octahedron. All three axes of each accelerometer would yield highly sensitive measurements. All components of the gravity gradient tensor could be determined with such a drag-free concept, leading to a gravity-field anomaly reconstruction accuracy of better than 4 mgal for a mission duration of three months and an orbital altitude of 180 km.

The studies of the non-drag-free concept resulted in the use of a planar GRADIO mounted at right angles to the satellite's flight direction. The GRADIO in this case consists of four accelerometers with highly sensitive measurement axes perpendicular to, and a less sensitive axis in the direction of, flight. This concept allows two of the three diagonal components of the gravity-gradient tensor to be determined. System performance simulations showed a gravity-field anomaly reconstruction accuracy of better than 5 mgal for a mission duration of six months at an altitude of about 200 km.

The system-performance simulations assumed an instrument accuracy of 0.01 EU** for measurement of the diagonal components of the gravity-gradient tensor. The GRADIO instrument and the satellite design are expected to meet this performance.

*MTS = Microwave Tracking System

**1 EU = 1 Eötvös Unit = 10^{-9} sec^{-2}

Overall, the non-drag-free concept was shown to meet the primary mission objective, to be technically feasible and to comply with the imposed cost and schedule constraints. The more sophisticated drag-free concept, on the other hand, would yield a somewhat improved gravity reconstruction accuracy, but was judged to involve greater risk, to be more expensive, and to require a considerably longer development period. The non-drag-free concept was therefore chosen as the baseline for further study.

The constraint of a dual launch imposes an injection orbit quite different from the final orbit needed for the gravity mission, and leads to a nine-month pre-operational phase at a high altitude. Parts of the optional missions like magnetic-field and point-positioning measurements could be performed during this phase. A series of manoeuvres then transfers the satellite into the low-altitude, Sun-synchronous, near dawn-dusk orbit needed for the six-month gravity-determination mission, during which measurements of the Earth's crustal magnetic field could also be performed. After this phase, the satellite's orbit can be re-adjusted for further point-positioning and magnetic-field measurements if so desired.

Aristoteles must be kept within an altitude bandwidth of a few kilometres during the low-orbit phase in order to counteract decay due to aerodynamic drag. This aspect, and the limited contact with the single TTC station (about once per day), means that the satellite itself and its operations scenario must be highly reliable, with a considerable degree of autonomy.

A number of MTS/PRARE ground stations are necessary to determine the spacecraft's orbit, especially during the gravity mission phase, with an accuracy compatible with the requirements for orbit maintenance. These and additional MTS/PRARE stations can be used for the precise a-posteriori orbit determination necessary for the evaluation of the GRADIO data and for point positioning.

The gradiometer is mounted in the centre of the satellite with its plane perpendicular to the flight direction. The propellant tanks are arranged symmetrically to the gradiometer in order to reduce the self-gravity effect.

The spacecraft flys with the two deployable solar-array wings edge-on to the aerodynamic flow. To reduce the overall area of the solar-array wings, and thereby limit aerodynamic disturbances from lateral winds and misalignments, there are additional solar cells on the Sun-facing side of the satellite body. Field-of-view requirements mean that the TTC and other antennas have to be mounted at the tips of the solar-array wings. The satellite electronics are mounted in two side pods on the spacecraft (Earth and anti-Earth faces).

The GRADIO accelerometers, the main Aristoteles payload instruments, use electrostatically suspended proof masses, which are kept motionless with regard to the instrument frame by closed-loop control.

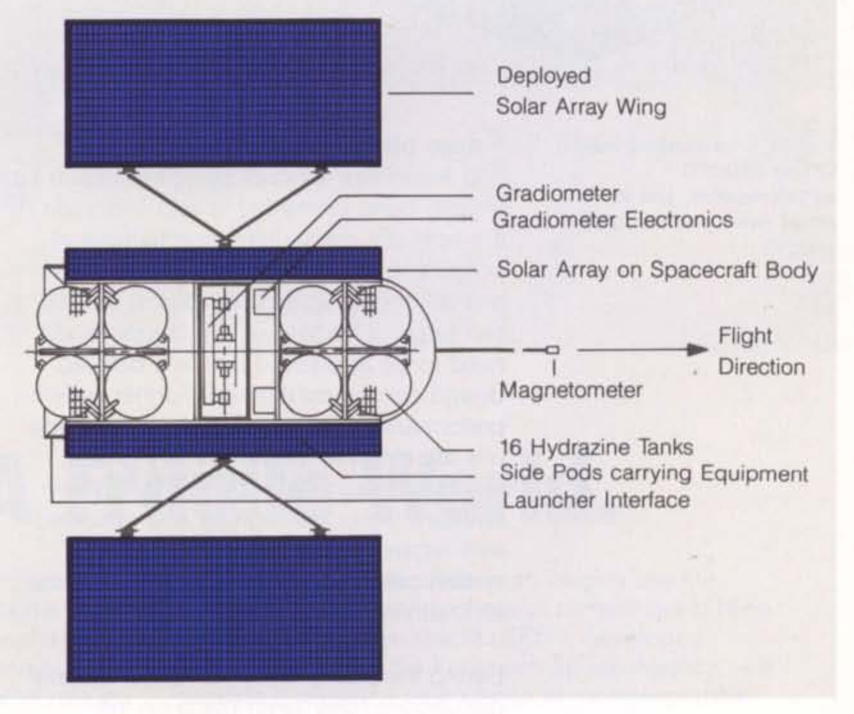


Figure 3. Aristoteles payload configuration, showing the GRADIO instrument at the centre of the spacecraft, directed perpendicular to the flight direction, and the (optional) magnetometer on a boom at the front. Hydrazine propellant in the symmetrically arranged tanks makes up half of the satellite's launch mass

These accelerometers are a critical element of the mission, and pre-development of an accelerometer specifically tailored to Aristoteles' needs was therefore initiated in 1988. The French company ONERA, supported by a European industrial team, has already manufactured and successfully tested a complete laboratory model (Fig. 4).

In the data-processing area, two software packages have been prepared in 1988/89 that simulate the generation of GRADIO output data and their processing for recovery of the gravity-gradient tensor. While one of the packages involves important simplifications regarding instrument and satellite characteristics, the other represents a more elaborate model that includes the impacts of moving parts, aerodynamic interactions, and all stages of the data-processing chain. Both software packages are currently being used for system-sensitivity analyses.

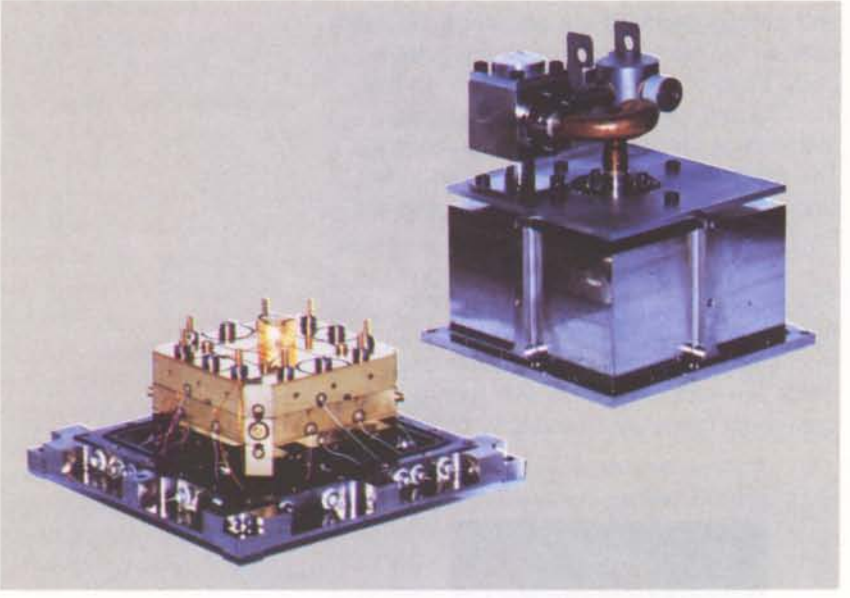


Figure 4. Laboratory model of the GRADIO accelerometer, and its proof mass and electrode plates

Future plans

The Aristoteles concept described above has already been presented to and endorsed by the scientific community on a number of occasions. While the mission's preparation has advanced significantly during the last two years, a number of key questions still need to be addressed before a detailed design can be established. Further system-performance evaluations and system trade-offs are required for the primary gravity mission. Design alternatives at subsystem level are being investigated and evaluated with regard to their merits for improved system performance using upgraded data-simulation software.

During the past year, a number of bilateral discussions have taken place on the Aristoteles mission, as an optional Agency programme, between the ESA Executive and Member-State Delegations. As a result, Italy is willing to take the lead in this programme and to contribute a major share. In addition, important support has already been indicated from a number of other European countries.

A final decision on the payload complement to be flown on Aristoteles will be taken in the near future, based on more detailed investigations of the impacts of the optional payloads on the primary mission. Accommodation of a GPS receiver and a magnetometer in the context of a possible ESA/NASA cooperation is one such question that is still to be resolved.

Several launch opportunities in the mid-nineties, including an APEX flight on an Ariane-5 launch, are being investigated in terms of technical, cost and schedule implications. Operational aspects, especially those related to overall mission analysis, satellite autonomy, and possible tracking systems, will also be further scrutinised.

The pre-development efforts on the GRADIO accelerometers are continuing, with further optimisation of the electrical and mechanical designs, the manufacture of another laboratory model, and additional ground testing. The present industrial team is preparing for the transition towards a possible project consortium for later phases.

Conclusion

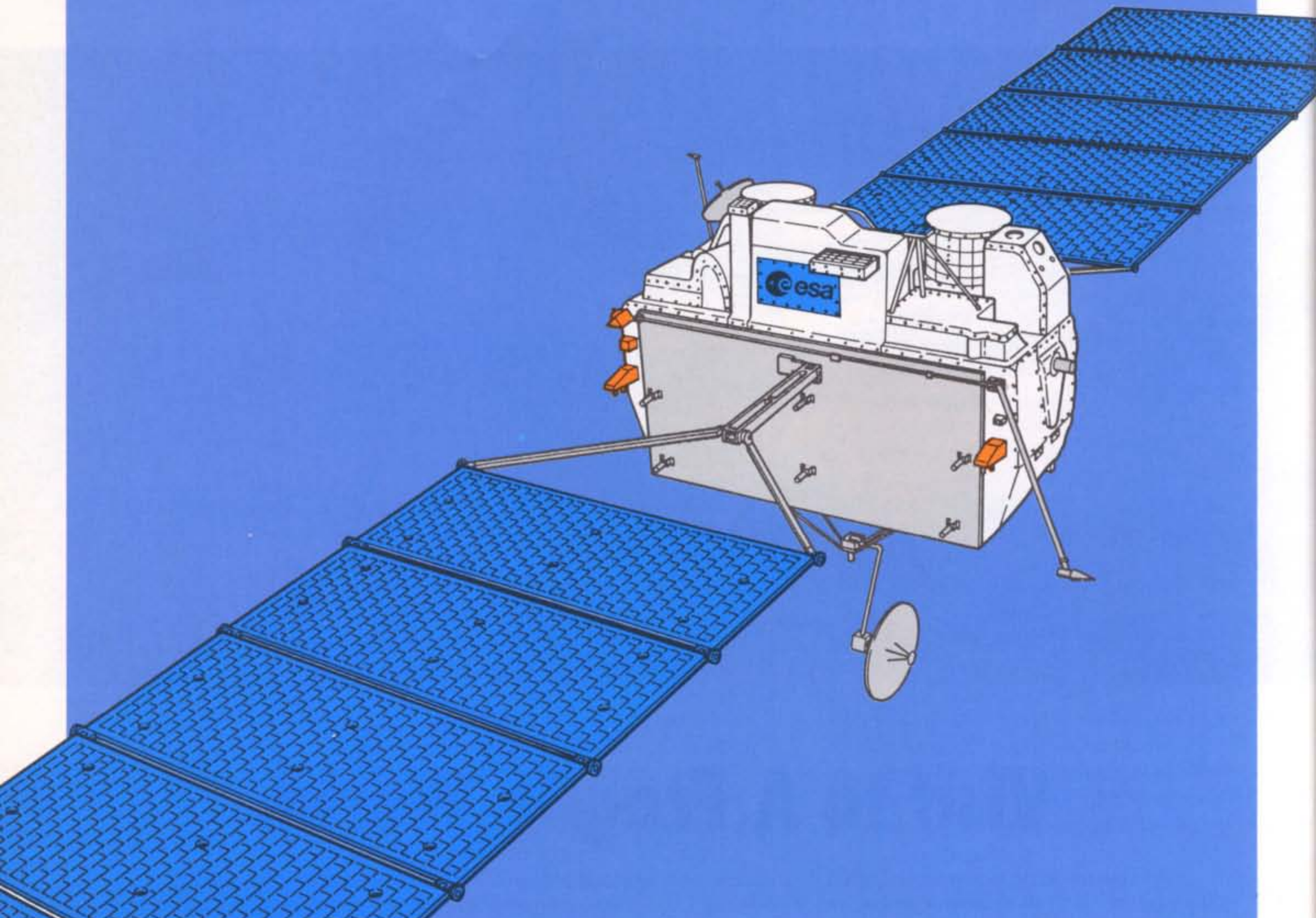
The present baseline mission concept for Aristoteles will greatly expand our knowledge and understanding of the physical forces affecting our planet's core, mantle and outer crust. The data obtained will benefit all solid-Earth disciplines, as well as studies of environmental problems (including man's disturbing effect on the sensitive equilibrium of environmental processes), and satellite navigation. The mission concept that has been arrived at, and which has the endorsement of the European scientific community, has been shown to be technically feasible and consistent with the schedule and cost constraints applicable. It also allows the accommodation of additional mission elements such as magnetic-field and point-positioning measurements.

Final programme approval for the Aristoteles mission is expected in 1990, commensurate with a possible launch in the mid-nineties.

Acknowledgement

This article is based on a paper entitled 'Aristoteles - Status of Overall System Definition and Preparatory Activities of the Programme' by R. Bonnefoy and G. Mecke (ESTEC), presented at the 'Italian Workshop on the European Solid-Earth Mission Aristoteles', Trevi, Italy, 30—31 May 1989.

The author wishes to thank all those both within and outside ESA, who have contributed directly or indirectly to this article, and the groups at Dornier, in Friedrichshafen (D), and ONERA, in Chatillon (F), for material used in its preparation.



	TYPE A	TYPE B
MASS	1000 KG	1000 KG
VOLUME	8.5 M^3	8.5 M^3
POWER (CONTINUOUS)	1000 W	800 W
THERMAL CONTROL	ACTIVE/PASSIVE	PASSIVE
CONTINUOUS ONBOARD PAYLOAD DATA ACQUISITION	1 KBIT/S	45 KBIT/S
ATTITUDE POINTING		
— DIRECTION	TO SUN	CELESTIAL
— ACCURACY	+/− 1°	+/− 1° ARCMIN
— STABILITY	+/− 0.5°	+/− 1 ARCMIN/H
— RECONSTITUTION	+/− 0.5°	+/− 5 ARCSEC
ORBIT ALTITUDE/ INCLINATION	~ 500 KM/28.5°	~ 500 KM/28.5°
MICROGRAVITY CONSTRAINT	$<10^{-5}$ G AT 1 HZ	NA
IN-ORBIT OPERATIONAL CAPABILITY	6 MONTHS	18 MONTHS

Figure 1. Artist's impression of Eureca

Eureca Flight Operations

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The European Retrievable Carrier (Eureca) is a multipurpose, reusable space platform to be launched by the Agency for the first time in 1991. Its prime role is to provide opportunities for conducting experiments at very low gravity levels, namely about one ten-thousandth of that prevailing on Earth. The first mission, designated Eureca-A1, will carry the largest ever payload supported by an ESA spacecraft.

Introduction
The Eureca platform, which will be launched and retrieved by the NASA Space Shuttle, will stay in space for between six and nine months on successive missions. Hydrazine thrusters will be used for coarse attitude control and orbit manoeuvres. During experiment operations, attitude control will be provided by nitrogen thrusters to guarantee low acceleration disturbance levels. As some payloads will generate large amounts of heat, an active freon cooling system will be used to transport this excess energy to space radiators.

Flight operations will be conducted from the Operations Control Centre (OCC) at ESOC, in Darmstadt, where the satellite and ground-segment monitoring and control system is being implemented on a dedicated computer, the Eureca Dedicated Computer System (EDCS). Special software has been developed to support the new concepts of packet telemetry and telecommanding to be used with the platform.

Eureca's flight operations will involve a variety of new and challenging tasks, as the platform is guided through the deployment, operational and retrieval phases of the flight, ensuring at the same time that the fifteen instruments that will make up the first payload operate safely together. The hundreds of different experiment runs to be conducted each have various needs and constraints, and must also share the necessarily limited resources available on-board.

Payload
The payload for the first flight can be classified into four main elements: the microgravity core payload, the microgravity add-on payload, the space-science experiments, and the space-technology experiments.

The core payload itself consists of five facilities, all of which have been developed under ESA contract:
— the Automatic Mono-ellipsoid Mirror Furnace (AMF)
— the Solution-Growth Facility (SGF)
— the Protein-Crystallisation Facility (PCF)
— the Multi-Furnace Assembly (MFA), and
— the Exobiological Radiation Assembly (ERA).

These facilities provide in-orbit 'laboratories' in which to process samples of metals, solutions, biological tissues, and proteins. European scientists from eight ESA Member States will conduct a total of 37 different experiments in the five facilities during the 1991 flight.

The two micro-gravity add-on instruments:
— the High-Precision Thermostat (HPT), and
— the Surface-Forces Adhesion Experiment (SFA)

will also exploit the unique microgravity conditions that will be offered by the platform. Each of these instruments is dedicated to one specific experiment.

Since Eureca offers a wide spectrum of capabilities in terms of payload accommodation, and the core payload does not fully exploit the full resources available (particularly in terms of mass capability, electrical power and onboard data storage), several additional instruments can be flown on the platform. These will include several experiments in the space-science field:
— the Solar Spectrum Experiment (SOSP)

— the Solar Variation Experiment (SOVA)
— the Occultation Radiometer (ORA)
— the Wide-Angle Telescope for Cosmic and Hard X-ray Transients (WATCH)
— the Time-band Capture Cell Experiment (TICCE)

and in the space-technology field:
— the Radio-frequency Ionisation Thruster Assembly (RITA)
— the Inter-Orbit Communication Experiment (IOC), and
— the Advanced Solar Gallium-Arsenide Array (ASGA).

Mission profile

A microgravity mission's success is based on the retrieval from space of processed material samples for complete ground-based analysis. There are three options for this: one is to retrieve only the samples (e.g. using a re-entry capsule and parachute descent); a second is to retrieve the entire payload (as in the case of sounding rockets). With Eureca, the whole spacecraft will be retrieved, allowing re-use of the carrier and its facilities for up to four additional missions after servicing.

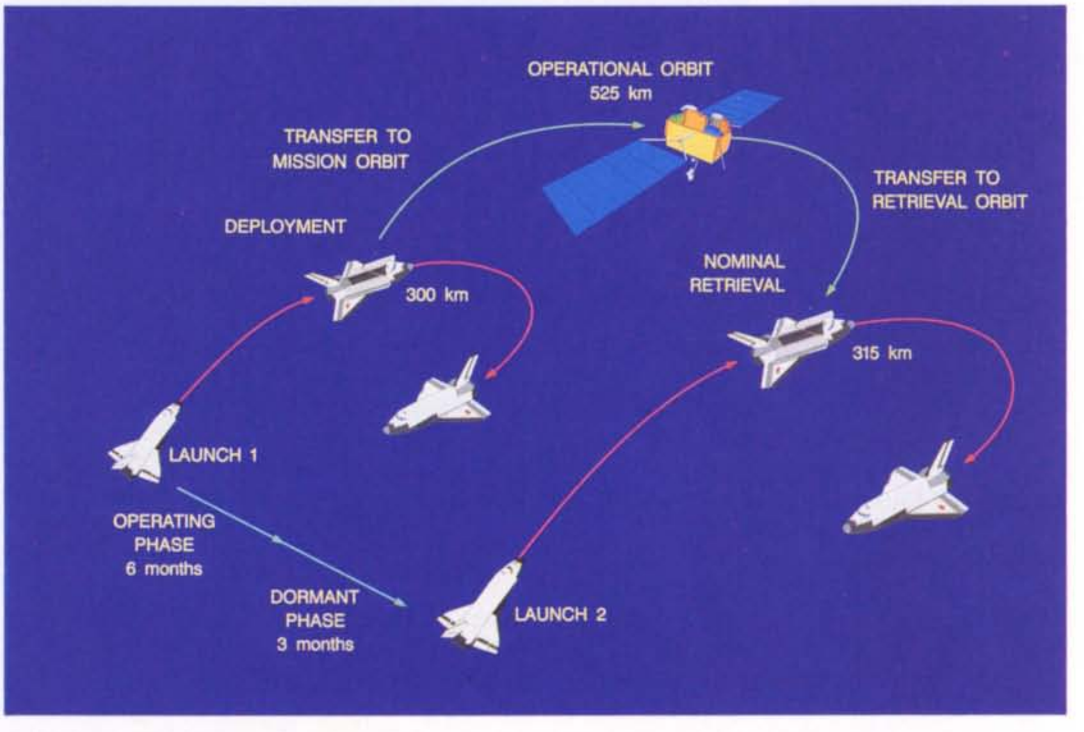
The choice of retrieving the 4 ton spacecraft has two predictable consequences: selection of a low Earth orbit, for reasons of fuel economy, and use of NASA's Space Shuttle for launch and retrieval, this being the most practical 'soft' means currently available for bringing a large spacecraft back to Earth. The orbital inclination of 28.5° for Eureca is also a consequence of the Shuttle launch and retrieval.

The main mission phases are 'deployment', 'operation/experimentation', 'dormant' and 'retrieval' (Fig. 2). After Eureca's launch and deployment by the Shuttle, just three days will be needed to execute a complex series of operations, including system activation, transfer of the platform to its 200 km higher operating orbit, and subsystem checkout and commissioning, before committing the platform to payload operations.

The nominal operations phase will last 180 days, during which all the platform services necessary to support payload operations, e.g. power, cooling, attitude control and data handling, will be continuously available. The dormant phase will bridge the gap between the nominal end of this experimentation phase and the start of the retrieval phase. Depending on the resources available, some payloads may continue to operate during this phase, although no active cooling will then be available.

From the platform-operations and mission-success points of view, the retrieval phase is the most critical of the mission. To increase contact between the platform and the ground, the deployment and retrieval phases will be supported by three ESA ground stations: Maspalomas on Gran Canaria, Perth in Western Australia, and

Figure 2. The Eureca-A1 mission profile



Kourou in French Guiana. During the experimentation and dormant phases of the mission, operations will be supported only by the primary ground station at Maspalomas.

Operations concept

Maspalomas has been chosen as the primary ground station because of the relatively favourable pattern of contact periods available from there. Figure 3 shows that Eureca will pass over Maspalomas for five or six consecutive orbits. Between two consecutive sequences of passes, i.e. once per day, the platform will be invisible to the ground control system for a period of 16 to 18 h (by comparison, use of an equatorial station results in two to three passes during consecutive orbits, with a half-day repetition cycle).

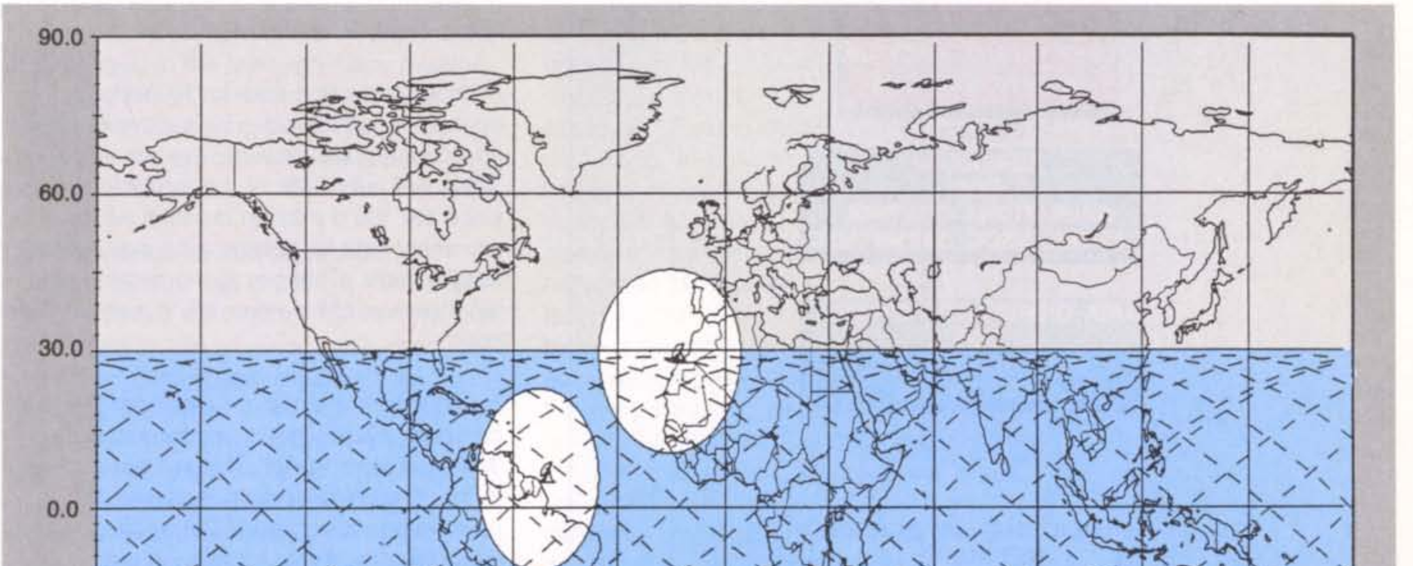
Each station pass will last less than 10 min, and passes within the same pass sequence will be approximately 90 min apart. Overall, the platform will only be visible from the ground for about 3% of the mission's duration. In the event of a malfunctioning of the primary ground station in Maspalomas, a back-up station will be available in Perth, Western Australia.

The IOC experiment onboard Eureca can use ESA's geostationary communications satellite Olympus as a data-relay station for telemetry and telecommands. This experiment could improve the total visibility time between OCC and platform to about 200 min per day, while the longest non-coverage period remains about 18 h, similar to when only Maspalomas is used. If the IOC experiment performs adequately, and onboard and ground-segment constraints and resources permit, this possibility will certainly be exploited.

The extremely limited periods of visibility have a dramatic effect on the flight-operations concept for Eureca. Real-time interaction between the OCC and the platform, i.e. the sending of telecommands for immediate execution, will be minimal. A so-called 'Master Schedule' will therefore be stored onboard the platform containing a list of time-tagged telecommands, each of which will be executed at a specified time to perform the requisite payload and platform operations. The OCC will prepare and uplink up to 1000 telecommands for entry into the Master Schedule on a daily basis.

Scientific and housekeeping telemetry will also be stored onboard and transmitted to ground at high data rates during the short contact periods.

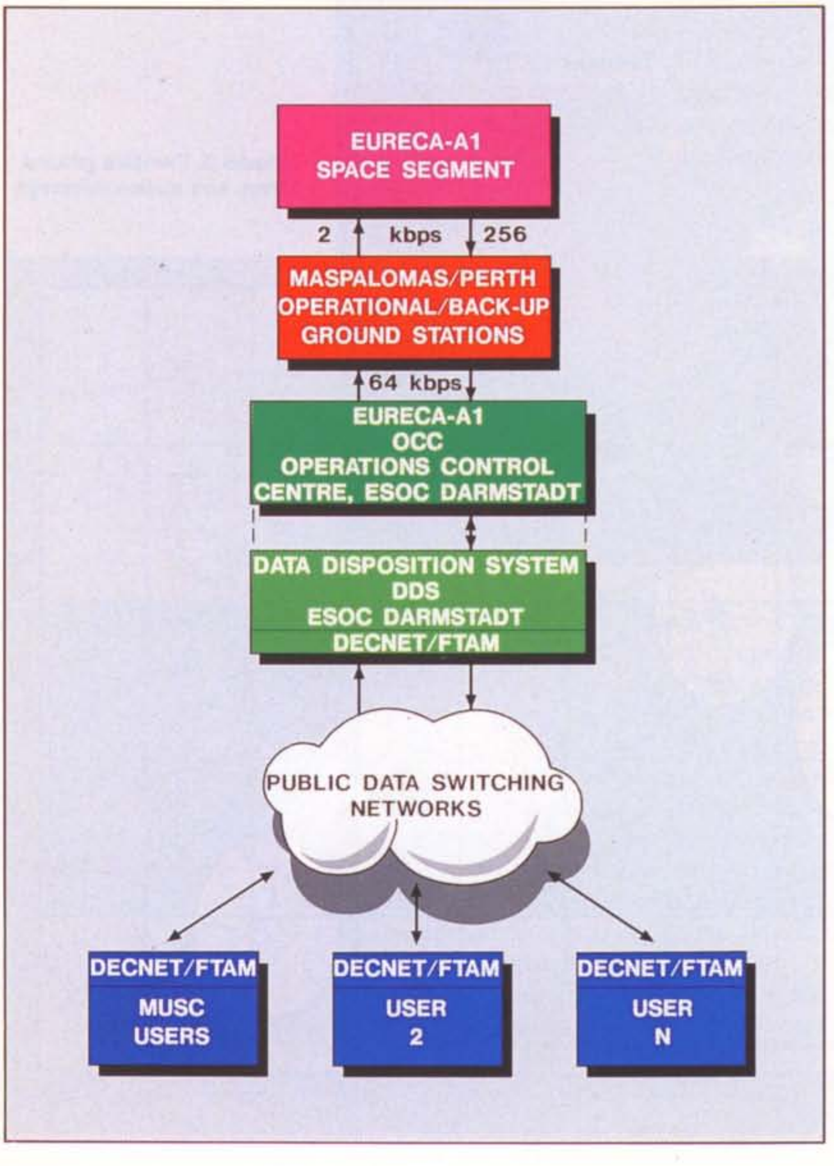
Figure 3. Eureca's ground track and station coverage



Each individual operation, such as the activation of an instrument or the changing of its operating mode, will be conducted in two parts, by two different persons. The Mission Planner will first prepare the sequence of telecommands needed to execute the operation off-line, checking that it does not conflict with the overall platform resources budget, and specifying the precise times at which the commands must be executed. The Spacecraft Controller will then uplink this telecommand file, selecting the appropriate telemetry transfer from the ground station, and supervising the EDCS operations.

The experiment representatives will be able to communicate with the OCC via the public data switching networks, using commercially available software (Fig. 4). This channel of communication will be used both for sending requests for execution or modification of payload operations (command requests), and for the reception of such data as telemetry and orbit and attitude information.

Figure 4. Ground segment for the routine phase of Eureca-A1 mission operations



All of Eureca's microgravity-payload operations will be supported by the Microgravity Users Support Centre (MUSC), being set up near Cologne in West Germany. Scientists conducting experiments using any of the platform's microgravity facilities will use this Centre to plan and to test their experiments, send telecommand requests, and receive and analyse their scientific data.

Mission planning

During the so-called 'experimentation phase', a continuous 1000 W electrical supply will be available to the payload. However, if all fifteen Eureca experiments were to be activated simultaneously, the power needed would be well over 2000 W. An appropriate experiment operating schedule has therefore to be established to resolve this conflict, while still meeting the scientific objectives of the individual experiments.

Apart from these electrical limitations, other significant onboard constraints to be managed are cooling capacity, application programs usage and the average rate of data generation. The latter is limited by the platform's onboard data-storage capacity and the availability of ground station passes to downlink stored telemetry data. The infrequent data up- and down-linking possibilities will also affect minimum experiment turn-around times in those cases where analysis of data from one experiment is needed prior to the initiation of another.

A baseline mission plan for all payload operations will therefore be established and approved prior to launch. The aim will be to utilise well over 90% of the available power, since the 180 d mission duration will be extremely tight for satisfying all experiment requirements. Changes to the mission plan will, however, still be possible during the flight itself.

To assist with the mission planning, Eureca's computer system has a specially designed 'Mission Planning Aid'. This will be used prior to the mission to develop the baseline payload-operations plan. During the mission, in addition to its role for mission plan maintenance, it will be used to plan the detailed operation sequences for quasi-automatic telecommand generation.

Telecommanding

The nominal payload operations will be conducted by translating the pre-mission-defined plan into sequences of time-tagged telecommands. The complete sequence will be directed to the Master Schedule of

Any 'exception telemetry packet' that has been stored onboard will be transmitted to the ground station when dumping of the onboard memory is initiated at the beginning of each pass. From there, it will be routed to the OCC, together with the real-time telemetry data. When an exception telemetry packet is received at the OCC, the EDCS will generate both an audible and a visible alarm, thereby alerting the spacecraft controller immediately.

The traditional recovery procedures used for geostationary satellites cannot be used in the case of Eureca, because the time available for real-time commanding during a normal station pass will not be sufficient to perform even the simplest failure analysis and recovery procedure. The first step will therefore be to collect as much information on the anomaly as possible, by commanding the platform to generate additional telemetry data (extended telemetry packets) at drastically higher rates than under nominal conditions.

If the quick-look analysis shows that the autonomous onboard recovery actions have not been successful, the spacecraft controller can suspend all subsequent pre-planned autonomous command activities, by commanding the platform in real time into a standard safe configuration, to await further recovery actions during subsequent passes. The Flight Control Team can then analyse the failure flagged in the telemetry data, prepare commands for failure recovery, and re-plan future operations during the period when Eureca is out of contact with the ground station.

Orbit determination and prediction

Another important new aspect of the Eureca flight operations, also stemming from the low orbit chosen for the mission, is the need for more accurate orbit determination and prediction. Spacecraft in low Earth orbits are in fact subject to high and highly variable perturbing forces (primarily aerodynamic), which reduce the precision of orbit predictions. Furthermore, the short duration of the ground contacts makes the prediction accuracy of the pass-start and pass-end times extremely critical: a few seconds become very significant in the context of a pass lasting only a few minutes.

The need for daily updating of the precise orbital data to be transmitted to the onboard orbital-modelling software used by Eureca's Attitude and Orbit Control Subsystem (AOCS) to maintain the platform's attitude within the required accuracy limits (based on the measurements of the onboard optical sensors) is a substantial challenge for the ESOC ground segment. The daily nature of the orbit-determination and prediction calculations, and the criticality of the uplinking of the orbital model parameters, call for a departure from the traditional approach of offline flight-dynamics computing. In Eureca's case, close and frequent interaction between the flight-dynamics computer and the real-time operations computer (EDCS) becomes necessary. Most of the routine tasks like orbit determination, orbit prediction and orbital model parameter generation are executed automatically when the tracking data from the last pass of the daily pass sequence have been received. The daily frequency and the time-criticality of these tasks also affect the reliability requirements on the flight-dynamics computer system, which has to guarantee both a low probability of, and fast recovery from, failure.

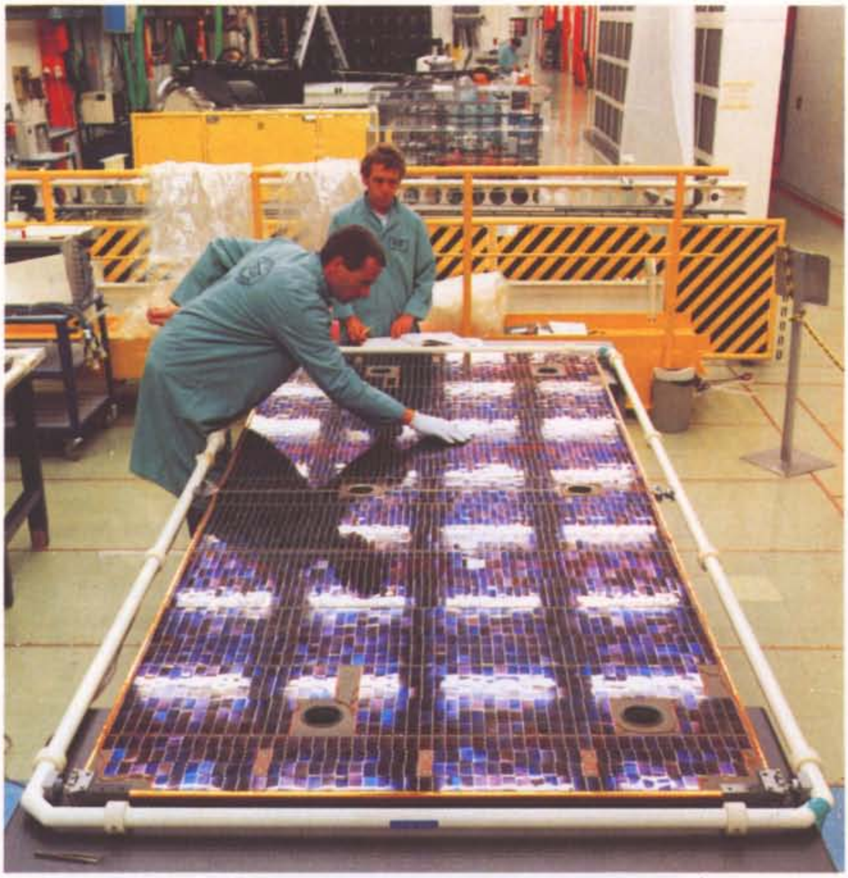


Figure 7. Solar panel of the Eureca carrier under test at ESTEC

Retrieval

The initial manoeuvring activities will begin approximately one month before the actual retrieval, due to fuel-economy considerations. To avoid the need for an active orbital-plane correction manoeuvre to make Eureca's orbital plane coincide with that of the Space Shuttle at time of retrieval, a passive method has been selected which involves manoeuvring the platform to an orbital altitude where the rate of orbital precession aligns its orbit at the right moment with that of the Shuttle.

In order to be retrieved by the Space Shuttle, Eureca is obliged to manoeuvre itself into a strictly bounded 'control box' on an orbit about 200 km below its normal operating altitude. This retrieval phase proper will last 72 h, starting with NASA's authorisation for the Shuttle to 'go for descent', and terminating with the berthing and securing of the Eureca platform in the Shuttle's cargo bay using the craft's Remote Manipulator System. Although three operational ground stations will be in use during this critical phase, there will still be substantial waiting time for tracking and command uplinking opportunities.

NASA plans require that future Shuttle retrievals will have to be accomplished within 48 h rather than 72 h, calling for a further increase in Eureca's onboard autonomy. Significant improvements are promised in the future with the availability of a Global Positioning System (GPS), which will provide the onboard AOCS with accurate positional information at any point in the orbit. The use of data-relay satellites to increase communications coverage will also help to accelerate retrieval operations.

Conclusions

The most important new aspects of the Eureca-A1 mission and the novel supporting flight-control concept have been described.

The challenges of the mission stem from the complications of: the low Earth orbit; the limited periods of direct contact with the platform via the ground station(s); the large number of experiments being carried; the deployment and retrieval by NASA's Space Shuttle; the degree of platform autonomy required; and the implementation of the packet telemetry and telecommand concept for the first time.

The wealth of relevant operational experience that will be gained in the preparation and execution of the Eureca platform's flight operations will undoubtedly be of substantial benefit to the Agency in the context of its future Columbus operations, as part of the International Space-Station (Freedom) project.

Related Articles

The Eureca Design Concept, by W. Nellessen
ESA Bulletin No. 47, August 1986

The Eureca Concept and its Importance in Preparing for the Columbus Programme, by R.D. Andresen & W. Nellessen
ESA Bulletin No. 52, November 1987

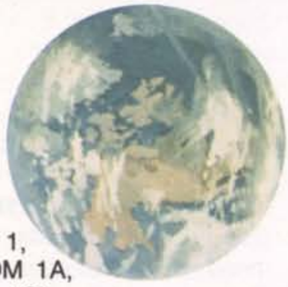
New Ground Data Processing System to Support the Agency's Future Satellite Missions, by K. Debatin
ESA Bulletin No. 53, February 1988

A New Generation of Spacecraft Control System - SCOS, by C. Mazza & J.F. Kaufeler
ESA Bulletin No. 56, November 1988

Precise Orbit Determination at ESOC, by J. Dow et al.
ESA Bulletin No. 50, May 1987

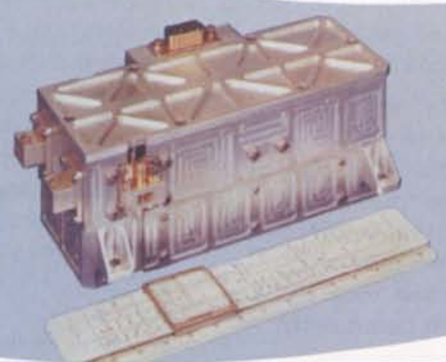
SIEMENS

ONE MORE ACHIEVEMENT OF SIEMENS TELECOMUNICAZIONI IN SPACE PROGRAMMES

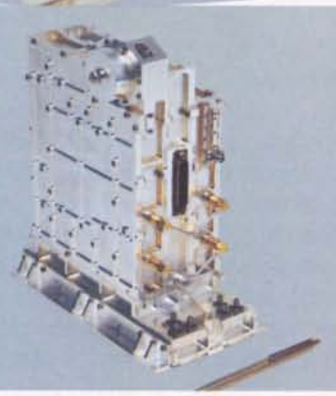


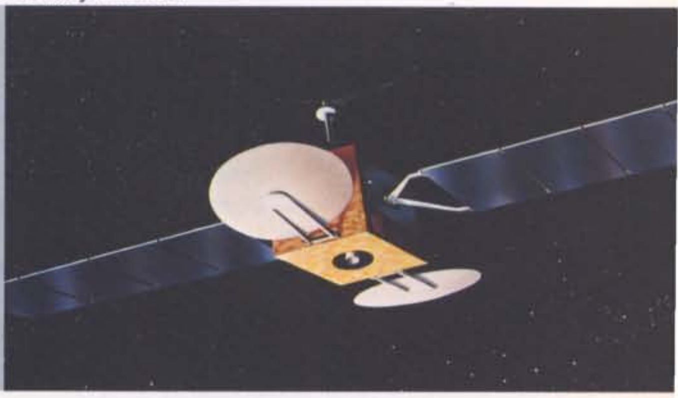
1976 **1st ON BOARD PARAMETRIC AMPLIFIER**

On January 17th, 1976 a parametric amplifier was flown for the first time on board a telecommunications satellite (CTS - HERMES). So far Siemens Telecomunicazioni paramps have cumulated a total of 1.3 million operating hours without failure (CTS, OTS 2, ANIK B, ECS 1, ECS 2, ECS 4, EÇS 5, TELECOM 1A, TELECOM 1B, TELECOM 1C).



Courtesy TELESAT





1990 **1st ON BOARD 147 Mb/s BURST MODE QPSK COHERENT DEMODULATOR***

Planned for launch in mid-1990, ITALSAT will be the first regenerative telecommunications satellite. Its 9 demodulators, developed and manufactured by Siemens Telecomunicazioni, represent a further step towards exploitation of Satellite Telecommunications.

Siemens Telecomunicazioni (formerly GTE Telecomunicazioni) have given important contributions to many space programs for more than 15 years, leading to a total backlog of more than 20 satellites. Presently we are involved in: DFS, TELE-X, OLYMPUS, ITALSAT, EUTELSAT II.

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*Work under SES contract for ASI.

Flight Opportunities for Small Payloads

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A first Workshop was organised by the Agency earlier this year, at ESRIN in Frascati (Italy), on the topic of 'Flight Opportunities for Small Payloads'. The Proceedings of the meeting have already been published (as ESA Special Publication SP-298*). This article is intended to bring the main results of the dialogue that took place to the attention of the wider scientific/technological community.

* Available from ESA Publications Division.

Organisation of the Workshop

The Frascati Workshop responded to a real need for an exchange of views in Europe on the subject of flight opportunities for small payloads, as was evidenced by the large number of requests received for participation. They came mainly from the space industry (payload and satellite manufacturers, suppliers of launch services, etc.) and, to a lesser extent, from the user community (scientists from various disciplines, universities, and payload-development institutes). As the number of participants that could be accommodated at ESRIN was strictly limited, the Agency had the difficult task of making a selection. Nevertheless, 150 delegates (listed in the Proceedings) were ultimately able to attend, representing about 90 space research institutes and industrial concerns.

ESA's management was strongly represented at the Workshop, with the Agency's Director General, Prof. Reimar Lüst, its Directors of the Scientific Programme, Prof. Roger Bonnet, of the Earth Observation and Microgravity Programme, Dr. Philip Goldsmith, of Space Transportation Systems, Mr Jörg Feustel-Büechl, and the Agency's Inspector General, Prof. Massimo Trella, all present.

The Workshop Programme was divided into five main sessions:
— user requirements for small orbiting payloads;
— microsatellites and micropayloads;
— small satellites and technologies;
— recoverable systems and payloads;
— existing and planned launch services and opportunities.

Thirty-three short presentations were made, and the Workshop concluded with a discussion and synthesis session. The corresponding papers are included in the Proceedings, together with a number of written contributions that, although relevant, could not be presented due to lack of time.

Outcome of the Workshop

At the Concluding Session, the Session Chairmen presented a synthesis of the presentations and of the comments made; this was followed by a general discussion involving all participants. The outcome of this discussion can be summarised as follows:

User requirements

User requirements exist, but they are still of a preliminary nature. They need to be better defined and grouped by type of mission and/or sectors of activity. 'Genuine users' were not sufficiently well represented at this first Workshop; further user-specific workshops would be advisable.

ESA has subsequently organised an 'Information and discussion meeting on flight opportunities for small experiments in the domains of Space Science and Earth Observation' at its Paris Headquarters (25 to 27 September 1989).

Microsatellites

Microsatellites and micropayloads have masses of up to 50 kg. They have been found to be of major interest for basic scientific investigations, for technological

Opening comments by ESA's Director General, Prof. Reimar Lüst

When the European Space Research Organisation (ESRO) began its scientific satellite activities in the early 1960s, the satellites being built weighed between 80 and 300 kg (ESRO-1, ESRO-2, HEOS, etc.). These were what we would term small spacecraft by today's standards. However, at that time they seemed large to us, and we were proud of these spacecraft as they demonstrated that European scientists, industry and intergovernmental organisations could indeed work together and achieve results beyond the reach of individual entities working alone.

Since these exciting beginnings, Europe's space activities have steadily increased, as witnessed by the growth of ESRO and its transformation into ESA. We have completed several more scientific satellites, designed applications satellites for communications and meteorology, produced the Ariane launcher family, built the reusable space laboratory Spacelab, as well as undertaking many other programmes.

The ESA Council, at its Meeting at Ministerial Level in The Hague, in November 1987, endorsed a further growth of ESA's programmes and ambitions: we now serve to consolidate the presence of Europe in all major fields of space activities, and we are aiming at achieving European autonomy in manned space flight.

Single payloads of up to 20 tons in low Earth orbit are no longer cause for surprise, and one might be tempted to believe that a satellite weighing in at less than 500 kg is too small to be worthy of our attention. However, we must never lose sight of the fact that large space projects are only possible thanks to the experience accumulated from many much smaller projects, carried out by enthusiastic young students and experienced space scientists alike. Indeed, the short response time possible in small space projects allows the testing of new ideas, the opening of promising new areas of research, and the education and training of our next generation of space engineers and scientists, without which our ambitious plans would not be achievable.

In addition, what we today perceive as small still appears large to those just entering the field. I can therefore well understand the occasional frustration I have seen growing in recent years in the space community based on the impression that, while the larger multinational projects appear to attract most of the public funding and attention, it is becoming more and more difficult to implement small projects.

It is for this reason that I have asked that this Workshop on Flight Opportunities for Small Payloads, the first of its kind, be organised by ESA. I believe its timing is opportune because the accident to the US Space Shuttle in January 1986 brought all small-payloads activities that were routinely being implemented on the Shuttle to a dramatic halt. We are happy that in the meantime the Shuttle has successfully returned to operational status, but the policies now implemented have led to a significant reduction in flight opportunities for small payloads. This sequence of events has, on the other hand, stimulated the user community into searching for other opportunities and has fostered the development of alternative launch solutions.

In particular, I believe that our own large space transportation systems (Ariane-4 and, later, Ariane-5) should allow for the possibility of carrying auxiliary payloads, albeit without inconveniencing the main passenger and without causing undue complications for the auxiliary passenger. The solving of this problem calls for creative and imaginative solutions. One such effort I would like to highlight here is that by Arianespace and ESA to develop the Ariane Structure for Auxiliary Passengers (ASAP) and the Ariane Technology Experiment Platform (ARTEP), which will soon allow a series of small payloads to be flown. These activities are represented in the Workshop programme.

However, it is likely that not all user wishes can be satisfied in an optimal manner using the means presently available. This Workshop is therefore also intended to allow all participants to state their needs, and those having solutions to present them. It will be our task to take the needs and ideas presented into account and define what additional developments should be undertaken.

I am confident that, by this means, an already coherent European space programme can be further improved so as to cover the whole spectrum of space activities, from the multitude of small and creative projects up to the large space infrastructure that will allow Europe to take its place amongst the major space powers.

I invite you all to make your wishes and also your criticisms known, and thereby contribute to a successful Workshop.

Figure 1. The 'Ariane Structure for Auxiliary Payloads', ASAP. The interfaces allowing the attachment of up to four microsatellites are clearly visible. The ASAP is 4m in diameter

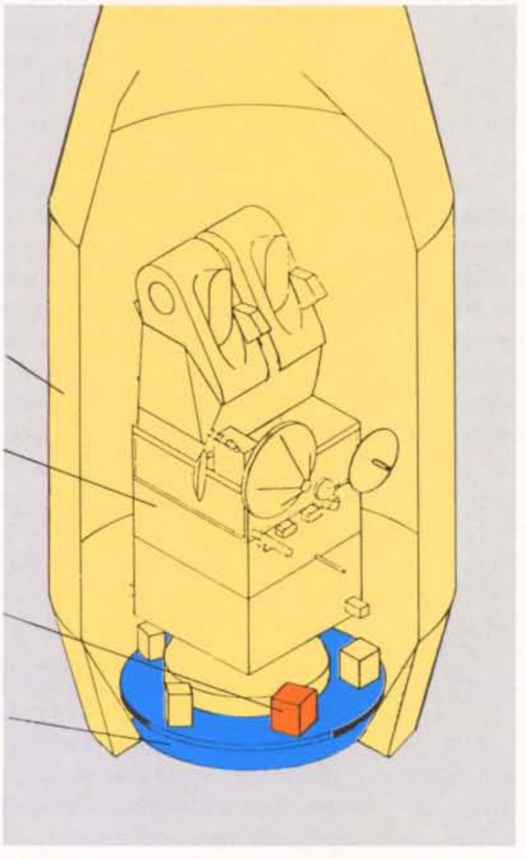


Figure 2. Implementation of the ASAP platform inside the Ariane fairing

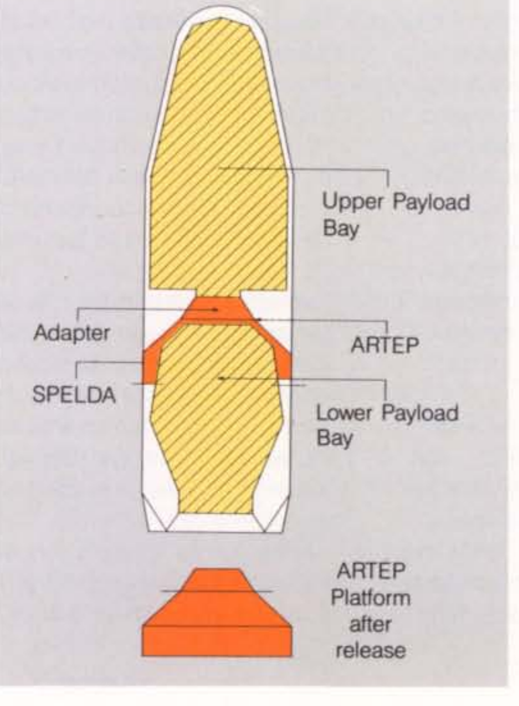


Figure 3. The 'Ariane Technology Experiment Platform', ARTEP, can be used whenever dual satellite launches are carried out by Ariane

activities, and for educational purposes. Typical examples can be found in the papers presented by speakers from Amsat and the Universities of Berlin, Bremen and Surrey. The development cost of microsatellites, said, in most cases, to be less than $US 1 million, should provide an incentive for other organisations to adopt this type of carrier.

Microsatellites can be developed relatively quickly and should benefit from regular inexpensive flight opportunities. With this in mind, Arianespace and ESA presented two complementary concepts: the Ariane Structure for Auxiliary Payloads (ASAP) and the Ariane Technology Experiment Platform (ARTEP). Thanks to these launch structures, up to three flight opportunities per year for several experiments or microsatellites can be offered on Ariane under particularly attractive financial conditions. These concepts are shown in Figures 1, 2 and 3.

Users recommended that the ASAP and ARTEP facilities should be accessible at the lowest possible cost and should offer sufficient flexibility for late changes. It was also suggested that they should be offered free of charge to Universities when the payloads to be flown serve an educational purpose.

Minisatellites

With masses varying between 150 and 600 kg, there does not, at present, appear to be a systematic solution that would allow inexpensive, minisatellite launches at sufficiently regular intervals. The availability of a dedicated small launcher (such as the Amroc, Conestoga, Littleo, Pegasus and Scout 2, presented at the Workshop) would be a good solution from the technical point of view. Studies have also begun on the means of using the incremental payload capabilities of Ariane-4 to accommodate such satellites. A typical example is shown in Figure 4.

Recoverable satellites

Recoverable satellites are considered essential to enable progress to be made in microgravity research pending the availability of larger platforms. They might also continue to be used even when the future in-orbit infrastructure is operational. By their very nature, recoverable satellites cannot be considered 'small', and designs with masses of between 600 and 2000 kg were presented. Further studies are required to identify the most promising solutions, i.e. those that can be available sufficiently early to be of relevance for the scientific

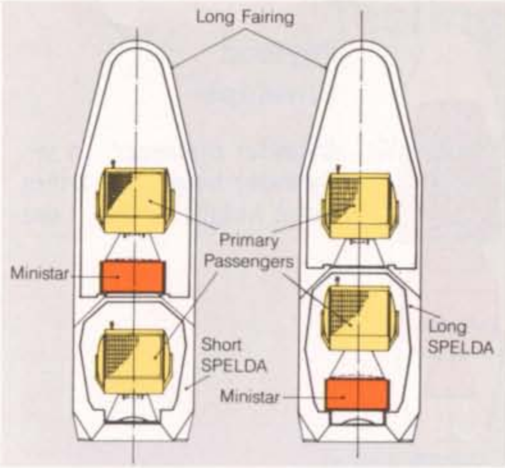


Figure 4. A possibility for accommodating a minisatellite 'Ministar' on an Ariane-4

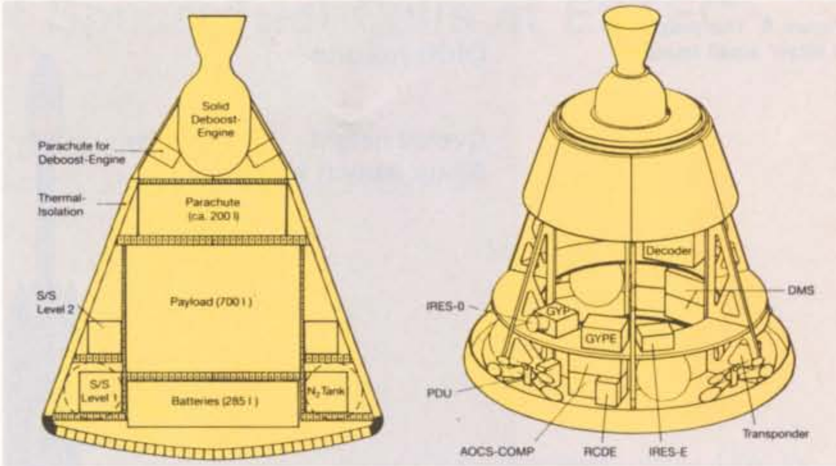


Figure 5. The 'Raumkurier', a proposed recoverable satellite (diameter, approx. 2m)

community. Typical concepts are shown in Figures 5, 6 and 7.

Launch opportunities

A high-inclination, low Earth orbit (LEO) is the most desirable one for both micro- and minisatellites. Such an orbit is not, however, often provided by Ariane. The only solution at present appears to be to use a dedicated launcher.

Whilst users have the resources to cover the recurrent costs of their mission, they do not have the funding needed for front-end development for specific carriers or systems, which should therefore be provided by the national or international agencies.

The development of small payloads is of real interest only if the total duration of such a programme, from inception until the first results are obtained, is less than three years. Users then require frequent launch or flight opportunities at an affordable cost (say, not more than 50% of the cost of the payload) and with simplified launch procedures.

Several plans and concepts for small launchers were presented. Of these, the US privately developed and air-launched Pegasus is closest to a first flight. Since the Workshop, Arianespace has announced its interest in marketing this launch service in Europe. Small-launcher proposals being elaborated in Europe are the Littleo and Scout 2, shown in Figures 8 and 9, respectively.

Recommendations

The above findings were summed up by ESA in the form of five specific recommendations:

— User requirements should be better defined in order to ensure that

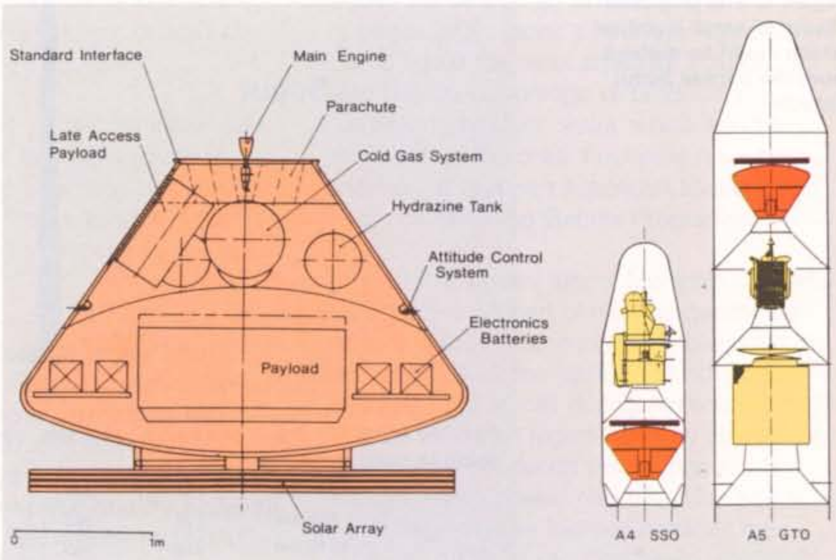


Figure 6. The 'Ariane Capsule', a proposed recoverable satellite, and its possible accommodation on an Ariane-4 and an Ariane-5

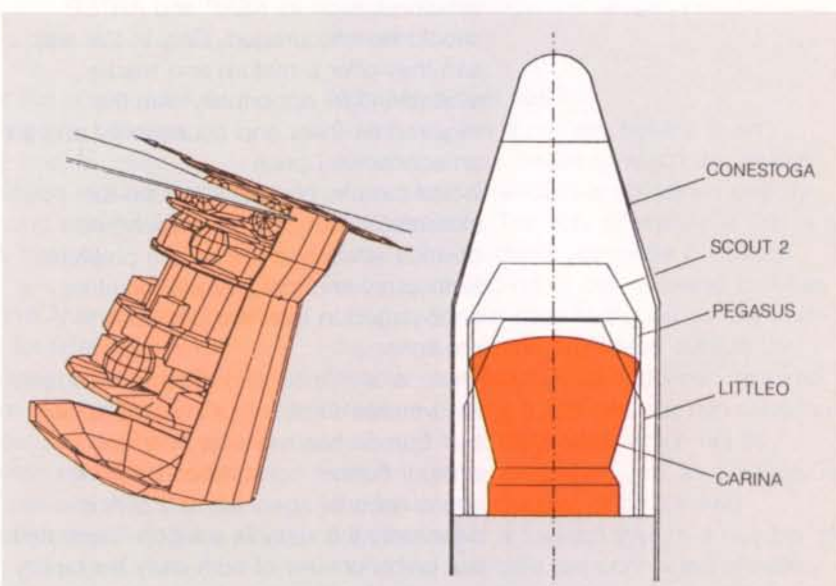


Figure 7. The 'Carina', a proposed recoverable capsule (diameter approx. 1.3m) and its possible accommodation on a small launcher

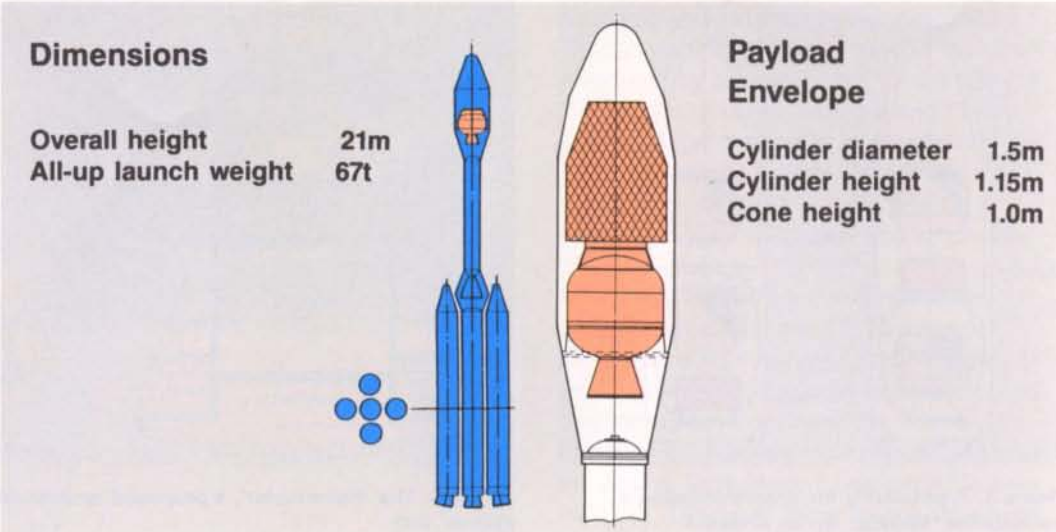
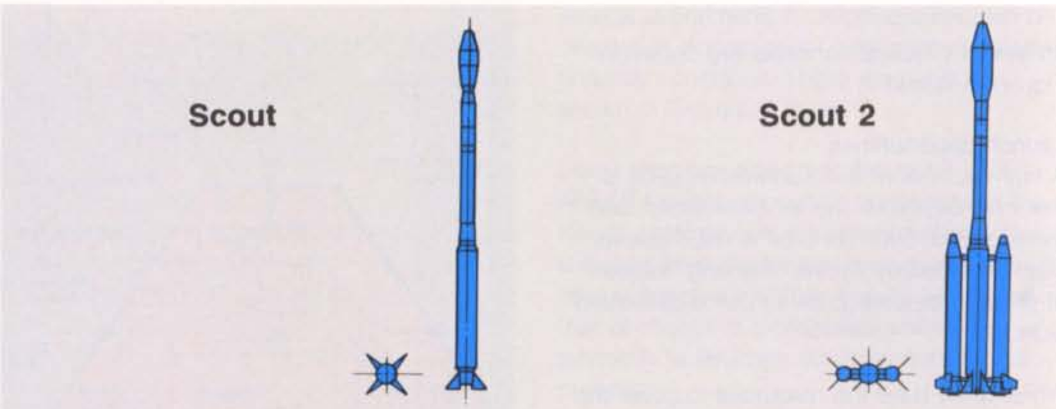


Figure 8. The proposed 'Littleo' small launcher



PAYLOAD CAPABILITY (kg) CIRCULAR ORBIT ALTITUDE	Scout: SAN MARCO	Scout: WALLOPS	Scout: VANDENBERG	Scout 2: SAN MARCO	Scout 2: WALLOPS	Scout 2: VANDENBERG
278 km	257	241	196	523	495	413
555 km	218	205	165	451	426	353
1110 km	155	145	114	331	312	254

Figure 9. The proposed 'Scout 2' small launcher, which could be derived from the normal Scout vehicle

consolidated solutions can be found.

— The use of microsatellite support structures such as ASAP and ARTEP should be encouraged. Only in this way can they offer a mature and readily available flight opportunity with the required flexibility and accessibility and at an economical price.

— Whilst there is obviously a need for minisatellites, there is, at present, no obvious solution to the launch problem. Both users and industry are therefore encouraged to look into possible solutions.

— There is a definite, and urgent, need for a recoverable satellite, but it would appear that Europe has room for only one design. Further consultation between users, national agencies and ESA is necessary if a suitable solution - from both the points of view of both early availability and affordability - is to be found.

— There is a distinct growth in the number of small launch vehicles being planned or developed. In order to provide European users with a maximum of launch opportunities, the market should be opened to all potential launch service suppliers. Such suppliers were therefore invited to inform the Agency of the status of their programmes.

In summary, the great interest shown in the Workshop, the large number who wanted to attend, and the relevance of the comments made, all confirm that there is indeed a serious demand for the flight of small payloads and that a considerable effort must be made to provide such flight opportunities. ESA has a leading role to play in promoting activities in this field; it has, in fact, already awarded study contracts on this subject and has commenced further studies immediately after the Workshop.

Testing of Space Fuel Cells at ESTEC

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Fuel cells are expected to play an important role in ESA's future manned space programmes, starting with the Hermes spaceplane. Although very similar to conventional batteries in principle, in practice fuel cells are much more complicated, requiring such ancillary devices as pumps and heat exchangers for their operation. In order to be able to evaluate and eventually space-qualify fuel-cell hardware, a Fuel-Cell Test Facility (FCTF) has been built at ESTEC as an annex to the existing European Space-Battery Test Centre (ESBTC), and is due to become operational in early 1990. The technology and types of tests required are discussed here and an outline is given of the planned design for the FCTF and its capabilities.

Introduction

One may ask 'Why do we need fuel cells when conventional batteries have fulfilled all ESA spacecraft energy storage needs so far?'. To answer this, one has to look at the particular needs of the different classes of space applications.

Orbital spacecraft rely on rechargeable (i.e. 'secondary') batteries to supply electrical power during periods of eclipse or peak power demand. For the remainder of the time, energy is provided directly by the solar arrays, both to power the spacecraft's payload and to recharge its batteries, for periods of between 2 and 15 years depending on the mission requirements. The vast majority of past and present ESA spacecraft operate in this way.

Launchers, such as the Ariane series, need electrical power only for relatively short periods (tens of minutes). Consequently, they have relied on non-rechargeable (i.e. 'primary') batteries, such as silver-zinc cells, which can provide several times as much stored energy per unit mass as rechargeable batteries during a single discharge.

Hermes, the European spaceplane, is different from both of the above in that it requires high power levels (about 4 kW) for intermediate time periods (1-2 weeks), during much of which the deployment of solar panels would be impracticable. To satisfy this power demand in an application where mass is particularly critical, a hydrogen-oxygen fuel cell is by far the most attractive solution. It also has the advantage of producing a valuable byproduct, water, which can be exploited by the crew. Fuel cells have been used on all manned American space missions since the Gemini Programme.

In the more distant future, fuel cells may also be attractive as part of the energy-storage system of large manned orbital platforms. In this application, the hydrogen and oxygen used by the fuel cell during periods of eclipse would be regenerated by electrolysis of the water produced during periods of sunlight using power from the solar arrays. Such 'regenerative fuel-cell systems' are currently under study. Compared with other power systems, they offer not only the bonus of integration into the crew's environment and life-support system, but also the possibility of supplying hydrogen + oxygen propellant for thruster motors.

What is a fuel cell?

A fuel cell, like a primary battery, is an electrochemical device in which the energy of a chemical reaction is converted directly into electricity. The only difference is that in a battery the reactants are totally contained within each individual cell, whereas in a fuel cell they (in our case hydrogen as fuel and oxygen as oxidant) are stored outside the 'reactor' and fed to it as and when required. Unlike a battery, a fuel cell has non-consumable and inert electrodes, which act as reaction site and catalyst. Just as a battery is made up of a number of cells linked together, so in a fuel-cell system a number of individual fuel cells are connected in series. Unfortunately, the resulting unit is still usually referred to as a 'fuel cell' rather than a 'fuel-battery', which would be more logical.

The theoretical gravimetric energy density obtainable from a battery or fuel cell is proportional to the free energy of the chemical reaction ('couple') that is exploited, divided by the total mass of the reactants. In practice, this is much reduced by the mass of necessary 'inactive' components (casing, connectors, etc). Of the possible reactions that can be harnessed electrochemically, that between hydrogen and oxygen offers one of the highest theoretical energy densities. Since both reactants are gases under normal conditions, it is necessary in the interests of compactness to store them cryogenically as liquids. Clearly, then, a fuel-cell configuration is required.

There are five major classes of hydrogen-oxygen fuel-cell technology, each characterised by the use of a different electrolyte and operation in a different temperature range:

Electrolyte	Operating temperature (°C)
Aqueous alkaline electrolyte	ambient to 120
Proton exchange membranes	60 to 120
Acidic electrolyte	100 to 300
Molten salts	300 to 800
Solid oxides	600 to 1000

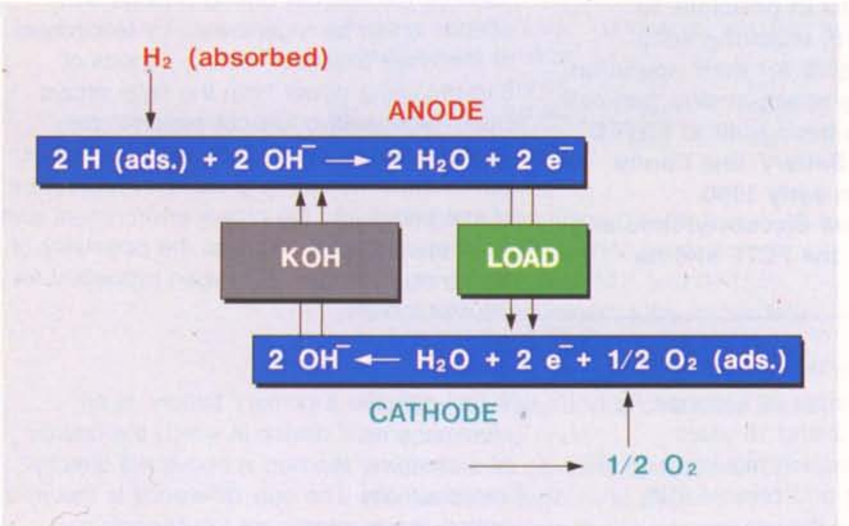

Figure 1. Electro-chemical reaction in an alkaline hydrogen-oxygen fuel cell

Only the first two of these have been used so far in space programmes. Since the first type is the baseline for Hermes, only fuel cells of this class will be considered further in this article.

When fuel cells with an alkaline electrolyte and hydrogen and oxygen as reactants are used, the reactions shown in Figure 1 (somewhat simplified) take place. The electrochemical process is based on simultaneous oxidation and reduction on separate electrodes. Hydrogen is oxidised on the anode (−), whilst oxygen is reduced on the cathode (+). To provide electrical power to the consumer (load), electrons have to move through the external connections and the same amount of charge in the form of ions has to move through the electrolyte (potassium hydroxide dissolved in water) to allow the energy conversion on the electrodes. At the reaction sites on the anode, water is formed, which must subsequently be removed from the system.

Fuel cells in practice

We have discussed how similar batteries and fuel cells are in principle. In practice, however, there are major differences. Whereas the thermal control for a battery can usually be passive, that of the fuel-cell system requires coolant circulation pumps and heat exchangers. Two alternative electrolyte and thermal-management schemes may be used. In the 'mobile-electrolyte' fuel cell, the electrolyte is also used as the heat-transfer medium and is pumped through the cells and heat exchanger. In the 'immobile-electrolyte' fuel cell, the electrolyte solution is immobilised in a matrix such as asbestos, and water (or another coolant liquid) is pumped through the cell stack and heat exchanger.

Some fuel-cell plants that have to operate in a completely closed environment, like those for submarines or spacecraft, need devices to separate liquids and gases. This is particularly difficult in zero-gravity, where one cannot rely on differences in density for fluid separation. Instead, special 'membrane separators' or 'mechanical cyclones' are needed.

A battery is usually a very simple device with no moving parts, whereas a fuel-cell system is more like a small chemical plant and therefore requires a sophisticated control system. When one adds to this the stringent reliability and safety requirements of manned space missions, the chemical-engineering aspects of the system become critically important.

In order to test the electro-chemistry of a practical fuel cell, all the peripheral components needed to manage the various fluids must be provided. A fuel-cell test bench is therefore very much more complicated than one used to test batteries. The available area in the existing European Space Battery Test Centre (ESBTC) at ESTEC is insufficient to accommodate fuel-cell tests and this, together with the safety concerns about the use of large quantities of hydrogen and oxygen on site, led to a decision towards the end of 1986 to build a dedicated Fuel-Cell Test Facility as an annex to the ESBTC, some distance from the main complex.

The Fuel-Cell Test Facility (FCTF)

Figure 2 shows the layout of the FCTF building, which was completed in May this year. Much attention has been paid to the potential hazards of working with large quantities of hydrogen and oxygen.

disturbing the tests. All gases, as well as closed-loop cooling water, are routed to the test benches through underfloor channels.

Types of fuel cell to be tested

Development of the fuel-cell power plant for the Hermes spaceplane calls for the evaluation of a number of different types and sizes of fuel cells, ranging from single cells rated at about 100 W, to complete modules delivering up to 10 kW of electrical power (Fig. 3):
— single cells (1 anode, 1 cathode) in frames

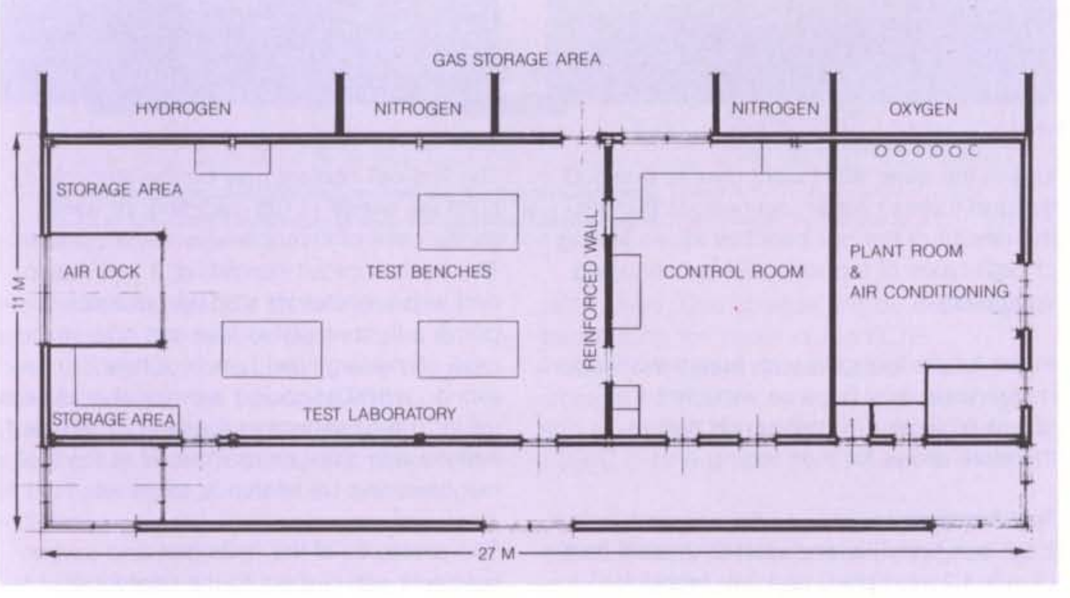

Figure 2. Layout of the FCTF building

The control room is separated from the test laboratory by a strong wall. The gas storage area is outside the facility and the hydrogen and oxygen lines coming into the test room would be shut off automatically in the event of fire, mains failure, excessive gas flow in the lines, or abnormal pressures. In the event of hydrogen leakage within the laboratory, gas detectors near the ceiling would trigger the operation of emergency (explosion-proof) extraction fans in the roof and shut off the hydrogen and oxygen supplies as soon as any detector registers a concentration greater than 10% of the lower explosive limit (LEL) in air. At 20% LEL, all mains power would be turned off and emergency (explosion-proof) lighting activated. All critical detectors are fed by an uninterruptable power supply.

Hydrogen and oxygen as reactants, and nitrogen (for flushing purposes during test shutdown and emergencies), are to be stored in 16-cylinder pallets outside the laboratory. Each gas-storage system consists of two sets of pallets, with an automatic switchover between them. This will allow empty pallets to be replaced without

— small cell stacks: up to 1 kW of electrical output
— large cell stacks: more than 1 kW of electrical output
— complete modules including peripheral equipment.

This wide range cannot be covered with one size of test bench and therefore two small benches (100 W to 1 kW) and one large one (1 kW to 10 kW) are to be installed initially. The small benches will be capable of testing two fuel cells of similar type simultaneously.

There is sufficient space to implement a further large test bench in the laboratory at a later date. The necessary ventilation and gas and cooling-water supplies are already provided. This location may eventually be used for testing regenerative fuel-cell systems. In principle, all types of low-temperature hydrogen-oxygen fuel cells can be tested.

Both immobile and mobile KOH fuel cells have been evaluated for the Hermes Programme. Although in the one case water

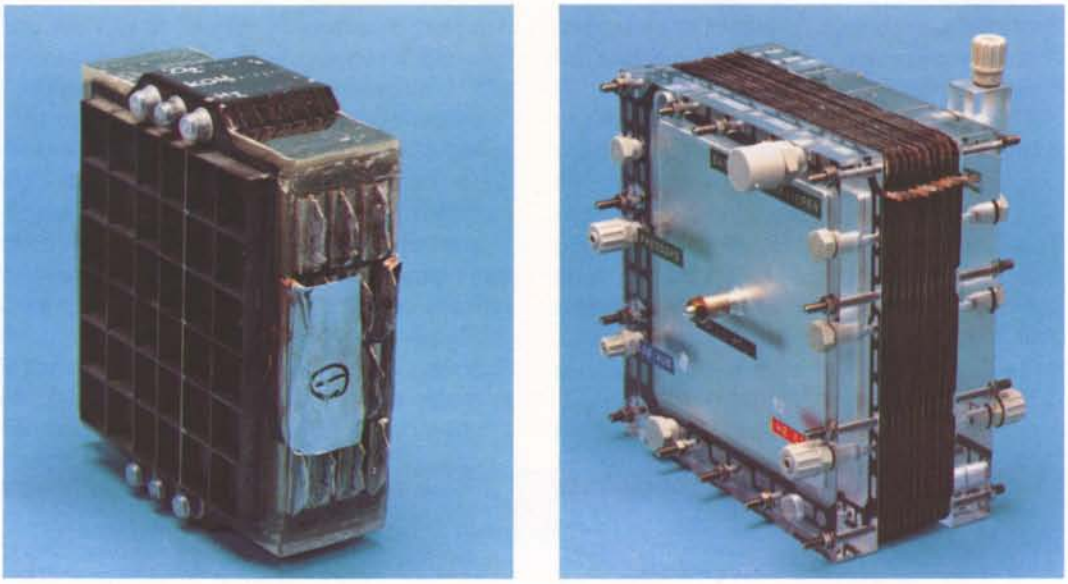

Figure 3. Laboratory-scale fuel-cell stacks from Elenco (left) and Siemens (right)

and in the other KOH electrolyte is pumped through fuel-cell stack and heat exchanger, the design of the test benches allows testing of both types of fuel cells without changing equipment.

In the future, fuel cells with proton-exchange membranes may become important for space projects. The test-bench design therefore allows for their testing also.

Test benches

Each test bench is enclosed by a steel frame (3 m x 1.2 m in plan, and 3 m high) clad with removable transparent plastic panels. A fume-extraction hood provides continuous low-rate ventilation. High-rate ventilation that is switched on automatically if reactant leakage is detected will ensure rapid evacuation of any potentially hazardous gases. Detection of hydrogen in a concentration of more than 20% LEL, or failure of the fume-extraction fan, will result in automatic shutting down of the test.

The main components of a single test bench and the associated fluid interconnections are shown (in simplified form) in Figure 4. At the heart of each bench is the pressure container in which the fuel cell under test can be mounted. This allows tests to be carried out at pressures of up to 7 bar on fuel cells not equipped with their own pressure containment. This pressure is usually the same as that of the electrolyte or coolant loop, but it can be controlled independently, for example for testing fuel cells that require a higher external pressure to maintain stack compression. The Hermes fuel cells will be operated at higher than ambient pressure because efficiency increases with reactant pressure.

The fuel-cell coolant may be the electrolyte, KOH (as shown in the diagram), or water (in the case of immobile-electrolyte systems). The coolant circuit consists of a tank equipped with a heater for start-up purposes, a pump with controllable flow rate and, in the case of the large test bench, a heat exchanger (KOH-cooler) with variable bypass valve. The gas-space in the tank is filled and flushed with nitrogen maintained at the fuel-cell operating or 'reference' pressure.

The pressures of the hydrogen and oxygen reactants with respect to the reference pressure are generally quite critical, so pressure-change controllers are specially designed to maintain the required differentials under all normal and, as far as possible, fault conditions. Reactant gases are metered to enable fuel-cell efficiency to be calculated. On shutdown of the system, either planned or automatically as a result of a fault, the reactant gases are replaced by nitrogen. Purge lines are provided at the fuel-cell outlet side for each reactant. These operate at two rates: an adjustable, slow, rate to provide for elimination of accumulated impurity gases, and a fast rate to allow flushing with nitrogen during shutdown.

Controllable-flow-rate gas pumps are provided for fuel cells that require reactant circulation for water removal. Condensing heat exchangers in the reactant gas loops allow for water-product removal. They are equipped with level-measuring devices. The condensers are preceded by traps that collect any electrolyte/coolant that gets into the gas streams as a result of fuel-cell leaks. Such leaks can also lead to the release of reactant gases into the pressure container and, via bubbles in the electrolyte or coolant,

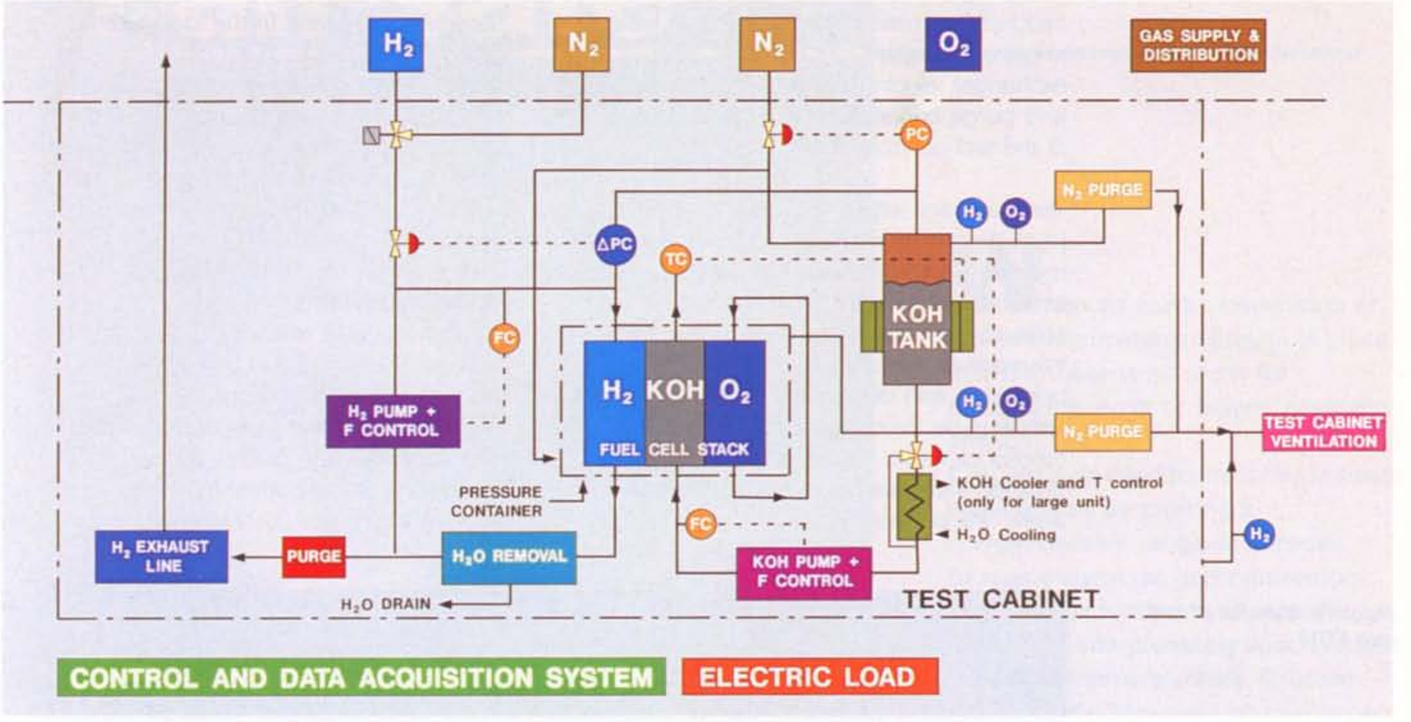

Figure 4. Block diagram of the fuel-cell-stack test unit

into the coolant tank. To prevent possible accumulation of explosive gas mixtures in these vessels, both are continuously purged with nitrogen and are equipped with hydrogen and oxygen detectors that automatically cause a test to shut down and an increase in purge rate when any leakage is detected.

The fuel-cell loading will be simulated with an electronic load capable of operating under set current, set resistance or (via a computer feedback loop) set power. For safety reasons this, together with the fuel-cell circuit-breaker, will be situated outside the test bench.

Fuel-cell test control

Although the test equipment in the FCTF will differ considerably from that in the existing Battery Test Centre, as much existing battery test control hardware and software as possible will be reused. Routine operations will be entrusted to the same contractor team (Serco) that has been running the Battery Test Centre at ESTEC since 1985.

'Decentralised' test bays, already developed and in operation in the ESBTC, will be used for test control and data logging (based on HP-300 series computers and HP-3852A multi-programmers). They will be located in the FCTF test room, but will be linked to the ESBTC data-processing computer (HP-1000) via a fibre-optic link.

Test data will be transmitted in the same formats as battery test data, allowing the same data-processing and archiving software to be used. One channel will be dedicated to transmitting the status of the FCTF laboratory's safety system and of the gas storage, so that any faults or impending gas shortages can be monitored directly in the ESBTC.

Just as battery tests are protected by a so-called 'Battery Protection Unit', designed to isolate a battery in case of loss of control from the decentralised test bay, failure of test hardware or of the battery under test, so fuel-cell tests will be protected by 'Fuel-Cell Protection Units' designed to ensure safe automatic shutdown. Since the actions required are much more complicated and may vary depending on the type of fuel cell under test, these will be implemented using high-reliability, programmable-logic controllers.

All test-bench controls that need to be operated during a test (as distinct from during test set-up) are computer-controlled. Consequently, it will not be necessary for the laboratory to be manned continuously. Video links with the ESBTC will be provided for remote surveillance.

The FCTF's role for Hermes and other future pogrammes

Since the main aim of the development effort for Hermes is to produce a weight- and volume-optimised fuel-cell power plant unit rated at 4 kW, complete with peripheral components, it will be necessary to carry out tests using progressively fewer of the test-bench peripherals as the design effort matures. Ultimately, the qualification tests might only require gas supplies, heat exchanger, electronic load, water collection and purge connections in addition to a part of the test control system.

Test durations will vary from a few hours (excluding equipment set-up time) to several months. Short-term tests will be sufficient to establish the primary characteristics of the cells, such as current/voltage characteristics, influence of temperature and pressure of operation, and design limitations (maximum temperature, pressure or flow rate). Failure modes can also be simulated. Medium-duration tests, lasting of the order of one week, will be required to demonstrate the thermal management of stacks and the water-removal properties of electrodes. Long-term tests (endurance tests) are, however, the most important and will need to be run for about six months. Here, the test control system will allow simulation of any required load profiles. Only these tests can measure the true degradation rates of materials and components (especially electrodes).

In this article, emphasis has been placed throughout on the Hermes spaceplane as the first programme requiring fuel cells and without which the FCTF would not have been built. It is hoped that the new facility will be able to make a substantial contribution to the very large effort that will be needed to achieve a European space-qualified fuel-cell manufacturing plant. In the longer term, it is expected that the FCTF's flexible design, wide range of operating conditions, and the possibility of carrying out continuous 24 h per day testing should make it attractive for other future fuel-cell and electrolyser testing, both for ESA programmes and for external customers.

Acknowledgments
The considerable efforts of ESTEC Technical Facilities Section staff in the design and realisation of the FCTF building, and the valuable contributions of our colleagues in the Energy-Storage Section in the preparation of test-control hardware and software, are gratefully acknowledged.

Figure 5. Exterior of the new FCTF

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Computer Simulation of Space Mechanisms

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Computers can now be used routinely and inexpensively to generate a model of a working mechanism that emulates the mechanical properties of the real thing, even responding to driving and resistive forces and torques in a realistic manner. To be able to observe the behaviour of his machine in action 'on the drawing board' has long been the designer's dream. This article discusses current computer technology that makes this feasible, and assesses its impact on the current approach to mechanism design.

Mechanisms

From the placing of a filter in an optical beam, to the deployment of a solar array or communications antenna, mechanisms are the means by which pieces of spacecraft hardware are moved from one point to another. A body in space can move along or about three perpendicular axes, in its so-called 'six degrees of freedom' (Fig. 1). A mechanism is a chain of such bodies linked in a particular way. It is the nature of the joints between the parts that allow or, just as importantly, restrict these motions that gives mechanisms their distinctive characteristics; in fact, they would otherwise actually be structures. The way in which they move and the paths that they follow depend upon their geometry, and how quickly and with what energy upon their mass-properties and their internal and external resistances.

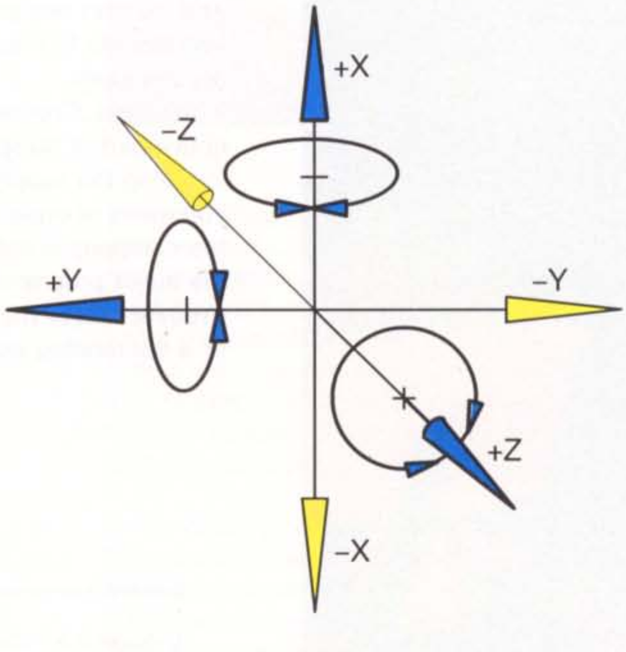

Figure 1. The six degrees of freedom of a body in space

Man has long observed things in action and tried to understand how they work; so it follows that the traditional approach to mechanism design has been one of making models and seeing how they behave. Being able to feel the model literally put men in touch with the machine. But this method relies upon analysis and interpretation before appropriate modifications can be implemented, and the drawback with the models is that they possess latent properties that are not all known or even evident. Prompted by the apple falling on Newton's head, the theory enabling the dynamic behaviour of any given configuration to be predicted, albeit laboriously, was worked out and refined three centuries ago, and is still valid for the mechanisms referred to here.

Starting with only a rough idea of what is needed, the designer will often modify an existing design which was made for a 'similar' task, rather than start from scratch. Whilst there is good reason to use existing designs where they are close to what is required, some properties may well be undesirable or even intolerable. For space equipment, much effort is expended merely trying to eliminate unwanted properties that should have been avoided from the outset, and costly re-development and re-qualification are needed when they come to light too late. The prerequisite is knowing and describing in sufficient detail the functions and characteristics that are required of the mechanism and, if possible, those that are undesirable. Only by checking against a detailed description of what is wanted can a proper assessment of any candidate design be made.

Computer simulation

The advent of the computer meant that enormous series of calculations could be done rapidly, and more aspects of mechanism behaviour could be ascertained more quickly, but this still provided only static and fragmented insights. To many engineers, the output from earlier computer programs was indigestible, arriving in the form of tabulated figures in forbiddingly large stacks of paper. Although undoubtedly an advance, it was a cumbersome means of finding out what was going on.

Computer programs have been commonplace for some time for structrural and thermal design, but their needs have not been as demanding as for mechanisms, and only recently has the complete process of calculation for mechanisms been coded in unified software. The breakthrough has awaited the development of fast processors, interactive graphics software and fast high-resolution display systems, enabling the writing of application programs for the visualisation of mechanisms in operation. Now, at last, we can synthesise models from scratch, and see what they look like and what they do, without having to wait months for manufacture, assembly and test. In this form, to which we can relate much better, we can 'play' with the model much as we would on a test-bench, but with the significant advantage of being able to extract information on its behaviour at any point without recourse to cumbersome instrumentation.

Being synthetic, the key feature of a computer model is that all its properties are known. Although this imposes the burden of defining them in the first place, as long as the code provides correct results, the observed effects are directly attributable to those properties. We can modify the design almost instantaneously, knowing that the effects observed are due to the change alone — and not, for example, to the reassembly of the mechanism which can result in changes even if nothing has been deliberately altered. Moreover, the mechanism model may be run indefinitely without wearing out.

A truly empirical approach is thus possible, with rapid learning and convergence to optimal designs. Often the designer has no exact data, but from his experience he knows the ranges in which the parameters will lie. Using the tools of computer simulation, he can experiment with the different values and determine the sensitivity of his design to a particular property. The speed with which this can be done is of enormous value for education, which is a most exciting and significant aspect of computer modelling. It is also valuable for early refinement of requirements, which are often established with large errors or margins to cover uncertainties.

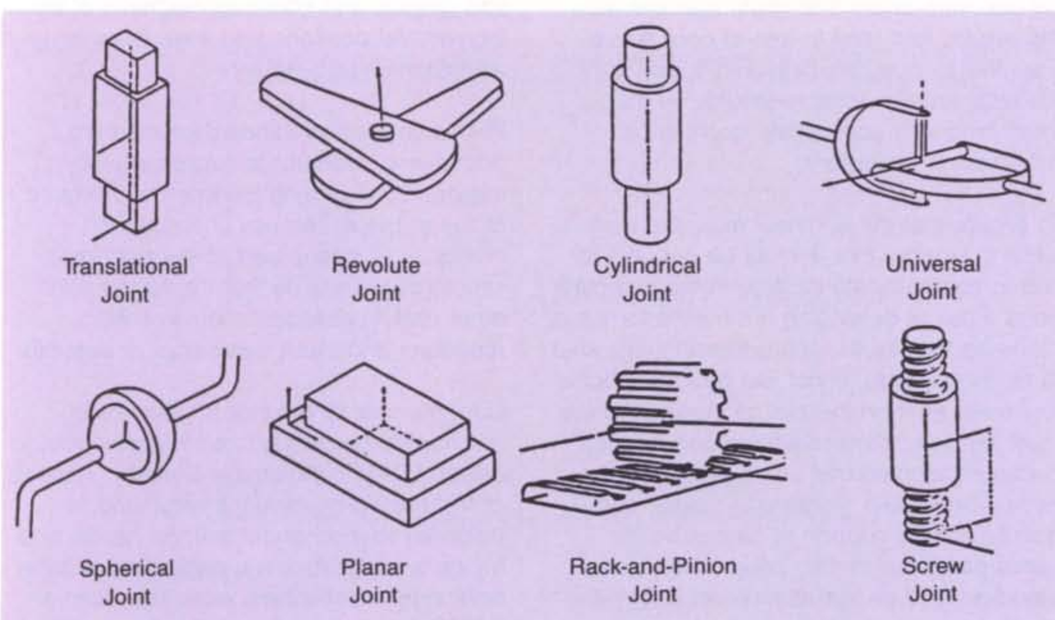

Figure 2. Mechanism joint representations in ADAMS (Courtesy of TEDAS, W. Germany)

Finally, the graphical outputs of the programs are understandable to non-specialists, thereby assisting the designer in communicating directly outside his realm.

'It always works on paper'

There will always be a balance between the theoretical and the practical, since ultimately a piece of real equipment has to be made. However, that balance is changing significantly as the theoretical approach gains more of the capabilities once only available in the practical, enhanced by its own particular advantages. The practical work will in future have to be concentrated on those problems that can only be solved by practical means. It is pertinent to mention here that two-thirds of the phenomena that influence the reliability of the mechanism lie outside the design area, in the activities associated with manufacture, assembly, test and operation. So the practical engineering is not diminished however good the design, and attention to detail, provision of required tolerances, correct manufacture, lubrication, assembly, test and operation must all receive the appropriate effort.

Software

While there is nothing magical about doing the necessary calculations, and many people think they can easily write a program for this purpose, it is frequently found to be much more complicated than at first thought. Starting with a simple set of calculations covering a specific need, complexity increases with the attempt to broaden it into a fully universal code. Besides the prerequisite of giving accurate results over the full range, it is essential that the program be free from errors that could interfere with the results, and lead to loss of confidence. Essential to the usefulness and speed of the technique is visual feedback, so that interfacing with appropriate geometrical modellers is necessary.

To ensure that the engineer feels it is worthwhile to use the tool, it must be possible for him to communicate easily with the computer code. Ease of describing the mechanism and receiving the results, and understanding what to do to get them, is not just desirable, but a legitimate right on the part of the user. There must be clear, comprehensive and detailed documentation so that users other than the author can obtain meaningful results, and good technical support to help solve the user's problems as they arise. 'User-friendliness' is an apt description of a real need in this context.

When all of this is taken into account, it becomes clear that only a commercially mature package will suffice. To do the job properly needs dedication and specialisation beyond that which is justifiable in most manufacturing companies, and suppliers of commercial packages necessarily take on the responsibility for this work. Even with these commercial packages, there are still problems, but the suppliers are usually able to carry out the necessary refinements on a continuing basis in close contact with the user community.

Of paramount concern to the user is the credibility of the results, especially in the absence of any alternative means of confirmation. Distinguishing between mechanism behaviour and problems with the program may be difficult, especially if the user does not recognise the characteristics displayed. Limitations in numerical integration are one source of problems, which must be overcome by careful selection of the integration step size. Experience in use of the software, together with cross-checks by other methods, quickly builds up confidence in the model's ability to provide meaningful results.

Dynamic modellers

The typical dynamic modeller will: provide a library of joints, such as hinges, spherical, universal, sliding, rack and pinion, screw and gear joints; request definition of the parts in terms of geometry and mass properties; request the nature of the results required, such as time- and displacement-histories; automatically formulate and solve the equations of motion to give displacements, velocities and accelerations, and then pass the results to a post- processor for formatting into graphs; and construct diagrams of the incremental positions and show them as an animation (Figs. 3—6).

For particular non-standard phenomena, user-written subroutines can usually be inserted by exploiting the open architecture of the software. The use of a common computer language and of standard data structures will ensure that interfacing with other useful packages, such as solid-modellers and mesh-generators, is possible.

Currently, one of the industry-leaders in mechanism modelling is a software package called 'ADAMS' (Automatic Dynamic Analysis of Mechanical Systems). It originated in response to mechanism-specific needs, and hence is formulated in a particularly suitable fashion for mechanisms work. It is used at ESTEC for studies of satellite antenna and

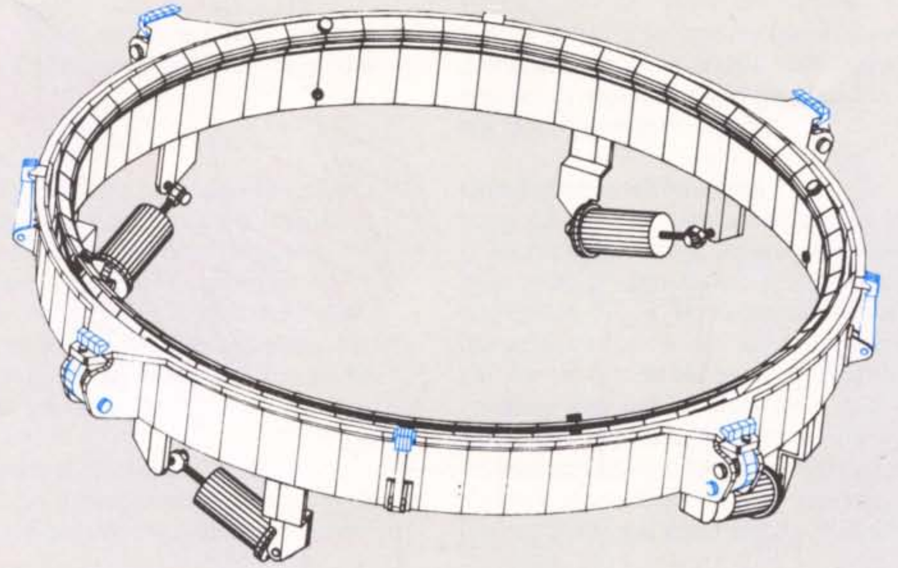

Figure 3. EUCLID solid model of the Spin-and-Eject Mechanism

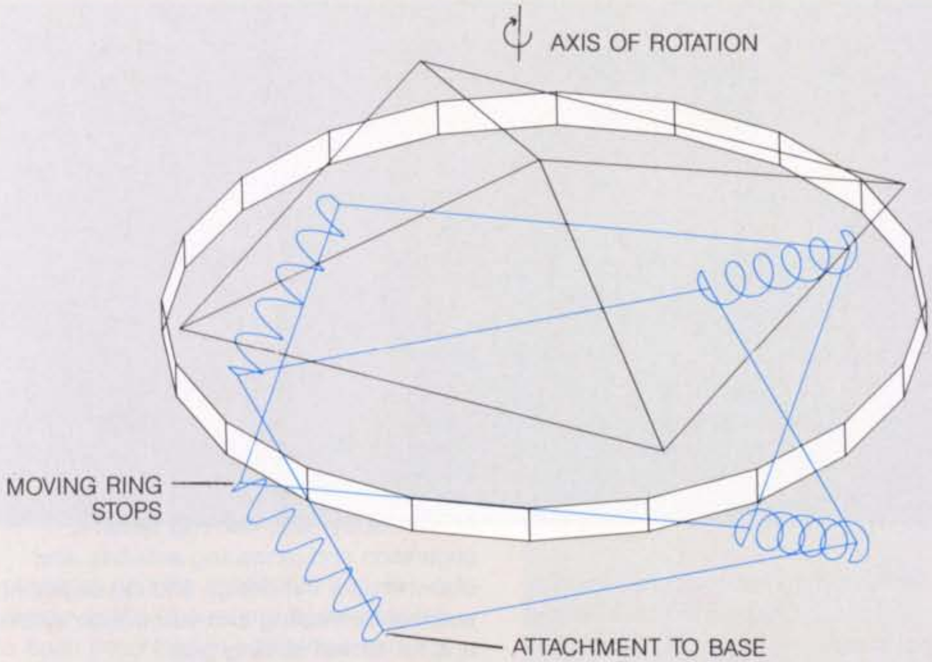

Figure 4. ADAMS dynamic-simulation model of the Spin-and-Eject Mechanism

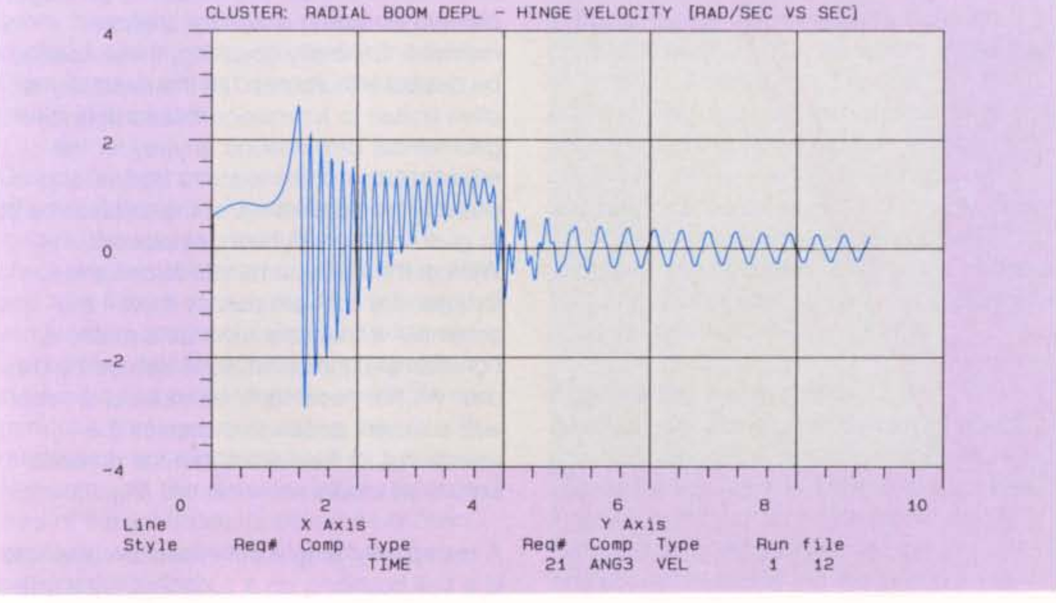

Figure 5. Velocity/time trace from a boom-deployment simulation, showing the distinct stages of initial motion, and oscillations following first and second hinge locking

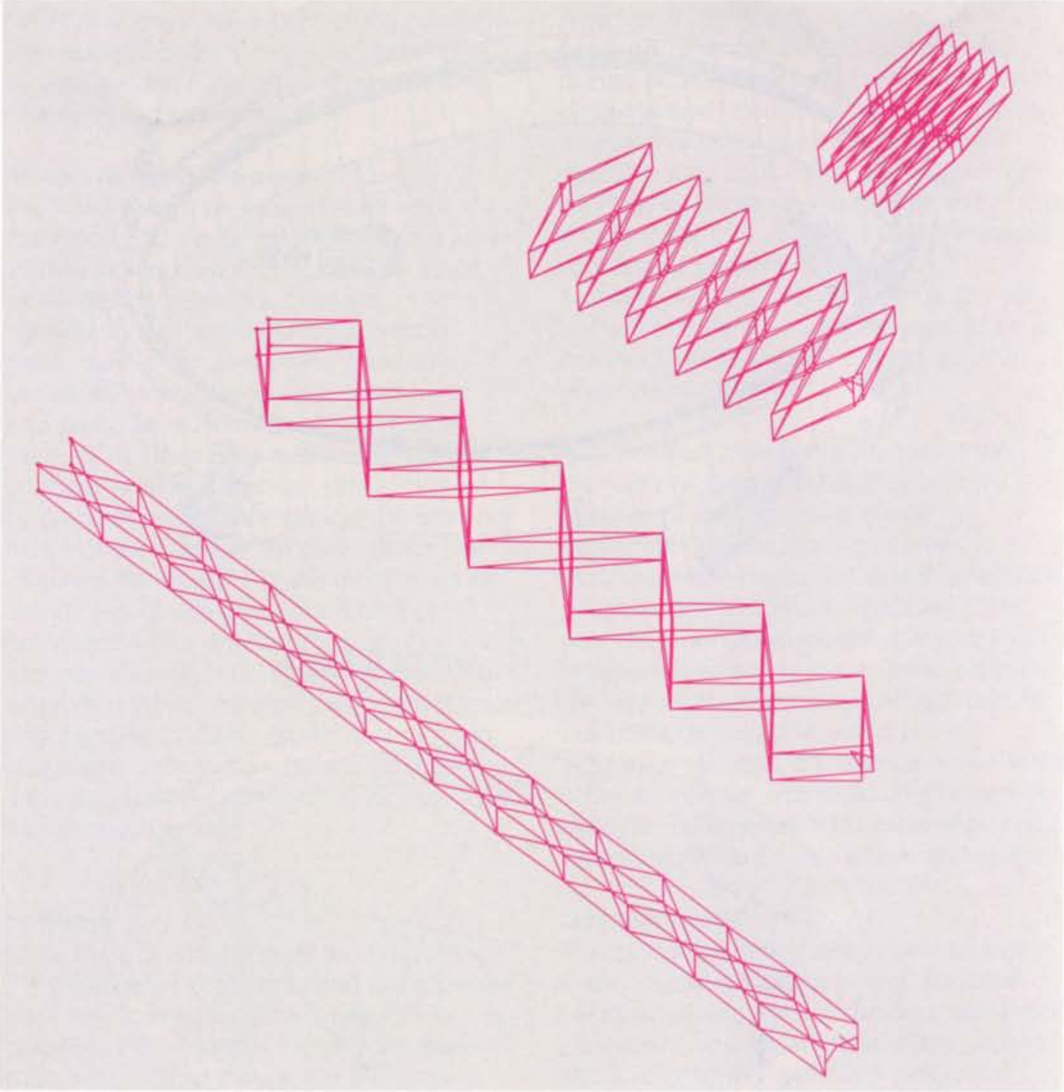

Figure 6. Sequence from a simulation of a truss boom deployment

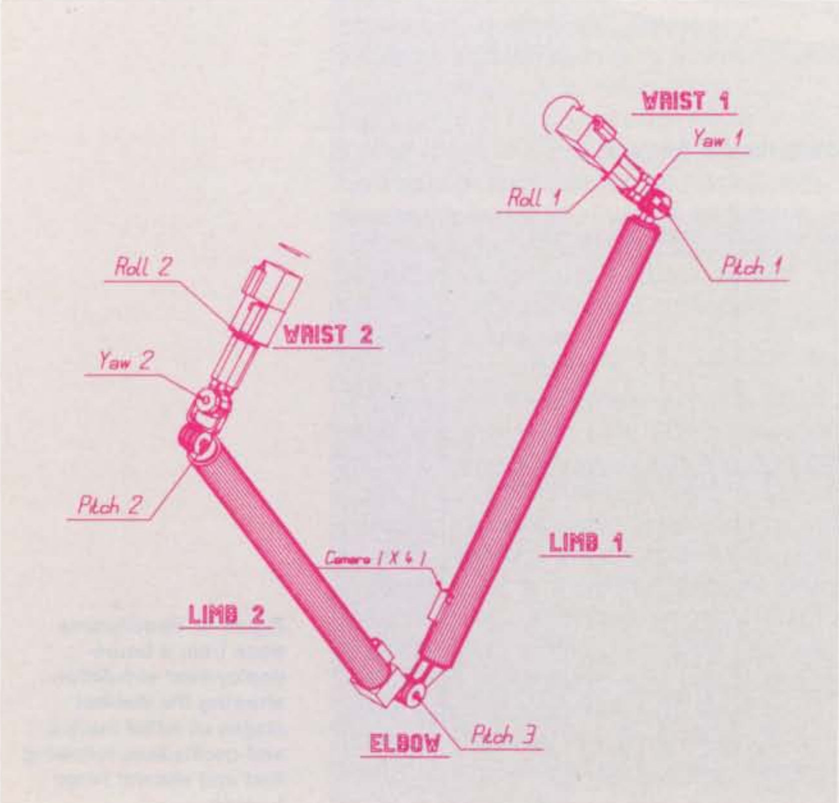

Figure 7. EUCLID solid model of the Hermes Robot Arm (HERA)

boom deployment, docking systems, separation and jettisoning activities, and elsewhere for the design and development of automobile steering and suspension systems and for aircraft landing-gear.

Many solid- and surface-modelling packages claim to provide mechanism-analysis modules. Generally speaking, these need to be treated with caution, as the capability is often limited to kinematics, based upon the geometrical data needed anyway for the representation of the discrete bodies, and possibly time-derivatives of the displacements to give so-called 'dynamic responses'. Without the ability to handle forces and torques, the software cannot show if the assembly will actually work as a machine. For example, the dimensions defined by the user will not necessarily be those of a motor with sufficient torque to overcome the resistances in the system, but the dynamic simulation model will show this (Fig. 7).

A deceptively simple but informative example is a ball bouncing on a surface. Only a true dynamic modeller can represent this process; the geometric modellers would show the ball passing straight through the surface.

Features

Most of the software has been based on rigid-body descriptions that are valid for many machine parts. For large space deployables, however, the structural properties of the linked bodies contribute significantly to the dynamic behaviour from release, through deployment, to the end of travel and thereafter.

Recent work at ESTEC on incorporating flexibility into dynamic models has provided valuable insight into the interaction between deployables and the spacecraft (Fig. 8). Phenomena like friction and backlash have also been described in subroutine form for use with dynamic models, while the characteristics of transmissions such as gears, harmonic and cyclo drives are being studied for formulation into usable modules. Other items, such as bearings, should join the list in the future.

One of the Agency's aims is to categorise the different features and to construct a library of models, the exercise itself being used to check whether this is appropriate or possible, and as a further opportunity to gain insight into fundamental mechanism behaviour as well as the specific techniques of describing the model and presenting the results. In one particular package, by coupling the mechanism equations package to a finite-element code, the stresses developed in the links of a mechanism in motion have been displayed as colour shadings on the component surface.

Where kinematics alone are required, there is a wide range of linkage-analysis software available, both independent from and integral with solid-modelling packages, but this does not give dynamic information.

Computing environments

Many people may be concerned that the use of such codes means expensive hardware investment or redundancy of their existing equipment. Generally, however, the packages are written in universally used languages that can run on a wide range of mainframe computers as well as many mini- and micro-computers. Typically, ADAMS is written in Fortran and uses a Tektronix display format for basic interactive graphics. The use of a three-dimensional graphics workstation enables instantaneous manipulation of the model and animated sequencing of the simulation, giving a clear view of the mechanism in motion.

With the rapidly improving ratio between price and performance, especially in the field of graphics workstations, the cost-effectiveness of mechanism simulation is improving all the time. Even on a micro-computer, without the full advantages of 3-D graphics, useful results can be obtained. A company possessing no appropriate computer can take advantage of the software by using a computer bureau, or by placing a contract with the software supplier.

Engineering implications

Justified concern is often expressed about the credibility of the results obtained from software simulations, but with the advances in graphics, much of the doubt can be dispelled by seeing the machinery in operation and examining the perfomance

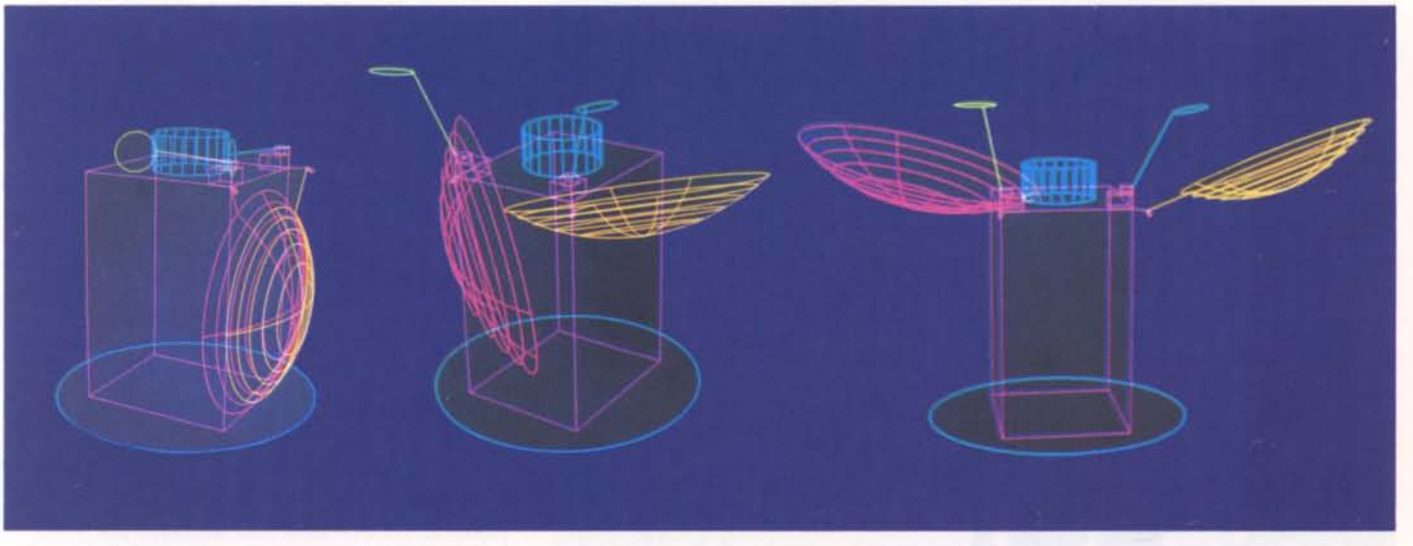

Figure 8. Simulation used to determine optimum deployment of antennas and reactions on spacecraft

results taken at points of interest. There is nothing mysterious about the software; it is just doing the calculations that the designer would do, but fast enough to display the action. As to the rejoinder 'There's no substitute for a test!', if not done correctly tests can lead to a false sense of security, as many additional indeterminate influences exist in a test rig which directly affect the performance of the item under observation, not to mention the effects of gravity. The logical way forward is a reasoned balance between the old and the new.

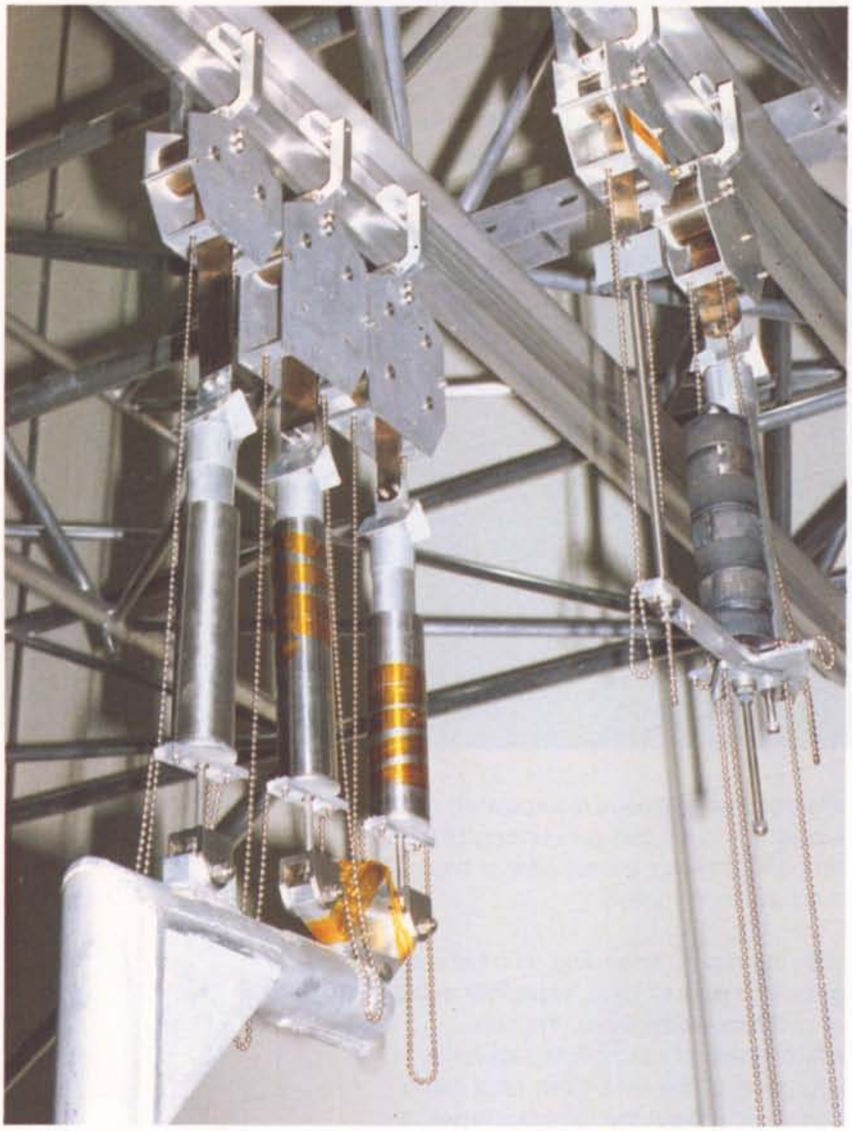

Figure 9. Deployment testing of a solar array in a gravity-compensation rig, involving many additional mechanisms, and hence a typical candidate for dynamic simulation

Optimising system design for performance, with mechanisms just strong enough for orbital operation, but not ground conditions, leads to problems of demonstration. The deployable structures now being planned are becoming so large that testing on the ground will either be impossible, or will at best produce dubious results due to the reactions from the rigs needed to support the gravity-distorted equipment. Mechanism simulation provides the answer in that the whole test-item and support-rig assembly can be simulated, including the effects of gravity, with the ground-test performance being used to generate confidence in the model. Removal of the gravity and test-rig influences from the model would then leave the orbital situation, which could be tested as many times as necessary to predict system behaviour over the full range of interest (Fig. 9).

Since the ultimate need was for items of equipment for building into a spacecraft, it has been commonplace to expect hardware as the end product of research and development contracts also. In future, however, dynamic models will be more valid as deliverable items instead of development hardware, especially as initial demonstrations of designs.

Financial implications

A common reaction to a computer-based approach is that it is 'so expensive', but in the wider context of global- rather than task-level considerations, the contrary is usually true. The older, isolated methods whose results must be further treated to arrive at a clear understanding are labour-intensive, and computing costs are diminishing progressively, while labour costs continue to rise. The argument that the tool would only be used from time to time, and hence is not justified, fails to take into account the technique's potential influence over the greater part of the whole design process for all mechanisms, no matter how small.

While the obvious candidates for dynamic simulation are the large deployable appendages like solar arrays, antennas and booms, the development costs of 'simple' on-board mechanisms show that these too would benefit from its use. Enormous sums can be saved by avoiding costly and lengthy prototype manufacture and test, which may only bring to light those unwanted characteristics. Mechanism simulation should be seen as an integral part of the overall design-to-test process. Since proficiency and effectiveness are directly related to practice, the more it is used, the greater will be the benefits.

Social implications

Questions are often raised about the social implications of such software, but dynamic modelling by computer is only a tool to help the engineer do his job more effectively, not to replace him. There has still to be a critical mind to set up, assess and modify the mechanism, evaluate the results, and know how to alter the parameters to achieve the desired result.

These tools mean that more design activity and improvement of understanding is now possible in a shorter time than before, leading to an overall improvement in quality. Moreover, in its educational role, computer simulation allows invaluable risk-free experimentation, making engineers more effective more rapidly. It is true that the hardware fabrication and test work should be reduced, but then saving of manpower and materials must be the aim of any commercially-minded organisation.

Conclusions

The time is ripe for pursuing this approach to establish confidence in the software and remove the few remaining problems, so that we can be ready to simulate the behaviour of mechanism chains too large and too delicate to be deployed or operated in Earth's gravity, but which cannot be strengthened just for this purpose as they would then be too heavy for launch. Mechanism simulation is becoming a significant contributor to good design and confidence in the equipment we place in orbit.

Acknowledgement

I wish to thank P. Dobson and P. Pearson for advice in the realm of computers and software, F. Panin for diagrams of ADAMS models and results, J. Pang and H. de Zeeuw for diagrams of EUCLID models and results, and all those who have, in their various ways, stimulated my interest in this subject.

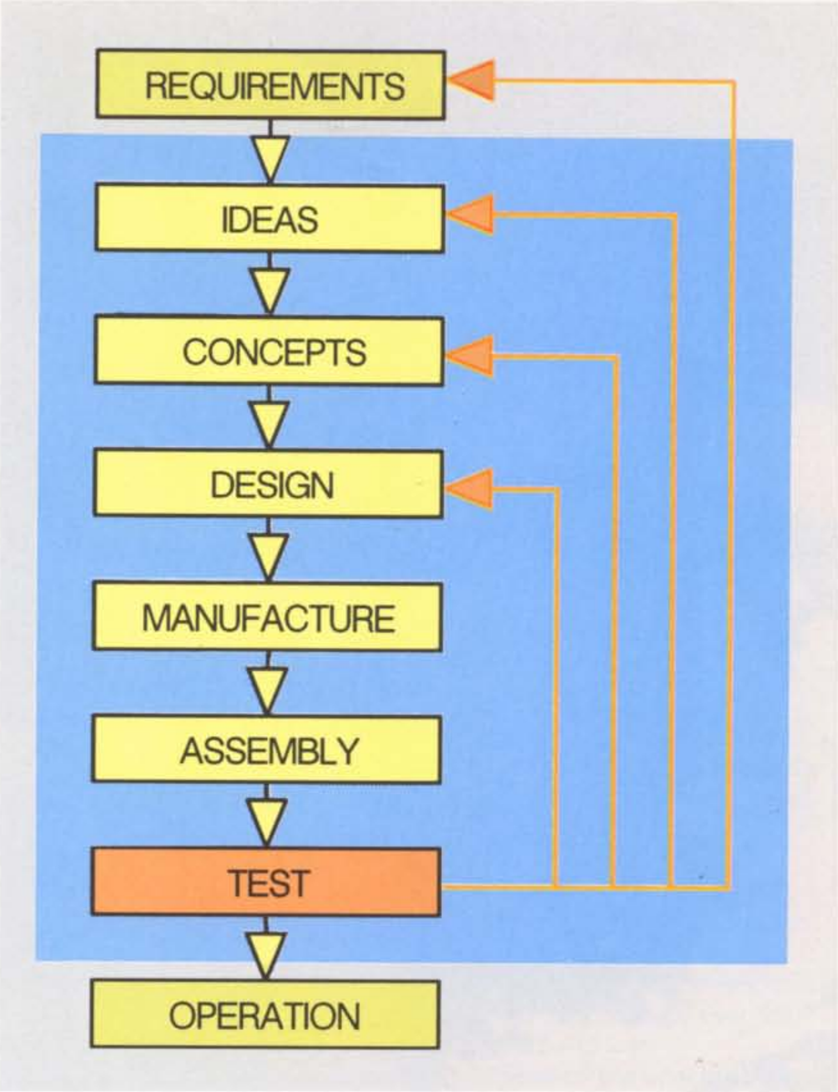

Figure 10. Extent to which dynamic simulation can affect the whole process of mechanism making

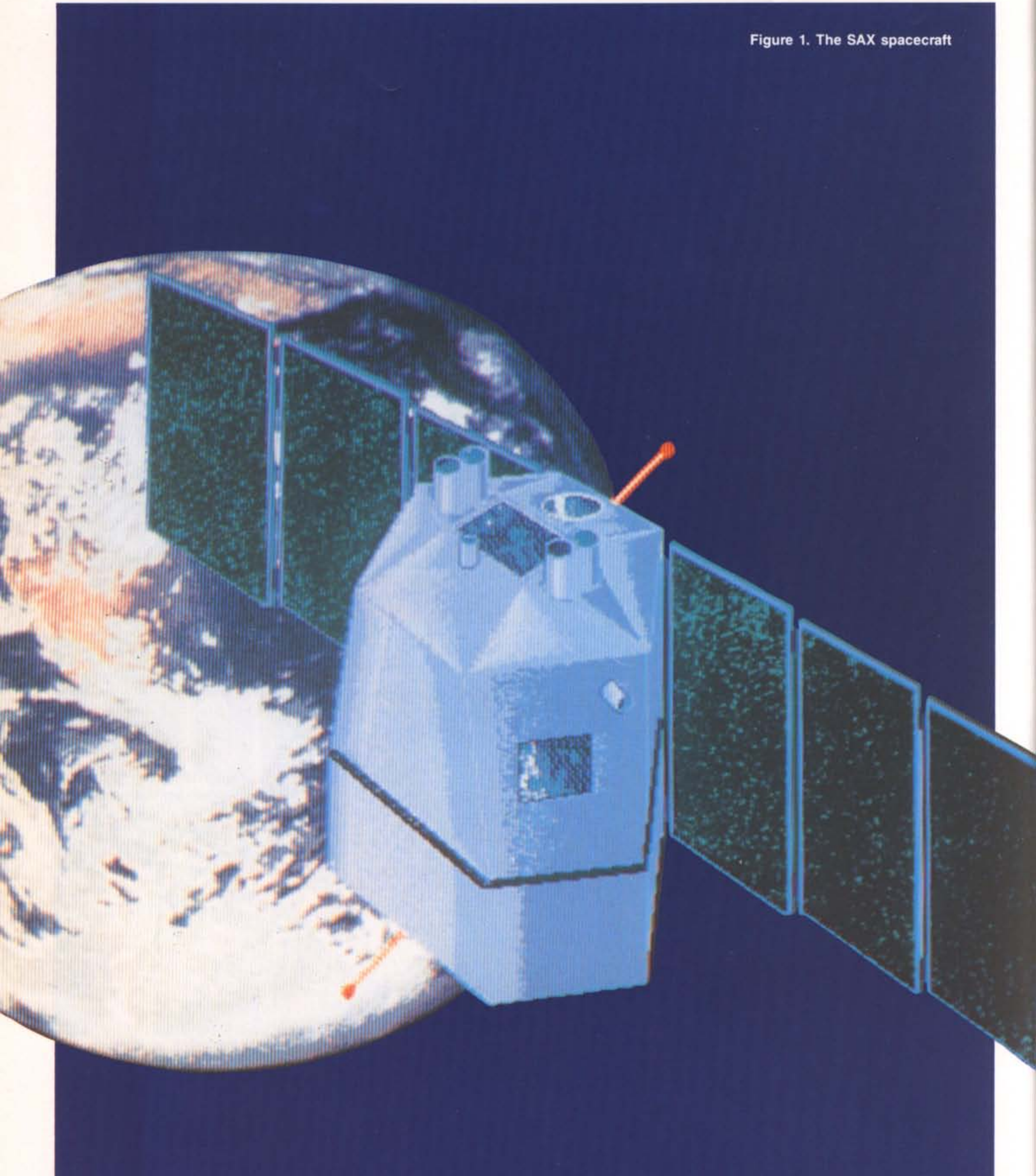

Figure 1. The SAX spacecraft

ESA Support for the Italian SAX Astronomy Satellite Mission

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In 1979, the Italian Government established a National Space Programme (PSN) based on a plan that was to be updated every five years. The Interministerial Committee for Economic Planning (CIPE) initially entrusted the overall management and administration of the Programme to the Italian National Research Council (CNR), and later to the Italian Space Agency (ASI) when it was formed in June 1988.

A collaborative link between ESA and PSN, established at the outset of the Italian space endeavour, also involved a consultancy agreement whereby ESA would assist PSN (now ASI) with technical and management issues*. One of the projects for which ESA is currently providing support is the SAX X-ray astronomy satellite, designed to make systematic and comprehensive observations of celestial X-ray sources, with special emphasis on spectral and timing measurements.

This article outlines ESA's contributions to the various SAX mission elements, which involve the Agency's latest standards and technologies.

* The overall ESA consultancy to the Italian space programme was described in the August 1989 issue of ESA Bulletin (No. 59, pp. 81-87).

Introduction
The SAX mission was conceived in the early 1980s to perform a systematic and comprehensive observation of celestial X-ray sources in the 0.1—200 keV energy range, with particular emphasis on spectral and timing measurements. It is being carried out in collaboration with several Italian scientific institutes, the Netherlands Organisation for Space Research (SRON) in Utrecht, and ESA Space Science Department's Astrophysics Division. In addition to the satellite itself, a ground segment consisting of an Operations Control Centre, Ground Station, Scientific Data Centre and Communications Network is also under development.

The SAX satellite (Fig. 1) will be injected into a circular equatorial orbit with an inclination $\leq 5°$ and an initial altitude of 600 km by an Atlas Centaur launcher in the last quarter of 1993. The nominal mission lifetime will be two years, with a design goal of four years.

The main industrial contractors are Aeritalia for space-segment definition, and Telespazio for the ground segment, under the management of ASI.

Scientific mission
The scientific objectives of the SAX mission are:
- imaging with moderate angular resolution and broadband spectroscopy over the energy range 0.5—10 keV;
- continuous cyclotron line spectroscopy over the energy range 3—200 keV;
- time-variability studies of bright-source energy spectra over time scales ranging from milliseconds to months;
- systematic observation of the long-term variability of X-ray sources, by means of periodic surveys of preselected regions of the sky (minimum intensity equivalent to a 1 mCrab source).

To achieve these mission objectives, a scientific payload has been designed which consists of a nest of four X-ray concentrators (C/S), a large-area phoswich detector system (PDS), a high-pressure gas-scintillation proportional counter (HP-GSPC), and two wide-field X-ray cameras (WFC) developed by SRON (Fig. 2).

Three of the four concentrators, the Medium-Energy X-ray Grazing Telescopes (MECS), will be sensitive to medium-energy X-rays in the range 1—10 keV. The other, the Low-Energy X-ray Grazing Telescope (LECS), developed by ESA Space Science Department, will be sensitive to relatively low-energy X-rays in the range 0.15—10 keV.

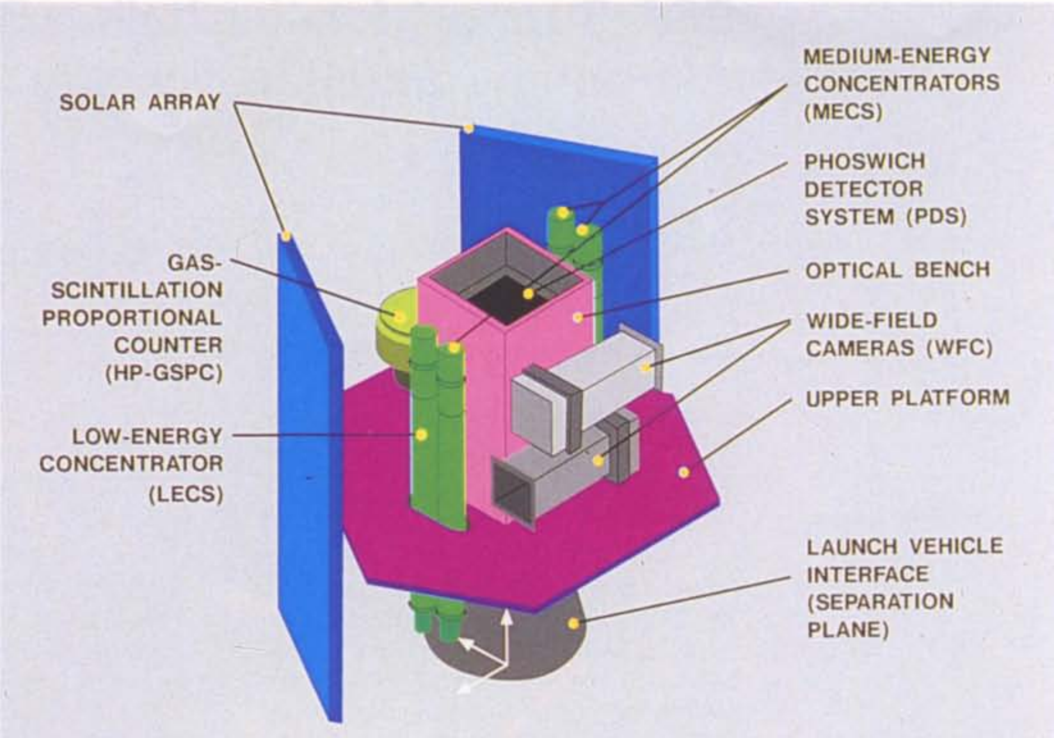


Figure 2. The SAX payload layout

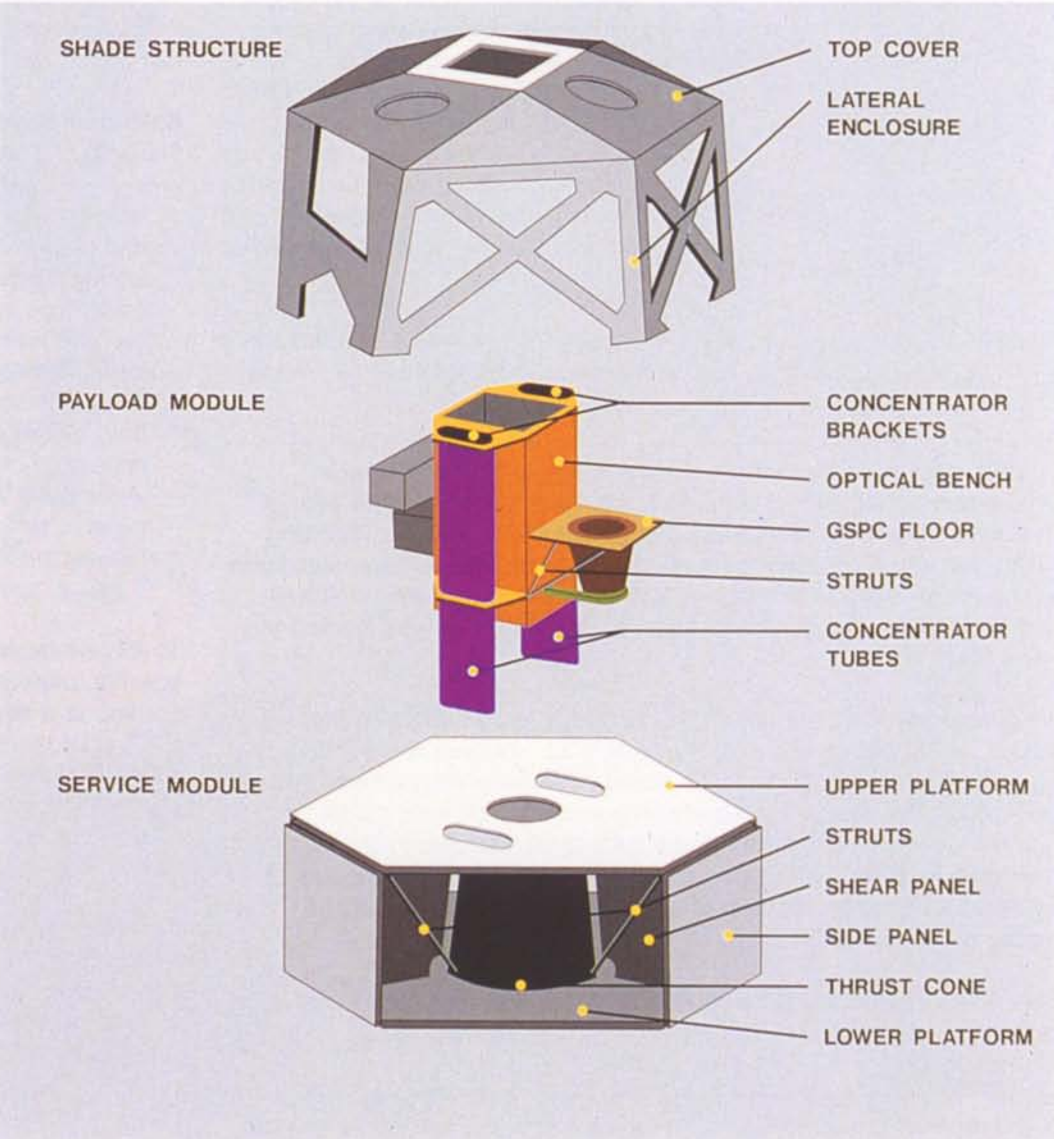


Figure 3. The three primary modules of the SAX spacecraft

The SAX space segment
In the design of the 1200 kg SAX satellite (Fig. 3), two main modules can be identified: the Payload Module and the Service Module.

The payload Module, consisting of a stable carbon-fibre optical bench, will carry all the scientific instruments and associated control electronics. The Service Module will house the subsystems required for the operation of the satellite and the various scientific instruments, namely:

- the Electrical Power Subsystem (EPS), developed by FIAR, the main function of which is to supply the satellite's electronic equipment with a constant voltage (regulated bus) of 29 V (both in sunlight and eclipse);
- the Solar-Array Subsystem (SAS), developed by Fokker, consisting of six solar panels, designed to generate 1700 W of electrical power at end of life;
- the Attitude-Control Subsystem (ACS), developed by Fokker/Aeritalia, to provide attitude control and stabilisation for the satellite in all three axes;
- the Telemetry, Tracking and Command Subsystem (TTCS), developed by Selenia Spazio based on ESA standards, which will provide the necessary interfacing between the satellite and the radio-frequency (RF) link with the ground. ESA-standard packet telemetry will be used;
- the On-Board Data-Handling/Data-Management Subsystem (OBDH/DMS), which is based on ESA-standard concepts and guidelines for spacecraft data-handling subsystems.

Three more subsystems, developed by Aeritalia, namely the Structure Subsystem (SS), the Thermal Control Subsystem (TCS) and the Harness Subsystem (HS), complete the satellite system design.

Mission communications and flight operations
The interface between the space and ground segments is provided by the RF link between the satellite and the ground station. All the satellite data will be packetised in accordance with the ESA Packet Telemetry Standard before transmission to the ground. This will allow a relationship to be established onboard the spacecraft between the various data sources and the channels used for data transmission, thereby allowing priorities to be established from the ground for the processing of data from particular satellite sources. This feature offers important advantages for the operation of low-orbiting satellites like SAX, which have short-visibility passes over the ground station lasting just 5 to 8 mins and thereby require intensive ground-based operational activities during the pass.

The SAX ground segment
The baseline communications scenario for the SAX mission is shown in Figure 4, together with the basic elements of the

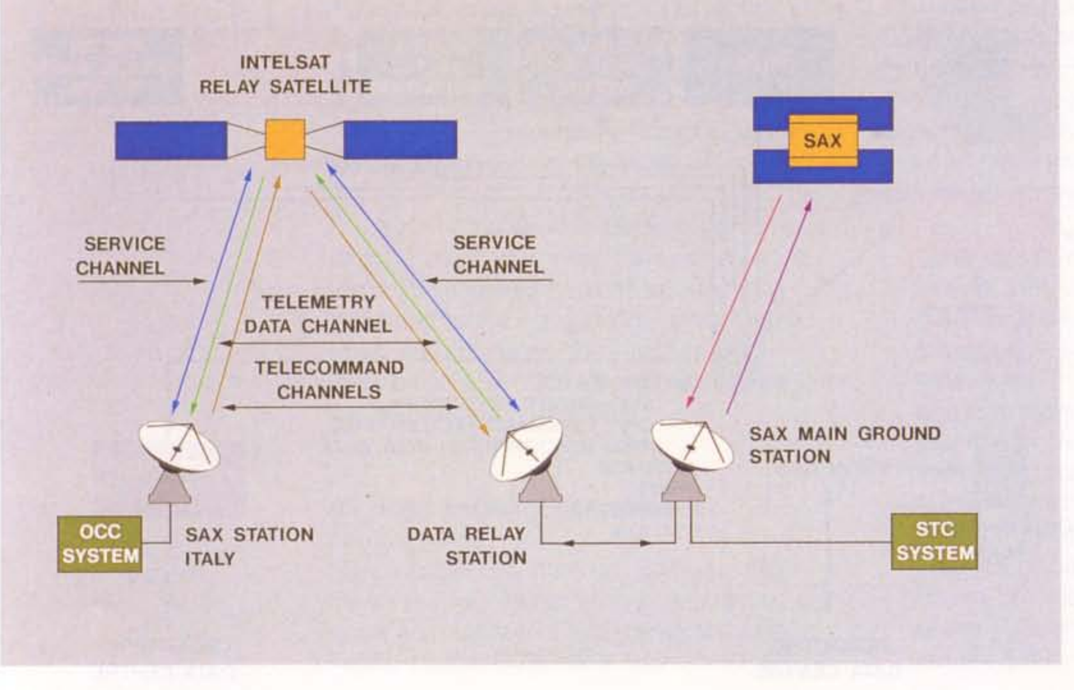


Figure 4. Overall SAX communications scenario

ground segment. They are a Ground Station (GS) to be located in the equatorial region (Kenya for nominal operations, with Kourou as a back-up), and an Operations Control Centre (OCC) and a Science Data Centre (CDS) to be sited in Italy.

The SAX Ground Station, equipped with an 11 m diameter antenna, will benefit from technology developed by ESA in cooperation with European industry, in particular for:
- the Telemetry Processing Subsystem, which will reassemble the telemetry packets after decommutation, catalogue them according to on-board data source, and store them ready for transmission to the OCC;
- the Tracking Subsystem, which will allow the satellite's range (distance between ground station and satellite) and the rate of change of this range (range rate), to be determined.

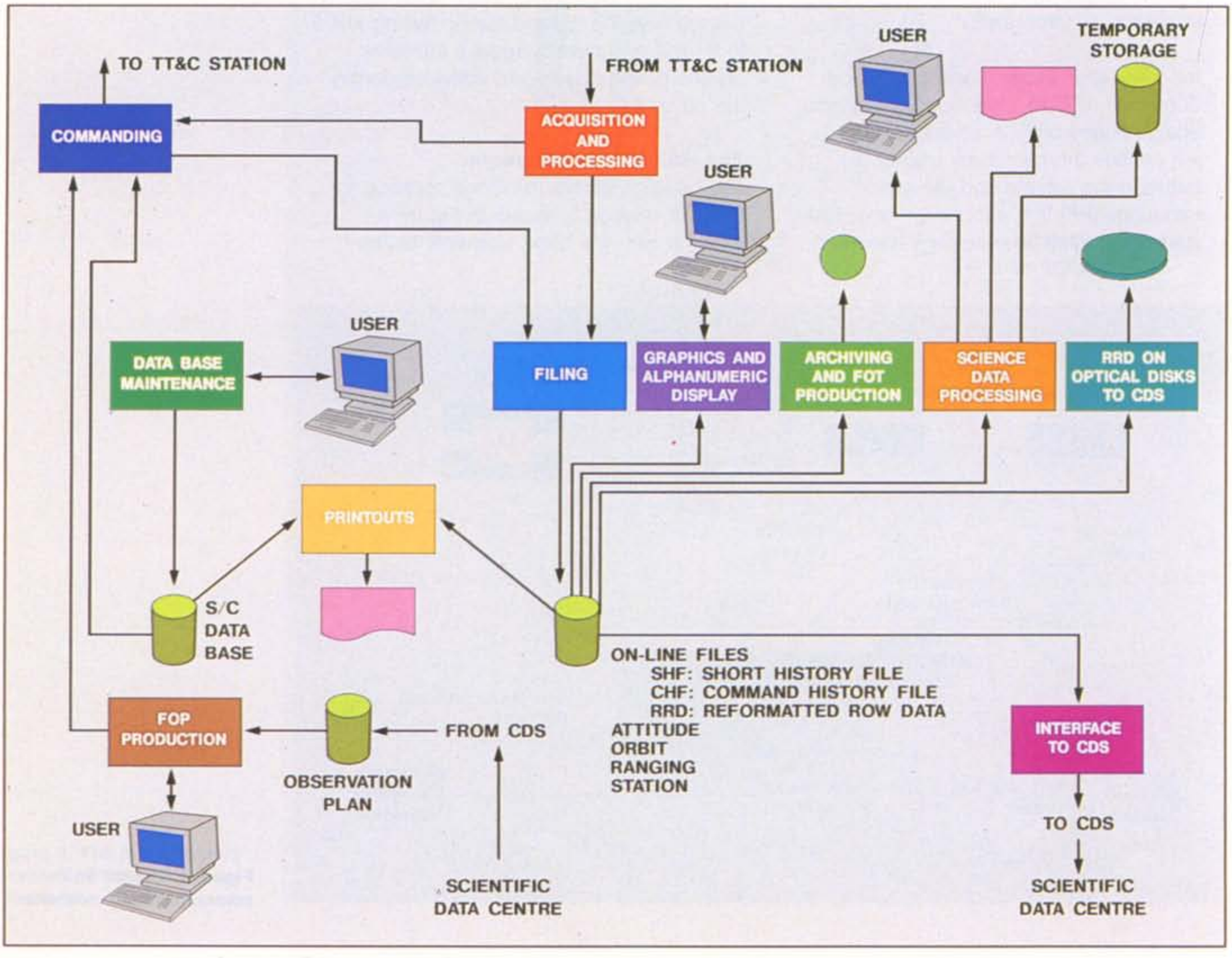
The prime functions of the Operations Control Centre (OCC) include (Fig. 5):
- establishment of operational plans and associated observation scheduling;
- spacecraft and ground-segment control;
- telemetry processing, display and archiving;
- command generation and verification;
- tracking initialisation, processing and orbit determination.

Conclusion

The scientific objectives of the SAX mission are unique and as such represent a challenge for the scientific community worldwide. With ESA's help, the design of the mission elements has based on advanced engineering concepts and state of the art technology.

The good collaboration established between ESA and ASI at all levels during the SAX project's development will therefore be a substantial benefit in the mission's implementation. Moreover, it will serve to foster further cooperation between the two agencies in the future.

Figure 5. SAX data flow



The European Centre for Space Law — A New Branch of Space Studies Opens at European Level

K. Madders
Legal Affairs Department, ESA, Paris

For some years now, space activities have been racing forward, leaving the legal means to govern them effectively far behind. The study of, and research into, space-law issues are also lagging behind present-day events. While large projects like Hermes and the Columbus Programme, for example, are posing legal questions on a new scale, the complexities of regulating trans-national aspects of telecommunications satellites in Europe still remain to be addressed in a coherent manner.

ESA's initiative

In 1988, the Agency's Legal Adviser, Mr Gabriel Lafferranderie, took the initiative of proposing a European Centre for Space Law (ECSL) as a means of strengthening Europe's space-law research profile. This idea elicited a very encouraging response, both from delegates to ESA's International Relations Advisory Committee (IRAC) and from leading figures in the space industry, the legal profession and the academic sector. As a result, the Agency called an exploratory meeting for October 1988.

Participants from all over Europe, representing the areas of both research and technology, met and unanimously endorsed the need for a space-law research body. They set up a Preparatory Group to establish the basic elements of the ECSL.

The fruits of the Group's labours, including a draft ECSL Charter, were then presented to some 70 interested persons at a meeting dedicated to the inauguration of the Centre, which took place at ESA Headquarters in Paris on 12 May 1989. The ECSL's operations formally began on that date.

A bridge between interested communities

Opening the May meeting, ESA's Director General, Prof. Reimar Lüst, characterised the wider significance of the Agency's role in setting up the ECSL as a partnership with outside communities, describing it as being: 'in the best traditions of the Agency . . . for ESA and its predecessor, the European Space Research Organisation, ESRO, have a long history of utilising the technical and intellectual resources at their disposal to foster space-related communities where only isolated groups existed before'. Moreover, the ECSL can, like the Agency itself, 'contribute to inter-disciplinary dialogue' among lawyers, engineers, economists and scientists.

Organisation

The proposed Charter, adopted at the May meeting, provides for a General Meeting of Members, and the establishment of a Board. The Centre is, however, only at an early stage of development. It has no juridical personality, and detailed rules and procedures are thus deliberately avoided at present. A more detailed Charter will be adopted once the Centre's work is more advanced.

ESA/ECSL activities

ESA has recognised the importance of the ECSL and has been a leading supporter in its development. The Agency has further shown this support in two major projects laying the ground work for the establishment of an effective framework for research and exchanges of views and information by:

- Opening up and expanding an existing internal ESA electronic database (ESALEX) including ESA/ESRO law and Europe-wide space-law bibliographical references. This will serve legal academics and practitioners across Europe via ESA's Information Retrieval Service (IRS, based in Frascati, Italy).
- Publishing a newsletter, the ECSL News, of which three issues a year are foreseen. (Two issues have already appeared, and copies are available from ESA Publications Division. Issue No. 2 contains the current ECSL Charter).

ECSL national members (e.g. the Institute of Air and Space Law of Cologne University and the University of Leiden Institute for Air and Space Law) provided inputs to both projects. ESALEX's efficacy in particular depends mainly on the willingness of individual ECSL members to supply bibliographical data and materials on space law and regulation to a common pool that all can access electronically via a desk-top computer and modem.

Progress has been good in this regard so far, and the ECSL Board has taken organisational steps to further the process. Once established (passwords should be available to ECSL members in early 1990), this resource will provide an important means to enable the Centre to become, in the words of ECSL News, 'Europe's powerhouse of ideas on space law.'

ECSL research projects

Another major function of the ECSL is to assist or execute research projects that can analyse the existing state of the law in its technical and policy context, and refine ideas even to the stage of formulating law-making proposals. Encouragement to do just this has already come from Mr H.J. Allgeier of the European Commission who, speaking at the Second Aerospace Conference EAC'89 'Progress in Space Transportation' in Bonn (22—24 May 1989), said: 'The Commission . . . welcomes ESA's initiative to create a European centre for space law, and will participate in its activities. This could form the basis of Community action in the harmonisation of legislation'.

The ECSL Board

The following Members were elected to the Board at the ECSL inaugural meeting on 12 May 1989:

- Prof. Karl-Heinz Böckstiegel, Director Cologne University Institute for Air and Space Law
- Dr. Michel Bourely, President International Institute for Space Law
- Prof. Francis Lyall, University of Aberdeen
- Prof. Claudio Zanghi, University of Rome
- Prof. Ingrid Detter de Lupis, Stockholm Institute for Research in International Law
- Dr. Bess Reijnen, University of Utrecht Institute of Public International Law
- Dr. Ralph Kröner, Private Practioner (Nolst Trenité)
- Mr Jean-Denis Dupuy, Industry (Spot Image)
- Mrs Marie Helen Pichler, Industry (Astra-SES)
- Mrs Tanja Zwaan, University of Leiden International Institute of Air and Space Law (representing student interests)

Ex Officio Members:

- Chairman: Mr Gabriel Lafferranderie (ESA Legal Adviser)
- Operations Manager for ECSL Secretariat: Mr Kevin Madders (ESA, DA/LA)

Secretariat:

- ECSL Secretary: Mr Mathias Spude (FRG) (responsible for day-to-day administration of the Centre)
- ESA Administrative Support: Mrs Eva Vermeer (ESA, DA/LA)

Figure 1. Inaugural meeting of the ECSL, at ESA's Paris Headquarters, on 12 May. From left to right: Prof. I. Detter de Lupis, Dr B. Reijnen, Prof. K.-H. Böckstiegel, Prof. R. Lüst, Mr G. Lafferranderie, and Mr G. van Reeth

Subjects currently being considered for ECSL space-law workshops are:

- The protection of satellite data derived from Earth-observation satellites.
- The regime for intellectual property rights in space on European space objects.
- Coordination mechanisms to use Earth-observation data more effectively in taking measures to protect the biosphere.

A Colloquium on Space Stations and the Law on 7—8 November 1989 at CNES Headquarters in Paris is being supported by ESA within the framework of its ECSL activities.

Above and beyond these types of research activities, though, a further task of the Centre is to stimulate the work of individual researchers (where possible through cross-frontier collaboration). A number of bursaries will be available to doctoral students and other researchers in fields targetted for inquiry by the ECSL Board.

Funding for such bursaries comes from ESA and donations to the ECSL Fund by individual members. After only a short period, over 14 000 French francs have been received from such members, in addition to a 10 000 French franc donation by the Agency.

Membership and further information

The ECSL is a European organisation. Membership is open to interested persons within any ESA Member State territory who are nationals of, or are permanently resident in, an ESA Member State, and who are not employed by non-European firms or other entities. In cases of doubt, the ECSL Board will decide on the basis of an applicant's circumstances.

Membership application forms and further information are available from:

Mrs Eva Vermeer
ECSL
8-10 rue Mario Nikis
73858 Paris 15
France

Olympus launch preparations, and lift-off on 12 July 1989

photo: CSG Kourou/ESA

ESA's Olympus Satellite and Distance-Learning in Europe — The Creation of a European Users' Association (Eurostep)

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

This article, continuing the story that appeared in the ESA Bulletin in November 1988, describes progress in preparation for using the Olympus satellite for distance-learning, in particular the establishment of a Users' Association, called 'Eurostep'.

Background

The earlier article in ESA Bulletin No. 56 described how so-called 'distance-learning' — education by satellite link or other means to remote users — had been identified as an ideal application for future broadcast and telecommunication satellites. The Olympus broadcast payload, covering all of Western Europe as well as states further east, is particularly appropriate.

In early 1988, individual distance-learning projects had begun, with over 3000 h of satellite time available annually free-of-charge from ESA. Since then the three high-power broadcast satellites TDF-1 (France), TV-Sat (Germany) and Olympus itself have been successfully launched, the start of transmissions is imminent, and a new users' association has been created.

At Avignon in April 1988, a meeting of distance-learning institutions formed a Preparatory Committee to establish a satellite users' association. The original name STEP (Satellites in Training and Educational Programmes) was quickly amended to 'Eurostep', to reflect the pan-European nature of the project.

The creation of Eurostep

After Avignon, the work of the Preparatory Committee was greatly assisted by the Leidse Universiteit Fonds (LUF), the association of the alumni of Leiden University, which has recently endowed a Chair in distance-learning. The LUF offered to provide salaried staff and accommodation for a small secretariat in Leiden. The Preparatory Committee gladly accepted this offer, realising that this implied that Leiden would become the seat for the new users' association. The LUF also obtained support for the project both from the university and from the town of Leiden, which was crucial at this early stage.

The full-time Executive Secretary was able to give invaluable help to the committee, in particular on the legal aspects of establishing the association.

Eurostep Articles of Association

The formation of an association requires 'Articles of Association' and a list of 'Founder Members'. The potential users of Olympus readily provided the latter and, at the Olympus Utilisation Conference in Vienna in April 1989, draft articles were tabled and adopted. In May 1989, under Dutch law, Eurostep was born.

It must be stated immediately that Eurostep does not intend to limit its scope just to Olympus, which obviously provides its seminal opportunity. This principle is enshrined in Article 3, which explains that the objectives of Eurostep are: to promote the use of satellite communications in education, to create opportunities for members, to manage and coordinate these affairs, and generally to act in the interests of its members.

Article 4 provides for institutional and individual membership of Eurostep. Institutions that are already satellite users are eligible for full membership, while those that intend to become users are awarded associate membership. An individual member is a person interested in Eurostep activities without implying institutional involvement. Individual members have no voting rights.

Articles 5 and 6 explain how membership is decided and terminated, while Article 7 covers the obligations of members.

Articles 8 to 15 define Eurostep's structure and decision-making mechanisms. Eurostep consists of a General Assembly of full members, which elects the majority of the members of a Management Board, which in turn establishes and maintains a full-time Secretariat. A minority of further members of the Board may be elected by the associate members and, whilst Eurostep uses Olympus, a single representative will be appointed by ESA. The Board also has an Executive Committee which conducts the routine business.

As this structure indicates, Eurostep is an association of practical users of satellites.

The Eurostep/ESA Agreement

It is customary for the Agency to make binding agreements with major users of its satellites. Accordingly an Agreement has been drawn up between ESA and Eurostep, which is expected to be ratified by a General Assembly in October 1989.

Article 1 of this Agreement gives Eurostep exclusive access to the Olympus European DBS channel from a date to be agreed, probably early in 1990. Eurostep will make the maximum possible use of the channel for transmitting programmes selected by Eurostep according to agreed criteria (see Table 1). In keeping with the international nature of Olympus's exploitation, this Article also states that not more than one third of the Eurostep Board shall be from any one country, and at least six different nationalities will be represented.

Table 1. The ESA/EUROSTEP Agreement — Criteria for the Selection of Programmes

General
- No single member has more than 5% of total time
- Preference to Olympus participating states
- After 2nd year, 20% of time allocated to new users.

Project Requirements
- Originality with new service concept
- Multipoint reception by an identified audience group
- Clear specification of programme content
- Video production facilities identified
- Results of interest to all.

International Dimension
- Coverage and appeal across Europe
- Cooperation in planning/production/evaluation.

Article 2 anticipates that Eurostep will use Olympus at least in the daily periods 02.00 - 05.00 h, 09.00 - 14.00 h, and 16.00 - 17.00 h (Central European Time). This schedule may be reviewed after the first year, and in any case occasional additional access can be arranged. Eurostep accepts full responsibilities as a broadcaster, but will give ESA advance notice of what is to be transmitted. The provisions of the Council of Europe convention on transfrontier television will be respected.

Article 3 obliges Eurostep to make arrangement for access to suitable uplink stations, but ESA's Redu ground station will of course be available. No charge will be made for service demonstrations carried by Olympus, but ESA reserves the right to negotiate recovery of a proportion of the operating cost of Olympus in the case of pilot or pre-operational services.

Article 4 requires Eurostep to make regular reports on its activities to ESA, while retaining intellectual property rights. ESA may only disclose information so received after written approval.

Article 5 acknowledges that Olympus is an experimental satellite, and that the Agency is not in any way liable following any malfunctioning of the system.

Article 6 foresees quarterly progress meetings between ESA and Eurostep to review operations. Eurostep must use the satellite for at least 70% of the hours allocated to it. While using Olympus, the Association is not allowed to make unnotified major changes and Article 7 states that it cannot pass on its rights and obligations to others.

The Eurostep Operating Agreement

This ESA/Eurostep Agreement transfers the obligations of using Olympus, including those of a broadcaster, to Eurostep. In its turn, Eurostep passes on some of these obligations to its participating members by means of an 'Operating Agreement' with each member actually taking advantage of the Olympus opportunity.

The Operating Agreement defines the rights and obligations of the member, and indemnifies Eurostep itself and its officers against legal and operational difficulties, and unforeseen costs. Members must submit programme synopses and applications for specific airtime to the transmit-scheduling commission 20 weeks in advance. Eurostep reserves the right to reject an unacceptable programme up to 15 days before the planned time of transmission.

The technical standards to be used are specified in detail in an annex to the Agreement. This avoids many of the problems arising from a potential diversity of standards in material contributed by a large number of sources.

Eurostep management of Olympus distance-learning activities
Eurostep will manage the disparate distance-learning activities on at least the Olympus DBS European channel. The Agency plans to negotiate a limited initial contract with Eurostep to cover the first few months' activities. The initial contract, expected to run until the end of 1989, will cover completion of the setting-up of the Executive Secretariat, the first few months of Olympus test transmissions, and negotiation of the main contract.

The main contract will cover: the establishment of information systems, the continuation of Olympus transmission scheduling, liaison with established users in six particular countries, and the general marketing of Eurostep and the Olympus opportunity.

National user liaison merits a special mention here. Eurostep is dealing with users right across Europe and face-to-face communication between identified representatives was felt to be essential. This representation was first arranged in the UK and France, encouraged and funded by their national governments. ESA has now placed contracts in Spain, Belgium and Italy, and Eurostep will continue this work, extending it to include Ireland.

It is hoped that other countries will decide to support this project by subscribing to the so-called 'ESA PSDE Slice-3 Programme'. Another option would be for Eurostep to gain financial support from a European institution, and this route is being vigorously explored.

Pan-European cooperation in Eurostep
By its very nature, Eurostep is a pan-European cooperative venture. It is coordinating more than 70 individual projects (Table 2), almost all of which are themselves the fruit of international cooperation. Many of

Table 2. Eurostep Members with Olympus transmission time

Organisations	City	Hours/year	Programmes
Training Commission	Sheffield	162	Adult Education
Open University	Milton Keynes	12	Tertiary Education
Birkbeck College	London	104	Medicine
Herriot-Watt University	Edinburgh	50	Tertiary Education
Educational TV Assoc.	York	50	Group
SCET	Glasgow	20	Mixed
University College	Dublin	120	Group
Fern Universiteit	Hagen	78	Adult Education
Universities Film/Video	London	150	Group
British Medical TV	Woking	150	Medicine
Univ. of Glasgow	Glasgow	50	Language Learning
Satecosse	Edinburgh	26	Language Learning
Brighton Polytechnic	Brighton	30	Language Learning
Centre for Int. Studies	Exmouth	16	Group
TVE1 Centre	Clwyd	36	Mixed
Univ. of East Anglia	Norwich	35	Tertiary/Adult Educat.
Univ. of London	London	144	Group
Gwynedd County Council	Llangefni	30	Mixed
Oxford University	Oxford	150	Language Learning
Integrated Info. Syst.	Athens	150	Mixed
Coventry Lanch. Poly.	Coventry	50	Mixed
Royal Coll. Psychiatry	London	24	Medicine
European Parliament	Luxembourg	36	Adult Education
IET	Thessaloniki	50	Mixed
University College	London	70	Technology
IASPA	Brussels	12	The Arts
Univ. of Leiden	Leiden	100	Medicine
Post-Grad. Medic. School	Exeter	50	Medicine
Vrije Univ. Brussel	Brussels	40	Tertiary Educat.
Aston University	Birmingham	30	Adult Education
Elec. Univ. Norway	Stavanger	75	Adult Education
TV-Inter	Stockholm	50	Religion
Generalitat de Catalunya	Barcelona	35	Culture
Internat. Space Univ.	Boston	20	Adult Education
Escuola Univ. de EGB	Tenerife	5	Culture
Cosejeria de Ed. (Anda.)	Sevilla	12	Culture
Univ. of Barcelona	Barcelona	12	Mixed
Cent. Cult. Tajamar	Madrid	26	Adult Education
Min. Education & Science	Madrid	24	Language Learning
Circulo de Bellas Artes	Madrid	74	The Arts
Trans World Radio	Hilversum	175	Religious Educ.
IBM	La Hulpe	50	Product Training
Univ. of Navarre	Pamplona	12	Culture
EON	Leatherhead	25	Religious Educ.
Rights and Humanity	London	28	Sociology
Nat. Inst. for Higher Ed.	Limerick	30	Umbrella
Univ. of Paris VIII	Paris	5	Training Trainers
VIDEOSCOP	Nancy	12	Medicine
Univ. of Montpellier	Montpellier	90	Umbrella
CNDP	Paris	113	Cult. and Lang.
AFT/IPT	Rantigny	17	Transport
Univ. of Nantes	Nantes	20	Training Trainers
Min. Affaires Etrangeres	Paris	96	Culture
Univ. P. et M. Curie	Paris	45	Maths

(cont'd)

Table 2. (cont'd) Eurostep Members with Olympus transmission time

Organisations	City	Hours/year	Programmes
Univ. of Poitiers	Poitiers	15	Mixed
Vlaams Theater Inst.	Brussels	36	Culture
Tekel	Bilbao	20	Technology
CGER	Brussels	36	Banking
IFA	Rome	8	Insurance
Intellink	Rome	100	Umbrella
Elemedia	Pozzuoli	60	Technology
Media Facilities	Mechelen	30	Culture
CNED	Rennes	15	Biotechnology
ENS Production	St. Cloud	9	Mixed
CNDP-CRDP	Nantes	7	Mixed
IFACE/Univ. Compeigne	Paris	18	Management
LERSCO-CNRS	Nantes	12	Sociology
UFCV	Lille	6	Perfume
Hopital Lapeyronie	Montpellier	6	Medical
Agropolis	Montpellier	12	Medical
CELA	Avignon	5	Lang. Learning
CAVILAM	Vichy	16	Lang. Learning
CLEMI	Paris	10	Culture
Univ. of Nantes	Nantes	6	Mixed

the project teams are made up of active users from several countries, and they are also in contact with many interested potential users, a number of whom are providing advisory support.

Eurotransmed, a medical project from the University of Leiden, is in contact with 30 Dutch organisations and doctors, and a further 103 doctors and medical institutions in 17 other countries. The British Universities' Film and Video Council is in contact with 252 organisations from 18 countries, including four East European states. The Vlaams Theater Instituut in Brussels is an international standing conference involving some 300 organisations in 20 European countries.

These three projects alone embrace a total of 555 participants in virtually every country in Europe. It is already clear that the total number of participants in all projects far exceeds the 300 estimated in early 1988. There must be several thousand potential participant institutions and many thousands of private individuals who are interested.

Figure 2. The Headquarters of Eurostep, on the Rapenburg, in Leiden (NL), next to the Leidse Universiteit Fonds (LUF) building (right)

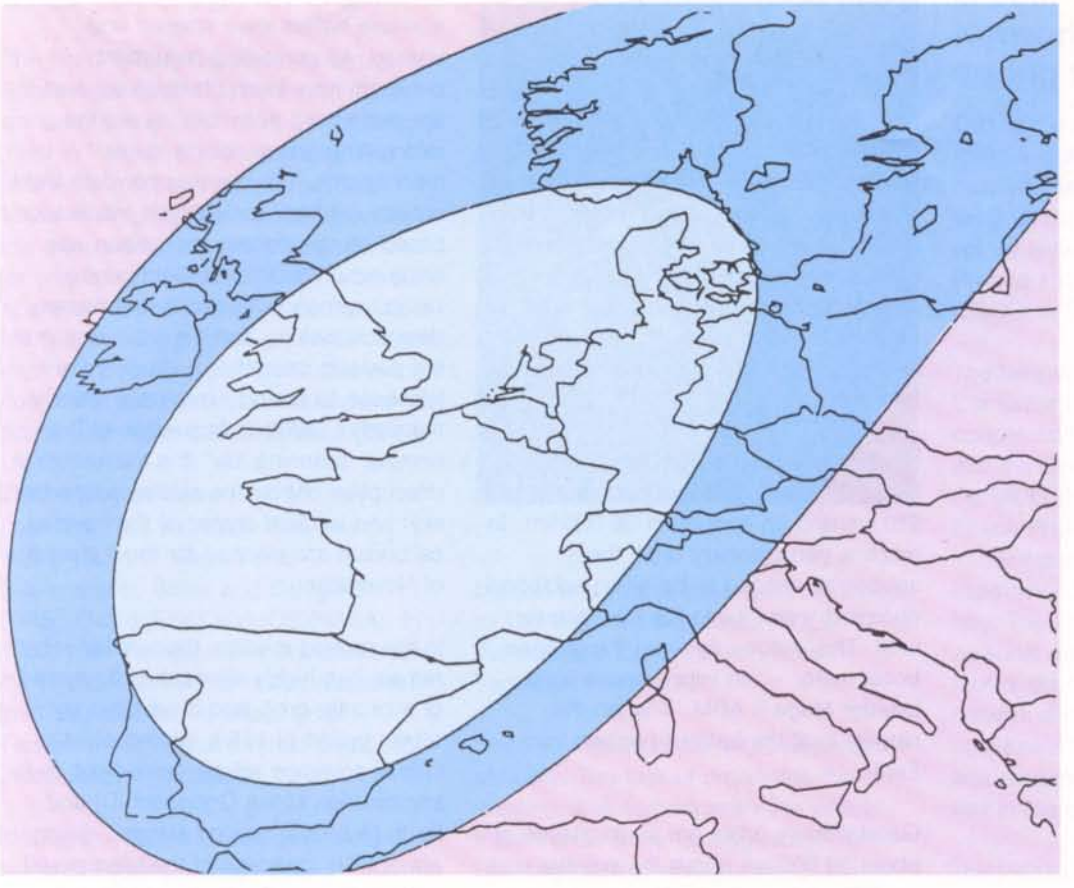


Figure 3. Typical Olympus DBS antenna coverage patterns, serving 45-cm and 90-cm antennas (inner and outer contours, respectively)

RAI and BBC interest in distance-learning

ESA has a long-standing agreement with the Italian broadcasting corporation RAI on the use of the Olympus 'Italian' DBS channel. Details of RAI's plans were released at the Olympus Utilisation Conference held in Vienna in April this year (more details can be found in ESA Special Publication SP-292, p. 429). RAI is willing to cooperate with the Olympus Users' Association, and intense use of the channel for international education and training programmes is likely to be the outcome.

A similar agreement was signed in June this year with BBC Enterprises, which will use the Olympus European DBS channel daily in the peak evening hours from 17.00 h onwards. Education and training, and particularly language skills, is a major area of proposed programming development for Enterprises Services. The BBC's existing educational services, particularly English by radio and TV, and its natural history and science output, are already being considered for broadcasting via Olympus.

It is clear that two of the major established broadcasting corporations are planning a major move into distance-learning, which will complement the programmes of the newer organisations cooperating within Eurostep.

Conclusion

Distance-learning via Olympus is a project that involves practical cooperation spilling over the traditional boundaries of the Agency's activities. The greatest problem of a project of this scale is its management. Eurostep is the solution to this problem, but it is as yet in an embryonic state and needs care and attention. Here is a genuine case of pan-European cooperation which merits pan-European multilateral funding. It is hoped that other institutions will follow ESA's example and give Eurostep their support.

For further information about distance-learning via Olympus and the Eurostep project, please contact the author or:

Eurostep
Rapenburg 63
2311 GJ Leiden
The Netherlands

Tel. (31) 71 277268
Fax (31) 71 140841

In brief

Hipparcos Update

Status on 26 October 1989

After the successful launch of ESA's Hipparcos (High Precision Parallax Collecting Satellite) on 9 August, attempts to ignite the apogee boost motor of the satellite to put it into its final geostationary orbit were not successful. Following several such attempts, experts met at ESOC, ESA's Operations Centre at Darmstadt (D), to plan a revised mission for Hipparcos.

Hipparcos was launched into a highly elliptical transfer orbit, with a perigee of 210 km and an apogee of 36 000 km. To reach a geostationary orbit, the spacecraft needed to be given additional energy to inject it into the new circular orbit. This is done by firing the apogee boost motor – on Hipparcos, a solid powder Mage II ABM – when the satellite is at the furthest position from Earth.

Geostationary orbits are at an altitude of about 36 000 km above the equator and are difficult to achieve since they require a high orbital speed. In such an orbit, the satellite moves from west to east with a period of about 24 h, staying in the same place above the Earth. The satellite appears to hang in the sky at one point and is, therefore, always accessible from a single earth station.

Following the failure of the Hipparcos apogee boost motor, plans for the revised operations of the Hipparcos satellite in its highly elliptical transfer orbit were completed in late August and have since been implemented.

In early September, the orbit perigee was raised to approximately 500 km, and the three solar panels and the fill-in antenna were successfully deployed. A week later, the unused hydrazine was drained from the satellite. The detection electronics were activated, and data taken by both the image dissector tubes and the star mapper detectors have been analysed to study the effects of Cerenkov emission during the orbit.

The Hipparcos satellite under test in the Large Space Simulator at ESTEC, Noordwijk (NL)

In late September, the two entrance aperture baffles were opened and latched. All prime and redundant detectors have been checked out and are performing nominally, as are the refocussing and switching mirror mechanisms. The star mapper data were entirely nominal, and attitude initialisation based on star pattern recognition was achieved on 8 October. Data is now being routinely acquired by the primary detection system, and the early stages of the payload calibration, including the telescope focussing, were completed at the end of October. Acquisition of the nominal 'scanning law' (the mathematical description of how the satellite scans the sky) and the final stages of the payload calibration are planned for the first week of November.

In the revised mission, the satellite will remain in a highly elliptical orbit, instead of a circular orbit, and it will have an orbital period of 10.5 h instead of 24 h. Orbital coverage will be carried out by a combination of the Odenwald (D) and Perth (Australia) ground stations, giving about 63% coverage of the telemetered data. Inclusion of a third ground station (Kourou), which should bring the data coverage to about 80%, should be finalised by mid-November.

The nominal observing programme, and the implementation of the scanning law are being retained without modification.

The most critical parameter in any assessment of the expected accuracy of the revised Hipparcos mission is still the satellite lifetime, determined by the degradation of the solar panels due to the high-energy proton radiation environment in the elliptical transfer orbit. Additional operational difficulties are also expected, due to the high radiation background, the long occultation intervals, and the higher perturbing torques that will occur around perigee passages. Estimates of the mission lifetime should be available in the near future.

M.A.C. Perryman
Hipparcos Project Scientist

IACG Meeting in Prague

The Inter-Agency Consultative Group for Space Science (IACG) held its ninth annual meeting on 21 and 22 September 1989 in Prague, Czechoslovakia. The IACG is a multi-agency international forum in which space science activities are discussed to maximise opportunities for multilateral scientific coordination on approved space science missions. The IACG member agencies are NASA, ESA, Intercosmos (representing 10 east block countries), and the Japanese Institute of Space and Astronautical Science (ISAS).

The IACG was formed in 1981 to coordinate the six space missions to Halley's Comet: Vega-1 and -2 (Intercosmos); Suisei and Sakigake (ISAS); Giotto (ESA) and ICE (NASA). In 1986, after the successful completion of the coordination of the Halley missions, the IACG decided to adopt Solar-Terrestrial Science as its next project for inter-agency coordination.

Starting in 1992, the four agencies will launch 12 spacecraft to make coordinated measurements of the Sun, the Earth's environment and solar-terrestrial relationships, namely:
- Geotail (ISAS/NASA)
- Wind (NASA)
- Polar (NASA)
- 4 Regatta spacecraft (Intercosmos)
- SOHO (ESA/NASA)
- 4 Cluster spacecraft (ESA/NASA)

A further 26 spacecraft from the four agencies, which have already been or will be launched before 1992, will complement the 12 'prime' missions.

Coordinating the solar-terrestrial science missions through the IACG will:
- make available to participating institutes in the IACG member states the scientific data from the maximum number of instruments on these spacecraft
- optimise the spacecraft orbits and experiment operation times
- further discussion and collaboration between scientists from all the countries of the member agencies through the organisation of IACG workshops and symposia.

These activities will be complemented by SCOSTEP's Solar Terrestrial Energy Program (STEP), which includes the coordination of ground-based, aircraft, balloon and rocket experiments from up to 100 countries worldwide (SCOSTEP is the Scientific Committee on Solar-Terrestrial Physics).

IACG

Inter-Agency Consultative Group for Space Science

Since its formation the IACG has met annually. The task of organising the meeting, and consequently the venue, rotates among the four agencies. Heading the four delegations for the 1989 meeting were: Prof. A.A. Galeev, Director of the Space Research Institute of the USSR Academy of Sciences, who also chaired the meeting; Dr J.K. Alexander, NASA's Assistant Associate Administrator for Space Science and Applications; Prof. R.M. Bonnet, ESA's Director of Scientific Programmes; and Prof. J. Nishimura, Director General of ISAS. SCOSTEP's President, Prof. J.G. Roederer, participated as an observer.

Topics discussed in Prague included general principles and timeliness of data exchange. The IACG recommended standard data formats and common software tools. The delegates also reviewed the progress in setting up the IACG Science Information System, an inter-agency network which is scheduled to be operational by 1992 to facilitate the exchange of science data from the coordinated missions. A practical demonstration of current possibilities for scientific data exchange was also given (see next item).

The next annual meeting of the IACG will be hosted by ESA and will take place in Spain in early November 1990.

R. Reinhard
IACG Secretary

Global Scientific Networking Demonstrated during the IACG

During the ninth IACG meeting in Prague, current possibilities for scientific data transfer between East and West were demonstrated. A satellite link was set up between the meeting hotel in Prague and ESA's operations centre (ESOC) in Darmstadt, Germany.

The temporary link, installed by ESOC's Computer Department with the full cooperation of the Deutsche Bundespost and the Czechoslovakian PTT, connected the IACG delegates to the European Space Physics Analysis Network (SPAN) in Darmstadt and the European Space Information System (ESIS) in Frascati, Italy. The link itself consisted of a Dornier personal earth station installed on the roof of the hotel in Prague, together with network switches and personal computers. One of the computer screens was projected onto a larger screen on a wall in the meeting room.

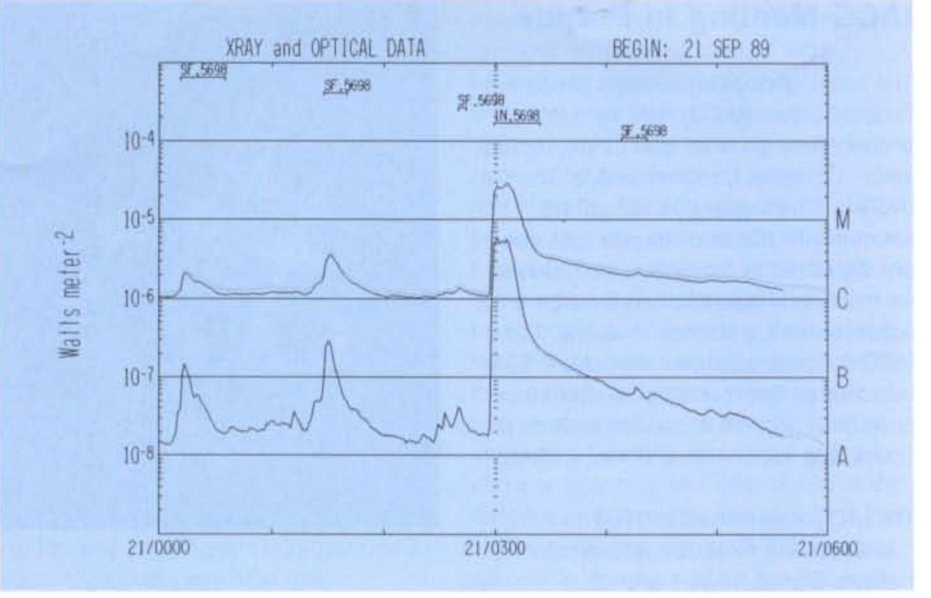
The IACG Data Analysis Working Group demonstrated the capabilities of the network connection, concentrating on five particular aspects. First, a simple mail message was sent to a colleague at the Geophysical Institute in Kyoto, Japan and a reply was received within two minutes. In the second demonstration the orbit of the recently launched Japanese satellite, Akebono, was predicted using the Satellite Situation Center of the National Space Science Data Center in Greenbelt, Maryland, USA.

Near-real time data from a scientific satellite were displayed as the third example. The data shown were from the X-ray instrument on the GOES geostationary satellite, and were obtained from the MAX91 database of the National Oceanographic and Atmospheric Administration's database at Boulder, Colorado. The plot, displayed in the meeting room, showed a solar flare that had occurred on the Sun on the previous day.

The NASA master directory was then called up and the Dynamics Explorer (DE) database in the South West Research Institute in San Antonio was accessed. Data from several instruments on DE-1 were transmitted over the network and displayed on the screen in the meeting room.

Lastly, the database of the Coordinated Data Analysis Workshop-9 was accessed. This database was assembled specifically for a workshop that was taking place simultaneously at the Goddard Space Flight Center in Greenbelt, Maryland, USA. A more detailed report will appear in the next issue of the ESA Bulletin.

T.R. Sanderson
ESA Space Science Department



Plot of X-ray data from the GOES geostationary orbiting satellite on 21 September 1989, as received in Prague one day later. The plot shows an enhancement in the X-ray flux at 03:00 UT due to a solar flare

ESA Experiments on Soviet Biology Satellite

ESA has been cooperating with the Soviet Union on a second joint space biology mission. On 15 September 1989, the Soviet Union launched Biokosmos-9, with five ESA experiments on-board. The first cooperative venture was successfully undertaken in October 1987, when two ESA experiments were carried on Biokosmos-8.

The main objective of Biokosmos-9 during its two-week voyage was to study the effects of microgravity and cosmic radiation on two primates, ten rodents and a variety of smaller organisms.

The Agency's experiments were selected by a scientific and technical peer group following a European-wide call for proposals. They are concerned with the smaller organisms and were conducted jointly by 30 scientists from Norway, Denmark, Germany, Switzerland, Spain and the USSR. Necessary ground equipment in Moscow and operational support were provided by ESA.

ESA's experiments were designed to investigate biological development and ageing, and sensitivity towards cosmic radiation. Questions the scientists would like to answer as a result of this mission include:

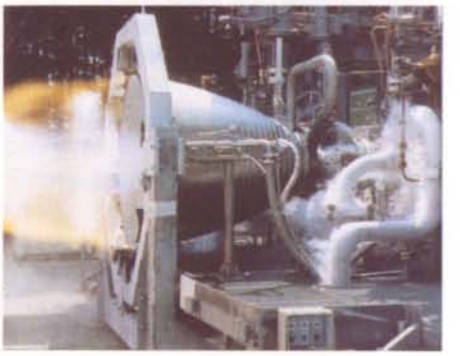
- Can insect development, starting from egg formation, occur normally in space conditions or is there a dependency on gravity in the early stages of development as observed previously?
- Does life shorten as a consequence of exposure to weightlessness? There is evidence from experiments with insects that the answer is yes. Some phenomena observed in astronauts could also be signs of accelerated ageing.
- Can seeds be kept in space and germinated normally if they have been bombarded with highly energetic cosmic ions?
- Will isolated carrot cells be able to build a new cell wall, divide, and eventually produce a new carrot plant without the guiding force of gravity?
- Are there some plant mutants that are more resistant to the space environment than others? Are there combined effects of the full spectrum of space radiation and microgravity?

Through these experiments, scientists hope to learn more about the role of gravity in the fundamental biological processes. This will contribute new insights into the evolution of life and cellular processes. It will also help us better to perceive the opportunities space offers to human beings, as well as the dangers to which they are exposed in its harsh environment.

Biokosmos-9 landed safely 14 days after launch, on 29 September 1989 at 05:30 h Moscow time. A recovery team at the landing site obtained the biological samples which were then flown back to Moscow in specially designed containers. The samples were handed over to the experimenters approximately 20 h after landing.

Ariane-5 Vulcain Thrust Chamber Test Facilities Inaugurated

An important milestone in the development of the Vulcain engine that will power the Ariane-5 central stage was reached on 19 September 1989 with the inauguration of the new P32 test facilities at Lampholdshausen (D). In the presence of the Vulcain engine project managers, MBB held a 17 sec test, during which a thrust level of 107 tons was reached. With this successful demonstration, the new installation was declared fully operational.



Courtesy MBB/ERNO

Vulcain thrust chamber under test at Lampoldshausen (D)

Three ESA Contracts Awarded to Spanish Industry

The Agency's Operations Centre (ESOC) in Darmstadt recently awarded three contracts to the Spanish space firm Grupo de Mecanica del Vuelo SA (GMV). The subjects of the first two contracts are: Flight dynamics software support (1989–1994), and on-line orbit determination and manoeuvre calculation. The third is a frame contract for study tasks in the area of orbital mechanisms.

The accompanying photograph shows the signing of the contracts on 12 September 1989 by Mr K. Heftman (right), ESA's Director of Operations, and Prof. J. Martínez García, Executive President of GMV.

ESA Co-sponsors 'Astronomy and Space'

ESA has combined efforts with the European Southern Observatory and the Aniane Observatory to sponsor the latest in a series of European meetings on 'Astronomy and Space' which took place on 20–23 September at Montpellier (F).

Astronomy is evolving and developments in space exploration mean that new research methods are available in every field. These changes prompt investigation into the implications of space research for society in general, the human presence in space and its philosophical implications. The next generation of scientists, who will be using the wide range of new equipment and techniques, are still in their formative years. Modern educational methods must take account of the new possibilities. This meeting, accessible to a general audience, was therefore convened to consider questions in space-related education in Europe.

Each day's programme focussed on a specific theme: 'People and Careers' examined problems such as mobility of researchers and students, transfer of knowledge, language learning and familiarisation with scientific language.

'The Sky in the Third Millenium' considered how the highly sophisticated instruments and equipment currently being conceived will affect the community, scientific research, and programmes under way worldwide.

'Space for All' invited speakers to present selected examples of the uses of space and what they can mean to the planet Earth. 'Life in Space' relived with American, Soviet and European astronauts/cosmonauts the space odyssey – from the moment man first set foot on the moon through to current developments involving the human presence in space.

An open day for amateur astronomers was also held at the Aniane Observatory.

First ESA Shuttle-Mission Specialist

ESA astronaut Claude Nicollier has been selected as mission specialist for the Space Shuttle mission, STS 46. This will be Nicollier's first flight and he will also be the first ESA astronaut to fly as a mission specialist.

Nicollier, a Swiss national, has been assigned to NASA since 1980 to receive mission specialist training under a special agreement between ESA and NASA.

The STS 46 mission objective is to deploy ESA's Eureca Free-Flying Platform, a space platform designed primarily for microgravity experiments. In addition, the STS 46 crew will demonstrate the Italian Space Agency's Tethered Satellite System (TSS), designed for the deployment, operation and retrieval of data-gathering probes. The system provides constant physical and electrical connection between the probe and the Shuttle.

N° 5

EUROPEAN SPACE RESEARCH ORGANISATION

CERS-ESRO 36, rue La Pérouse, Tel. 225.24.02 15 September 1964

NEWS IN BRIEF

I. ESRO NEWS

FIRST LAUNCHINGS : The two first launchings undertaken by ESRO took place on 6 and 8 July from the Salto-di-Quirra range (Sardinia). Skylark rockets carried experiments intended for the study of ejection phenomena and photo-ionisation in the atmosphere. The experiments had been planned by the Max Planck Institute in Munich and the Institut d'Astrophysique de l'Université de Liège, which are both concerned with the study of comets. ESTEC had assembled the payload.

During these two launchings, baryum and strontium as well as ammonia were relased at altitudes of approximately 150 and 200 km respectively (the expected altitude was not reached during the second launching, due to strong wind). The ejected clouds were observed from the ground by means of a number of cine-cameras, 1 television camera, photo-electric equipment and spectro-graphs.

The clouds were visible for $1\frac{1}{2}$ hours and not only from Sardinia, but also from Italy, Sicily and even Africa. The results are at present being examined and the scientific groups hope that the experiments will enable them to learn more, both about the upper atmosphere and of some of the physical phenomena occurring in comets.

SUMMER SCHOOL - A summer school on space technology, organised by ESRO was held in Oxford from 10 August to 4 September 1964. The Summer School comprised a series of lectures intended for junior engineers anc ...sicists who envisage a career in research and development ...pace field.

The lecture... subjects: instrumentation, launching v... ...l and stabilisation, power supp...

Furthermor... European s... the Frenc... vatory (C... satellit...

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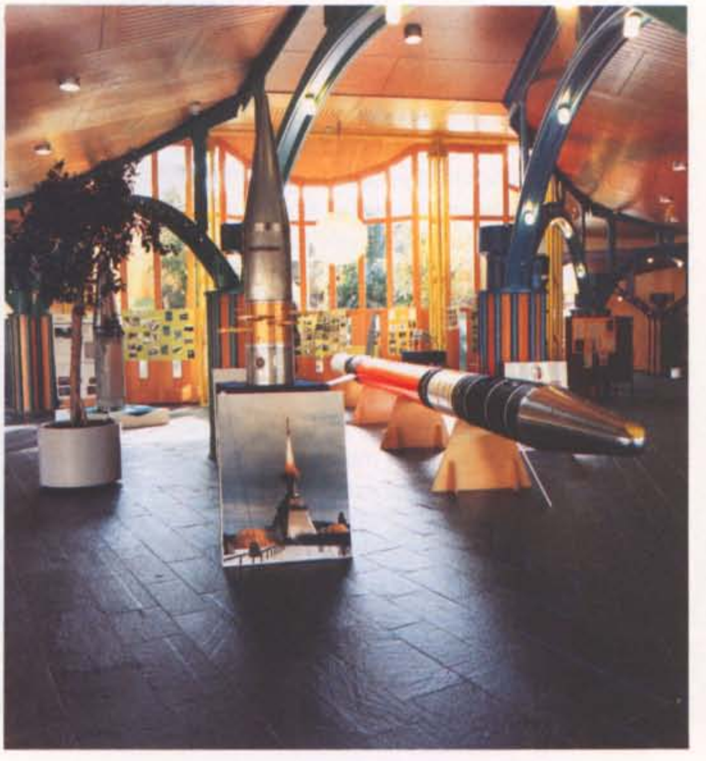
Mr D. Eaton (left) explaining the technicalities of an ESRO sounding-rocket payload to Mr W.R. Tyler, US Ambassador to The Netherlands, Mr J.T. Papendorp (US Embassy), and Prof. H. Bondi (far right), ESRO's Director General

At work on an early ESRO sounding-rocket payload



25 years later – the 1989 sounding-rocket exhibition at ESTEC

25th Anniversary of ESRO's Sounding Rocket Programme

To commemorate the 25th Anniversary of the ESRO sounding-rocket programme, a reunion of some 250 'ex-rocketeers' was organised at ESTEC on Friday 15 September. During the period 1964 – 1972 the Sounding Rocket Division launched a total of 183 rockets, carrying scientific payloads, from various launch ranges in Europe and Australia. The very first ESRO sounding rocket was launched from Sardinia on 6 July 1964. Aboard were instruments from the Institut d'Astrophysique de Liège (F) and the Max-Planck Institute (MPI) in Garching (D). One of the experimenters was Reimar Lüst, now Director General of ESA.

Appropriately then, the speeches preceding the evening's celebratory dinner included an address by Prof. Lüst. An opening address by M. Le Fevre, Director of ESTEC was followed by speeches from Prof. R. Bonnet, Director of Scientific Programmes, and Mr D. Eaton, Ulysses Project Manager (formerly Head of ESRO Sounding Rockets Division). A firework display formed a fitting climax to a day of slides, films and reminiscing.

An exhibition was open throughout the week, with photographs, hardware and other mementos provided by the 'ex-rocketeers'. Actual flight hardware, supplied by BAe, Dornier and Contraves, formed the centrepiece.

P. Colson
'Ex-rocketeer'

Noordwijk Space Expo Foundations Laid

In a ceremony to mark the start of construction of the 'Noordwijk Space Expo', The Netherlands' Deputy Prime Minister and Minister of Economic Affairs, Dr R.W. de Korte sank the first pile for the new Centre on 26 October. Minister de Korte, for many years a keen supporter of the European space endeavour, spoke during the ceremony of the Dutch Government's declared policy of 'broadening the social base of spaceflight' and the need 'to make the public more aware of the opportunities' that it holds.

The Noordwijk Space Expo (NSE), a cooperative venture between the NSE Foundation and ESTEC, is expected to contribute substantially to these two goals. The Centre itself is located within the grounds of ESTEC and will have a dual role; in addition to housing a permanent 1600 m² space exhibition open to the public, it will also serve as an official visitors' centre for ESTEC. Its facilities include a 150-seat auditorium.

The Centre is scheduled to be opened next summer. The exhibition will be open to the public six days a week and will feature actual flight hardware, models and audio-visual presentations on four main themes:

- the history of space flight
- the European space endeavour
- the future of space flight
- spin-offs from space exploration.

An additional attraction will be live video coverage of key events such as launches and major satellite tests. At least 100 000 visitors are expected annually.

Prior to the pile-driving ceremony, the 'Development and Operating Agreement' that will govern the running of Space Expo was signed by M M. Le Fèvre, Director of ESTEC, on behalf of ESA, and the Chairman of the Noordwijk Space Expo Foundation, Dr R.P. Dessing (above, right).

The Expo venture has been supported by more than 30 European aerospace companies within the ESA Member States, the local authorities, the Province of South Holland and the Dutch Ministry of Economic Affairs.

Noordwijk Space Expo, due to open in the summer of 1990

Information System for Columbus Users

The Columbus Promotion and Utilisation Department of ESA's Space Station and Platforms Directorate has developed a prototype electronic information system for the Columbus user communities. The system will be demonstrated to interested users at 'Space Commerce '90', in Montreux, 26–28 March 1990.

The Columbus Utilisation Information System (CUIS) will enable users to receive, process and exchange information on Columbus utilisation. An initial trial group of some 30 users has been selected from various international and national space agencies and European universities. The CUIS prototype will handle all the Columbus documentation needed by the users during the familiarisation, mission preparation, and operational phases of the Columbus Programme.

The system runs on any IBM-compatible personal computer connected to a public network anywhere in the World. Within the framework of the prototype, various advanced information-retrieval systems, expert systems and other media-oriented innovations are currently being studied and tested. In this context, the Columbus Pictures Databank (COPIDAB) has been set up. COPIDAB provides access to photographs, videotapes, viewgraphs and slides of equipment and experiments from the three Spacelab flights.

If you would like to see a demonstration of CUIS or COPIDAB at Space Commerce '90, or would like further information, please contact Philippe Willekens or Marilynne Taylor, European Space Agency, Paris; Tel: 33-1-42 73 88 or 33-1-42 73 20.

For general information on Space Commerce 90 (an international conference and exhibition on the commercial and industrial uses of outer space) please contact the permanent secretariat: Space Commerce 90, P.O. Box 97, CH-1820, Montreux, Switzerland (Tel: 41-21 963 23 54).

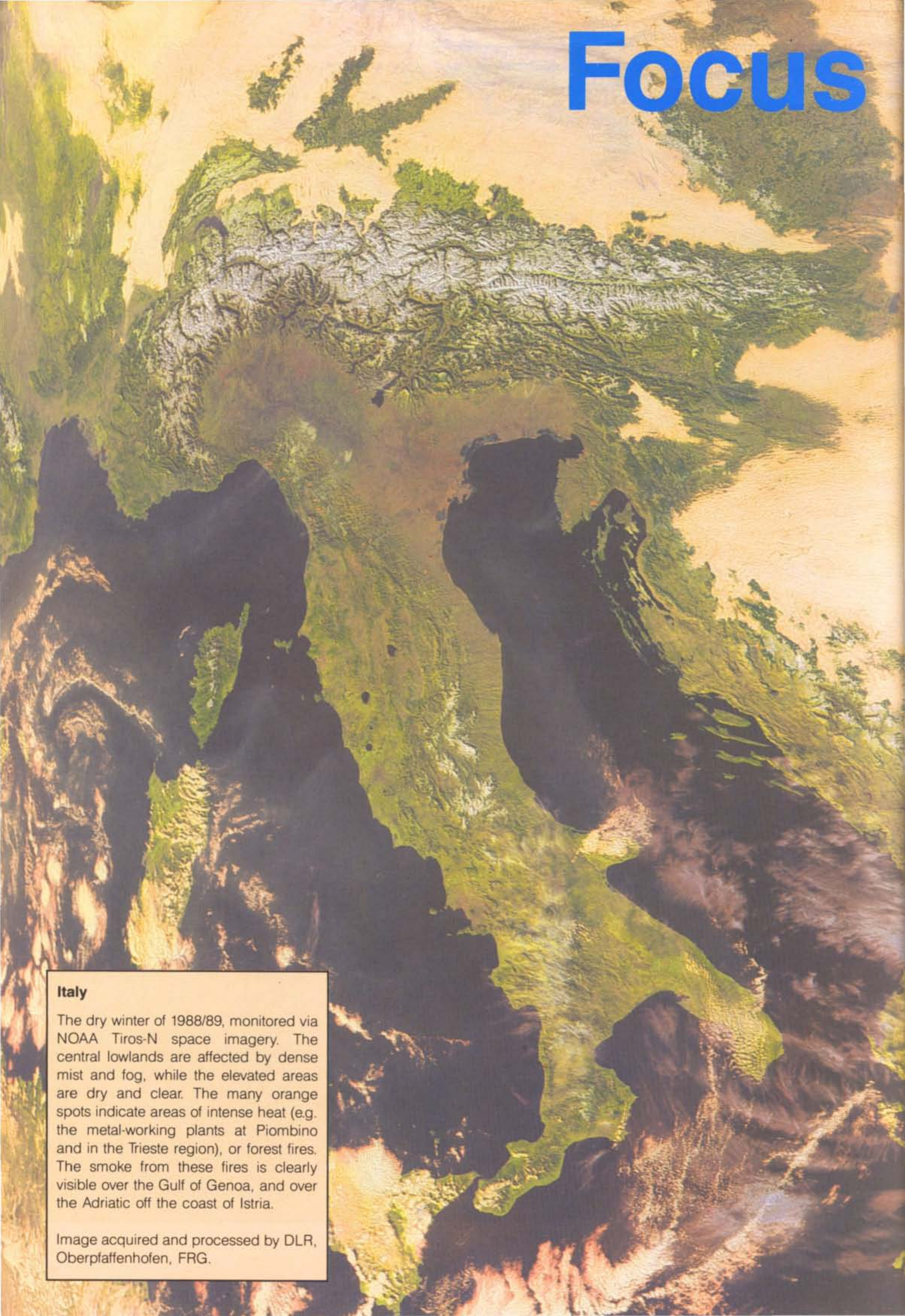
LATE NEWS

Intelsat-VI Launched by Ariane

An Ariane-4 launch vehicle equipped with four liquid strap-on boosters (known as version 44L) placed the Intelsat-VI F2 telecommunications satellite safely into geostationary transfer orbit in the early hours of Saturday 28 October (European time).

Intelsat-VI, Ariane's sole passenger on this flight, is the largest telecommunications satellite ever built. It is destined to be integrated into Intelsat's international communications network, and will be stationed at 335°E.

Focus

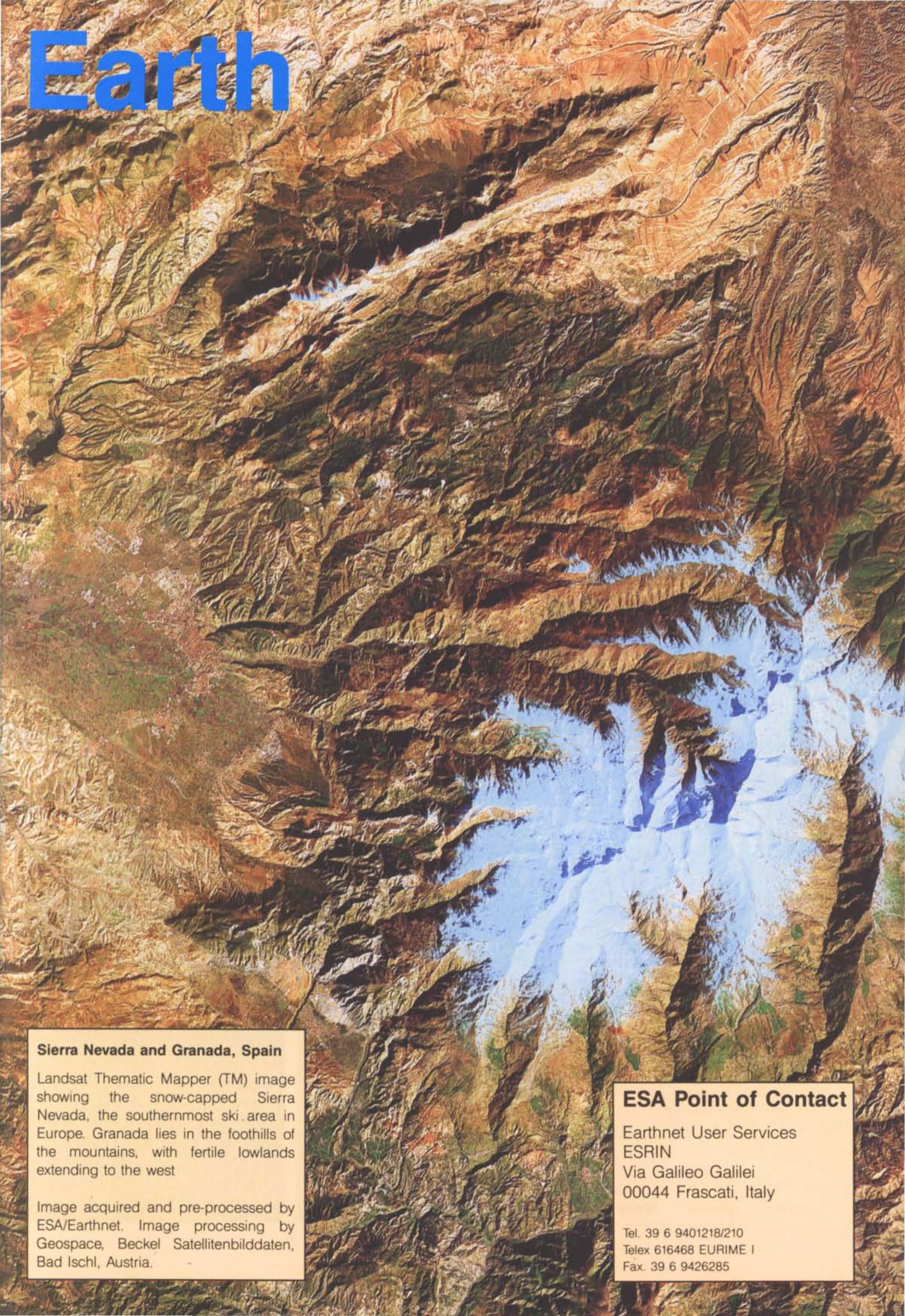


Italy

The dry winter of 1988/89, monitored via NOAA Tiros-N space imagery. The central lowlands are affected by dense mist and fog, while the elevated areas are dry and clear. The many orange spots indicate areas of intense heat (e.g. the metal-working plants at Piombino and in the Trieste region), or forest fires. The smoke from these fires is clearly visible over the Gulf of Genoa, and over the Adriatic off the coast of Istria.

Image acquired and processed by DLR, Oberpfaffenhofen, FRG.

Earth



Sierra Nevada and Granada, Spain

Landsat Thematic Mapper (TM) image showing the snow-capped Sierra Nevada, the southernmost ski area in Europe. Granada lies in the foothills of the mountains, with fertile lowlands extending to the west

Image acquired and pre-processed by ESA/Earthnet. Image processing by Geospace, Beckel Satellitenbilddaten, Bad Ischl, Austria.

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

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. 2:

HERMES – DEFI TECHNOLOGIQUE
BARON F M ET AL

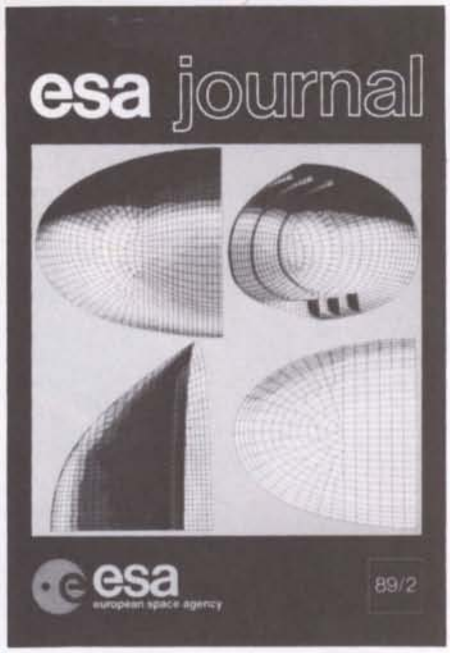
SATELLITE POWER SYSTEM TOPOLOGIES
O'SULLIVAN D

ASSESSMENT OF ELECTROSTATIC CHARGING OF SATELLITES IN THE GEOSTATIONARY ENVIRONMENT
FREZET M ET AL

PLASMA-DEPOSITED MULTIPURPOSE PROTECTIVE COATINGS FOR SPACE APPLICATIONS
KLEMBERG-SAPIEHA J E, WERTHEIMER M R & ZIMCIK D G

ELECTRON BEAMS AND NONDESTRUCTIVE TESTING OF MATERIALS IN SPACE
FRANCESCHI J L & CHAPUIS C

DETERMINATION OF THE G/T FIGURE OF MERIT OF GROUND RECEIVING STATIONS FOR METEOROLOGICAL SATELLITES
BENI P



ESA Special Publications

ESA SP-291 // 312 PAGES
PROC 9TH ESA SYMPOSIUM ON EUROPEAN ROCKET AND BALLOON PROGRAMMES AND RELATED RESEARCH, LAHNSTEIN, GERMANY, 3–7 APRIL 1989 (JUNE 1989)
BURKE W R (ED)

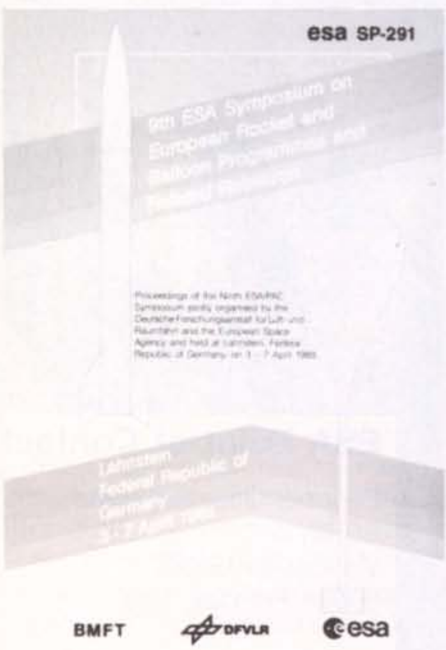
ESA SP-293 // 549 PAGES
PROGRESS IN SPACE TRANSPORTATION, PROC 2ND EUROPEAN AEROSPACE CONFERENCE, BONN BAD-GODESBERG, GERMANY, 22–24 MAY 1989 (AUGUST 1989)
GUYENNE T D & HUNT J J (EDS)

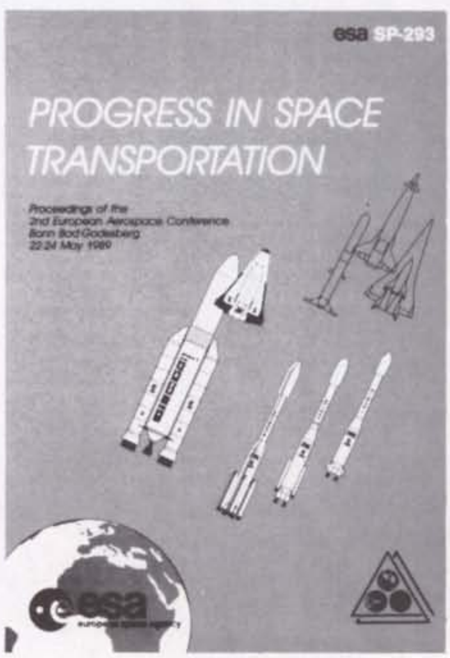
ESA SP-294 (2 VOLS) // 859 PAGES
EUROPEAN SPACE POWER, PROC EUROPEAN SPACE POWER CONFERENCE, MADRID, SPAIN, 2–6 OCTOBER 1989 (AUGUST 1989)
LANDEAU J (ED)

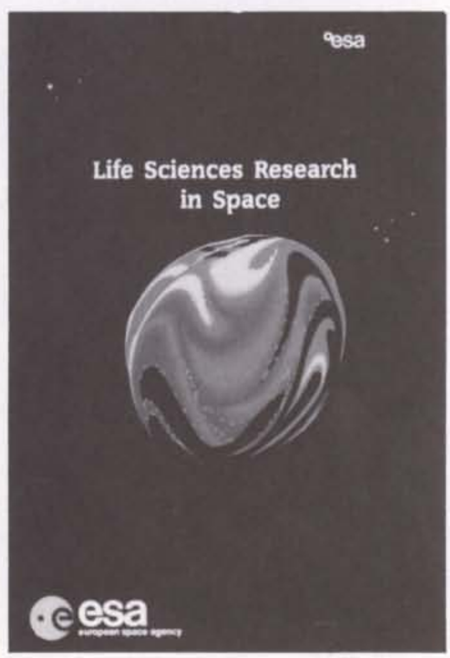
ESA SP-300 // 77 PAGES
CREW SAFETY AND RESCUE IN SPACE, AN AAAF, AIAA & ESA WORKSHOP HELD AT LE BOURGET, 7 JUNE 1989 (AUGUST 1989)
DAVID V & GUYENNE T D (EDS)

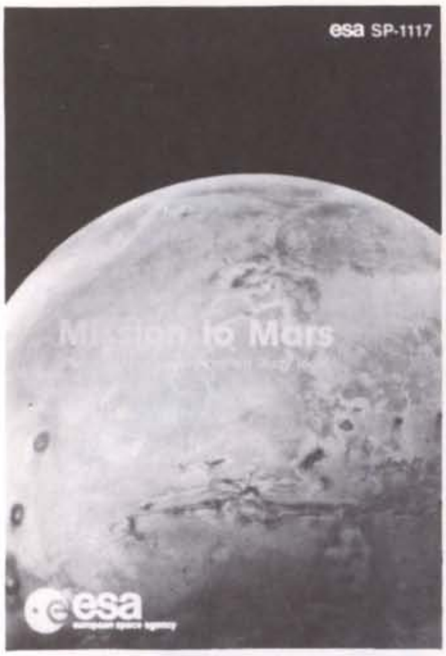
ESA SP-1088 // 43 PAGES
CATALOGUE OF ESA PUBLICATIONS IN 1988 (AUGUST 1989)
COMPILED BY BATTRICK B & DE ZWAAN F

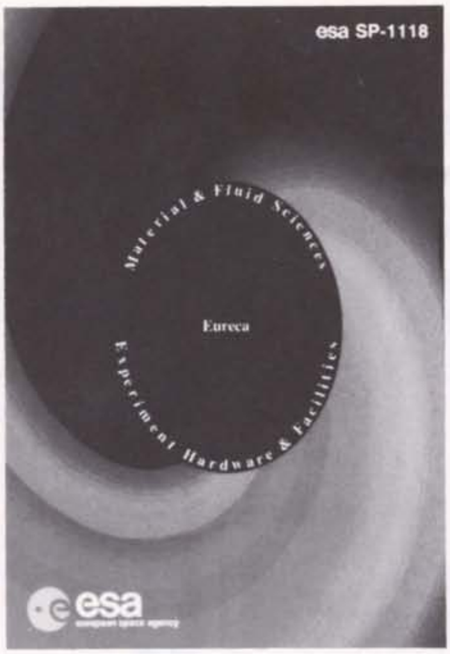
ESA SP-1105 // 135 PAGES
LIFE SCIENCES RESEARCH IN SPACE (JULY 1989)
OSER H & BATTRICK B (EDS)

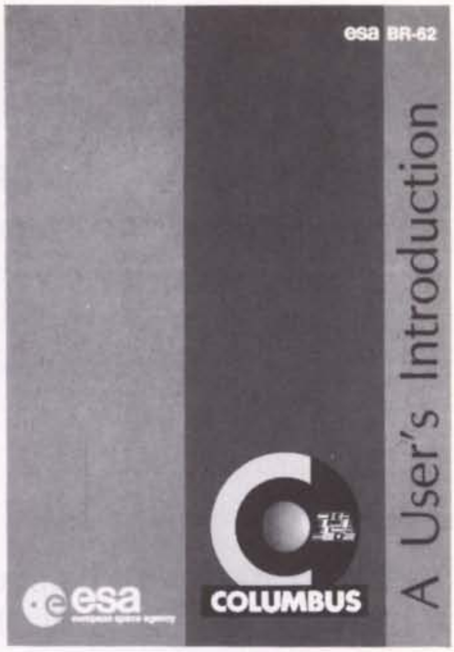










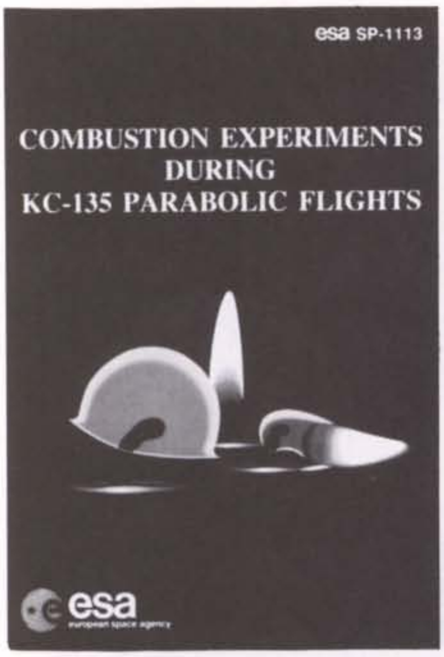


ESA SP-1113 // 69 PAGES
COMBUSTION EXPERIMENTS DURING KC-135 PARABOLIC FLIGHTS (AUGUST 1989)
KALDEICH B (ED)

ESA SP-1114 // 169 PAGES
IUE-ULDA ACCESS GUIDE NO 1 – DWARF NOVAE AND NOVA-LIKE STARS (SEPTEMBER 1989)
COMPILED BY LA DOUS C

ESA SP-1116 // 31 PAGES
FLIGHT EXPERIMENT HARDWARE FOR SOUNDING ROCKET INVESTIGATIONS – MATERIALS SCIENCE AND FLUID SCIENCES (AUGUST 1989)
WALTER H U & MINSTER O (ED: HUNT J J)

ESA SP-1117 // 138 PAGES
MISSION TO MARS – REPORT OF THE MARS EXPLORATION STUDY TEAM (JULY 1989)
CHICARRO A F, SCOON G E N & CORADINI M (ED: BATTRICK B)



ESA SP-1118 // 18 PAGES
EXPERIMENT FACILITIES FOR MATERIALS AND FLUID SCIENCES EMBARKED ON EURECA-1 (AUGUST 1989)
WALTER H U & RIESSELMANN (ED: DAVID V)

ESA SP-1120 // 52 PAGES
EXPERIMENT FACILITIES FOR MATERIALS AND FLUID SCIENCES EMBARKED ON SPACELAB (AUGUST 1989)
WALTER H U (ED: LONGDON N)

ESA Brochures

ESA BR-60 // 25 PAGES
FROM SMALL BEGINNINGS – THE STORY OF ESRO'S SOUNDING ROCKET PROGRAMME (SEPTEMBER 1989)
EATON D

ESA BR-62 // 28 PAGES
COLUMBUS – A USER'S INTRODUCTION (SEPTEMBER 1989)
LANDEAU J (ED)

ESA Newsheets

MICROGRAVITY NEWS FROM ESA // 48 PAGES
VOL 2, NO 2 (JULY 1989)
DAVID V (ED)

REACHING FOR THE SKIES // 8 PAGES
VOL 1/NO 2 (SEPTEMBER 1989)
LONGDON N & GUYENNE T D (EDS)

ECSL NEWS // 4 PAGES
BULLETIN OF THE EUROPEAN CENTRE FOR SPACE LAW (PUBLISHED TWICE A YEAR UNDER THE AUSPICES OF ESA), NO 2 (AUGUST 1989)
LONGDON N & GUYENNE T D (EDS)

NEWS & VIEWS // 8 PAGES
ESA-IRS NEWSLETTER VOL 14 NOS 2/3 (SEPTEMBER 1989)

ESA Scientific & Technical Reports

ESA STR-228 // 69 PAGES
SATELLITE SYSTEMS INTEGRATED WITH THE TERRESTRIAL CELLULAR NETWORK FOR MOBILE COMMUNICATIONS (AUGUST 1989)
DEL RE E (ED: BURKE W R)

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

In Orbit / En orbite

	PROJECT	1989–1995	COMMENTS
SCIENT. PROG.	IUE		
APPLICATIONS PROGRAMME	MARECS-A		LEASED TO INMARSAT FOR 10 YEARS
	MARECS-B2		LEASED TO INMARSAT FOR 10 YEARS
	METEOSAT-3		LIFETIME 3 YEARS
	METEOSAT-4 (MOP-1)		LIFETIME 5 YEARS
	ECS-1		LIFETIME 7 YEARS
	ECS-2		LIFETIME 7 YEARS
	ECS-4		LIFETIME 7 YEARS
	ECS-5		LIFETIME 7 YEARS
	OLYMPUS-1		LAUNCHED 12 JULY 1989

Under Development / En cours de réalisation

	PROJECT	1989–1995	COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE		LIFETIME 11 YEARS
	ULYSSES		
	SOLAR TERRESTRIAL SCIENCE PROG. (STSP)		LAUNCHES SOHO MARCH 1995 CLUSTER DEC. 1995
	HIPPARCOS		
	ISO		LIFETIME 1.5 YEARS
COMMS. PROG.	DATA-RELAY SATELLITE (DRS)		SYSTEM OPERATIONAL 1996
	PSDE TECH. MISSION		READY FOR LAUNCH END 1993
EARTH OBSERV. & MICROGRAVITY PROGRAMMES	ERS-1		
	EARTH OBS. PREPAR. PROG. (EOPP)		
	METEOSAT OPS.PROG.	MOP-1, MOP-2, MOP-3	MOP-1 LAUNCHED MARCH 1989
	MICROGRAVITY	IML-1, D2, IML-2	
SPACE ST. & PLATF. PROG.	EURECA		
	COLUMBUS	PHASE-1, PHASE-2	3 YEAR INITIAL DEVELOPMENT PHASE
SPACE TRANSPORTATION PROGRAMME	ARIANE-2/3	V28 V30 V32	
	ARIANE-4	V29 V31 V33 V34 V35 V36 V37	OPERATIONAL UNTIL END 1998
	ARIANE-5		FIRST FLIGHT APRIL 1995
	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

Télescope Hubble

Le lancement du Télescope Hubble (HST) reste fixé au 26 mars 1990. Le matériel de vol sera expédié, sur C5-A, de Sunnyvale (Californie) au Centre spatial Kennedy (KSC) à la mi-octobre. Le HST est complet, à l'exception d'un instrument, la chambre de prises de vues planétaire à grand champ, démontée pour modification, qui sera remontée au KSC. La chambre de prises de vues pour objets de faible luminosité est vérifiée tous les mois et ne montre aucune modification de fonctionnement. La fabrication du deuxième ensemble de réseaux solaires se poursuit, en soutien de la mission d'entretien du HST qui doit avoir lieu cinq ans après le lancement.

ISO

Les activités récentes liées à l'Observatoire solaire dans l'infrarouge (ISO) ont eu pour objectif de figer la conception du système et des sous-systèmes pour préparer la Revue de conception du système. Tous les aspects de la conception d'ISO, y compris les opérations en vol, ont été examinés par plusieurs groupes d'étude spécialisés. Début juillet, le Comité de revue est parvenu à la conclusion que la conception du module de charge utile (en particulier le grand cryostat à hélium) était bonne, que l'intégration mécanique du modèle structurel/thermique pouvait démarrer et que la définition du secteur sol était satisfaisante. On est préoccupé par la grande complexité de la conception du sous-système d'orientation et il faut travailler encore à éliminer les points critiques de défaillance préjudiciables aux missions dans le système électrique du satellite. La fabrication des unités électriques du modèle de qualification sera engagée par étapes au cours des prochains mois.

L'intégration du module de charge utile a commencé en juillet et progresse rapidement. Les travaux sur un problème de fuite du réservoir d'hélium liquide ont suffisamment avancé pour autoriser le démarrage de la réalisation du cryostat. La fabrication de la structure du module de service est bien avancée et le sous-système de commande à réaction à hydrazine est sur le point d'être livré. Le réservoir d'hydrazine, une nouvelle réalisation de Dowty (UK), a été livré et l'on a procédé à des essais de timbrage sur un deuxième réservoir qui ont montré que les marges de conception étaient largement suffisantes.

Les essais sur modèles de laboratoire de toutes les unités du sous-système électrique ont bien progressé.

Les travaux de développement de la charge utile scientifique se déroulent de façon satisfaisante. Les quatre groupes 'instruments scientifiques' ont entamé la fabrication de leurs modèles d'identification et de qualification. La définition du secteur sol progresse et les premiers modules du logiciel qui sera utilisé pour les essais d'instruments et pour les opérations en vol ont satisfait aux essais et ont été réceptionnés.

Le calendrier d'ensemble du projet est très critique et tous les efforts sont faits pour rattraper les retards. Bien que la date de lancement demeure la même, il ne reste qu'une faible marge de manoeuvre et l'on étudie actuellement la situation.

Olympus

Le satellite Olympus-1 a été lancé avec succès du Centre spatial Guyanais de Kourou, le 12 juillet à 00:14 h TU sur le vol V32, le dernier des lanceurs Ariane 3.

Les panneaux solaires ont été déployés une heure et demie après le lancement et le satellite a été placé sur orbite de dérive géostationnaire lorsque le moteur

Photo: MSS-UK

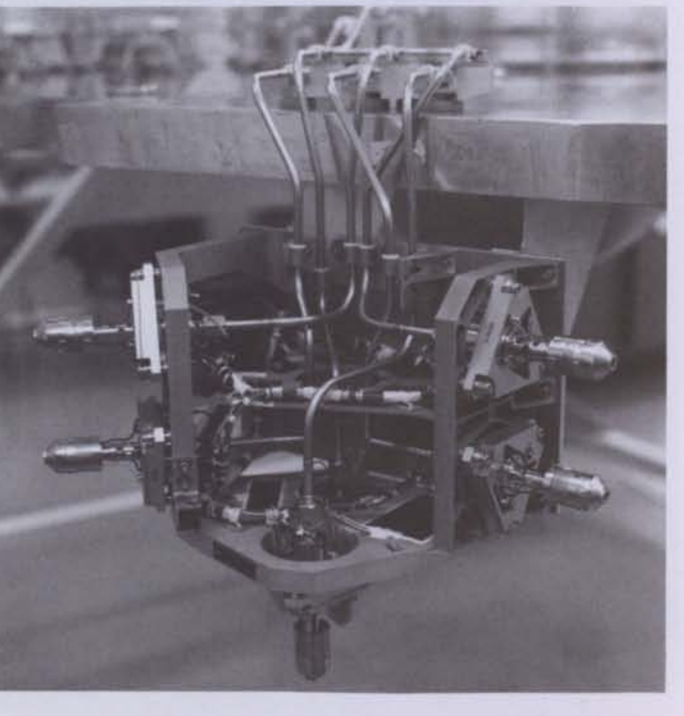


Photo: MSS-UK

Formal acceptance of the first model of ISO's hydrazine reaction control system (left)

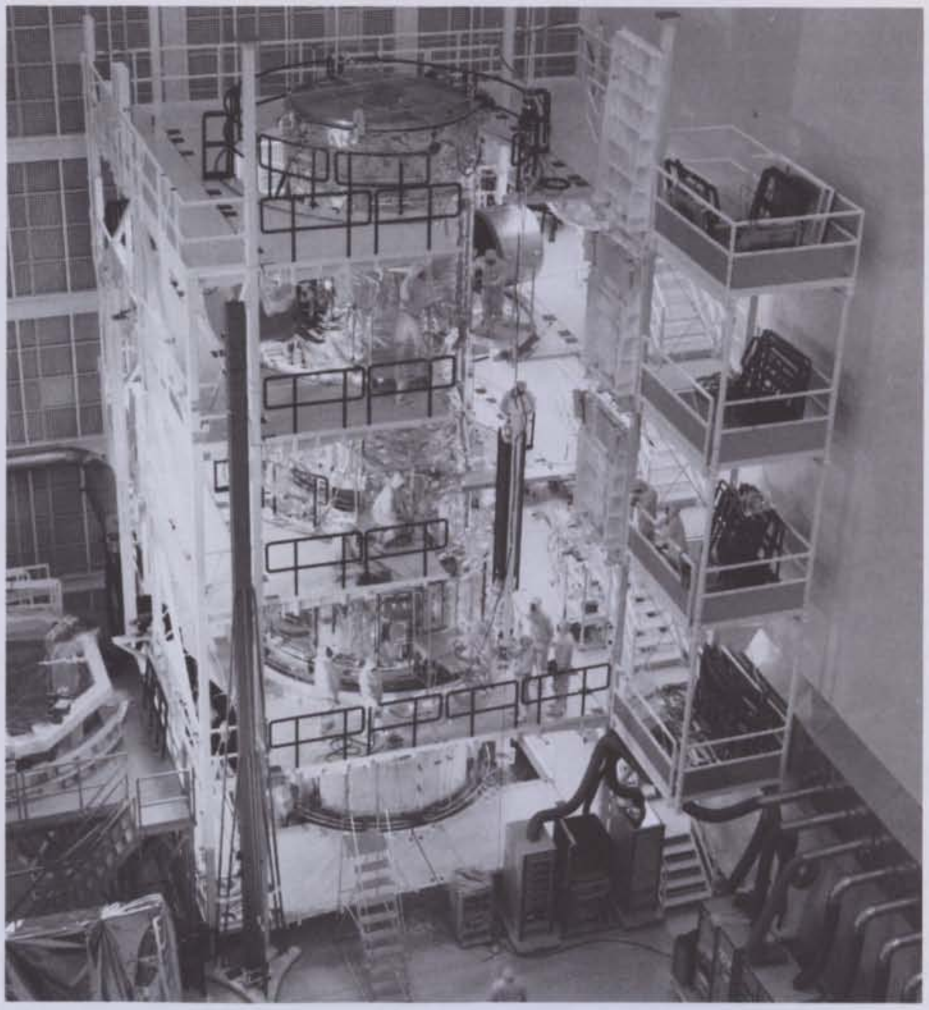
Recette formelle du premier modèle du système de commande à réaction à hydrazine de l'ISO (à gauche)

Thruster block for ISO's orbit and attitude correction (right)

Bloc du propulseur pour la correction d'attitude et d'orbite de l'ISO (à droite)

HST

The Hubble Space Telescope (HST) remains scheduled for launch on 26 March 1990. Shipment of the flight hardware from Sunnyvale California to Kennedy Space Centre (KSC) by C5-A aircraft is planned for mid-October. The HST is complete except for one instrument, the Wide-Field Planetary Camera, which has been removed for reworking and will be re-installed at KSC. The Faint Object Camera is checked out each month and shows no change in performance. Work continues on the building of the second set of solar arrays to support the HST maintenance mission planned for five years after launch.



Installation de l'aile du générateur solaire de vol du Télescope Hubble chez Lockheed à Sunnyvale, California

Installation of HST solar-array flight wing at Lockheed's facility in Sunnyvale, California

ISO

Recent activities on the Infrared Solar Observatory (ISO) have been geared to freezing the system and subsystem design in preparation for the System Design Review. All aspects of ISO's design, including flight operations, were examined by a series of specialised review panels. In early July the Review Board approved the design of the payload module (essentially the large helium cryostat); the start of mechanical integration of the structural/thermal model; and the definition of the ground segment. The design of the very complex attitude control subsystem is causing concern and further work is required to ensure no mission-critical single point failures remain in the satellite's electrical system. Qualification model electrical units will be released for manufacture in stages over the next few months.

Payload module integration started in July and is proceeding rapidly. A problem of leakage from the liquid helium tank has been reduced sufficiently to allow development of the cryostat to begin. Manufacturing of the service module structure is well advanced and the hydrazine thrust reaction control subsystem is about to be delivered. The hydrazine tank, a new European development by Dowty (UK), has been delivered and a second tank has been burst-tested, demonstrating generous design margins. All electrical subsystem units are in an advanced stage of breadboard testing.

Development of the scientific payload is progressing well. All four scientific instrument groups have now started to manufacture their engineering qualification models. Ground segment definition is proceeding well and the first modules of the software that will be used for both instrument testing and flight operations have been tested and accepted.

The overall project schedule is very critical. Although the launch date is unchanged, little contingency remains and this situation is currently being reviewed.

Olympus

The Olympus-1 spacecraft was successfully launched from the Guiana Space Centre in Kourou on 12 July at 00:14 h UT on V32, the last of the Ariane-3 launchers.

The solar arrays were deployed 1½ hours after launch, and the spacecraft was placed in geostationary drift orbit when the bi-propellant liquid apogee engine was fired as planned some 36 hours after lift-off. Platform sub-system commissioning tests were completed during the drift phase, and the station-acquisition manoeuvres to place the satellite in its final orbital position at 19°W were successfully completed on 4 August.

Preliminary tests have shown that all four payloads are working properly. A team of ESA and British Aerospace engineers are now engaged in payload commissioning and in-orbit testing from the Redu ground station. Initial results from these more detailed performance tests are good, and they are expected to be completed by mid-October, after which the satellite will be available to users.

d'apogée biliquide a été mis à feu, comme prévu, environ 36 heures après le décollage. Les essais de recette du sous-système de plate-forme ont été achevés pendant la phase de dérive et les manoeuvres d'acquisition de la station, visant à placer le satellite dans sa position orbitale définitive de 19°W, ont été menées à bonne fin le 4 août.

Des essais préliminaires ont montré que les quatre charges utiles fonctionnaient correctement. Une équipe d'ingénieurs de l'ESA et de British Aerospace procède actuellement aux essais en orbite et aux essais de recette de la charge utile à la station sol de Redu. Les premiers résultats de ces essais de fonctionnement plus détaillés sont bons et l'on pense qu'ils seront terminés pour la mi-octobre; après cela, le satellite sera mis à la disposition des utilisateurs.

ERS

ERS-1

La Revue des résultats de qualification, tenue en juin 1989, a confirmé que la situation d'ensemble du modèle de qualification du satellite était satisfaisante et a renforcé la conviction que le détecteur actif à hyperfréquences (AMI) et l'altimètre radar (RA) satisferaient aux impératifs de fonctionnement.

En juin et en juillet, le modèle d'identification de la charge utile entièrement intégrée a passé les essais d'équilibrage thermique et les essais thermiques sous vide dans la grande installation de simulation solaire (LSS) de l'ESTEC et la première évaluation de ces essais a montré que le fonctionnement était satisfaisant. La charge utile a été transportée chez Matra, à Toulouse, pour être intégrée avec la plate-forme du modèle de vol et pour subir des essais de compatibilité électrique. La plate-forme a déjà satisfait aux premiers essais en circuit fermé, commandés à distance du Centre de contrôle de missions de l'ESOC.

Parallèlement, l'intégration du modèle de vol de la charge utile se poursuit chez Fokker, après livraison de l'altimètre radar, du sous-système de traitement et de transmission des données des instruments et du radiomètre infrarouge et hyperfréquences à balayage dans le sens de la trace au sol. L'intégration et les essais du modèle de vol de l'AMI se poursuivent chez Marconi; la livraison est prévue pour octobre.

EEMS (ERS-2)

Une nouvelle proposition de programme, concernant le satellite européen de surveillance de l'environnement (EEMS), qui doit faire suite à ERS-1, devait être présentée en septembre au Conseil directeur du Programme d'observation de la Terre. La proposition EEMS porte notamment sur les instruments similaires à ceux prévus sur ERS-1 et sur une nouvelle expérience de surveillance de l'ozone à l'échelle du globe (GOME).

EOPP

Aristoteles

Une étude supplémentaire sur la mission Aristoteles du Programme 'solide terrestre', que le Conseil directeur du Programme d'observation de la Terre avait approuvée en juin 1988, a démarré en mai. Elle porte sur la définition plus poussée de la principale mission de mesure du champ gravifique qui utilisera un gradiomètre, définition entamée au cours de la phase A, et l'analyse des options additionnelles, notamment une mission de localisation précise, un magnétomètre et un récepteur pour le système mondial de localisation.

Les aspects programmatiques, y compris un lancement potentiel sur Ariane 502 en octobre 1995, sont à l'étude, l'objectif étant d'entamer en septembre 1990 une étude de définition du projet de phase B.

Un atelier consacré à la mission d'étude du solide terrestre 'Aristoteles' s'est tenu en mai à Trévi, Italie. Cet atelier, présidé par le Ministre italien de la Recherche scientifique et technologique a confirmé à nouveau l'intérêt scientifique et la faisabilité technique de la mission de référence proposée.

Météosat de deuxième génération

Deux études parallèles portant sur un système de satellite stabilisé par rotation ont été lancées en juin par l'Aérospatiale et British Aerospace. Des appels d'offres ont été envoyés en août pour deux autres études parallèles portant sur un satellite à stabilisation trois axes.

Un certain nombre d'études d'instruments sont en cours. Des appels d'offres ont été lancés en août pour le sondeur à haute résolution spectrale et les études de dissémination de données. Les études de modélisation du sondeur à ondes millimétriques et de l'imageur à haute résolution dans le visible ont commencé respectivement en juin et en juillet et les études de simulation du sondeur à ondes millimétriques et du petit ensemble optique sont en voie d'achèvement. Lorsque ces études seront terminées, le Conseil d'Eumetsat choisira les options les plus intéressantes. Pour que le lancement puisse avoir lieu en 1998, l'étude de faisabilité de phase A doit démarrer avant la fin 1990.

Plate-forme polaire

La réunion de lancement pour l'étude de phase A de la première mission d'observation de la Terre sur orbite polaire utilisant la plate-forme polaire de Columbus s'est tenue en juillet avec Dornier et les 12 sous-traitants 'instruments' chargés de l'étude des instruments candidats de l'installation du noyau.

Parallèlement, un certain nombre d'activités de soutien ont été menées:
- *réunion des groupes de consultants scientifiques de l'ESA pour les instruments MERIS, HRIS et ATLID*
- *réunions de liaison avec les sept équipes retenues pour les instruments afin de lancer leurs études de phase A*
- *réunions de liaison avec Eumetsat et la NOAA, consacrées à la charge utile opérationnelle*
- *travaux relatifs à l'intégration des activités d'instrument du MIPAS dans le cadre de l'étude de phase A*
- *poursuite des activités de développement des technologies critiques.*

Campagnes aéroportées

Deux campagnes aéroportées ont été menées à bonne fin. Entre le 16 mai et le 15 juillet, lors d'une campagne avec le spectromètre imageur, un grand nombre de données ont été recueillies au-dessus de zones-cibles maritimes et terrestres. En août, un accord a été conclu avec la NASA pour la collecte de données aéroportées au-dessus de sites d'essais terrestres, au moyen du SAR à triple fréquence et quadruple polarisation embarqué sur un DC8 de la NASA/JPL. Les données des deux campagnes seront mises à la disposition d'un grand nombre de centres de recherche.

ERS

ERS-1

The Qualification Results Review held in June confirmed the overall satisfactory status of the satellite engineering, and this has further increased confidence that the Active Microwave Instrument (AMI) and the Radar Altimeter (RA) will fulfil their performance requirements.

The fully integrated Engineering Model Payload completed thermal balance/thermal vacuum testing in the Large Solar Simulation (LSS) facility at ESTEC in June and July, and the initial test evaluation indicated satisfactory performance. The Payload has been transported to Matra, Toulouse for integration with the Flight Model Platform and electrical compatibility tests. The Platform has already successfully completed the first closed-loop test, remotely controlled from the Mission Control Centre at ESOC.

In parallel, Flight Model payload integration is progressing at Fokker, following the delivery of the Radar Altimeter, the Instrument Data-Handling and Transmission Subsystem and the Along-track Scanning Infrared and Microwave Radiometer.

The AMI Flight Model is still undergoing integration and testing at Marconi, with delivery expected in October.

EEMS (ERS-2)

A new programme proposal for a follow-on ERS-1 programme, the European Enviroment Monitoring Satellite (EEMS), will be presented to the Earth Observation Programme Board in September. The proposed EEMS instrument complement is similar to that of ERS-1, with the addition of a new Global Ozone Monitoring Experiment (GOME).

EOPP

Aristoteles

An additional study on the Aristotoles Solid Earth Mission, approved by the Earth Observation Programme Board in June 1988, was initiated in May of this year. The study includes the further definition of the primary gravity measurement mission using the Gradio instrument addressed during Phase A, together with an investigation of additional options including a Precise-Positioning Mission, a magnetometer and a Global Positioning System receiver.

The programmatic aspects, including the potential launch on Ariane 502 in October 1995, are being reviewed, with a view to a Phase B project definition study starting in September 1990.

A workshop on the European Solid Earth Mission Aristoteles was held at Trevi, Italy in May. This workshop, chaired by the Italian Minister for Scientific and Technological Research, reconfirmed the scientific validity and technical feasibility of the proposed baseline mission.

Meteosat Second Generation

Two parallel studies for a spin-stabilised satellite were initiated in June with Aerospatiale and British Aerospace. Invitations-to-tender for two further parallel studies for a three-axis-stabilised satellite were issued in August.

A number of related instrument studies are underway. Invitations-to-tender were issued in August for the High Spectral Resolution Sounder and the Data Dissemination studies; the Millimetre Wave Sounder Modelling and High Resolution Visible Imager studies were initiated in June and July, respectively. Studies on the Millimetre Wave Sounder Simulation and Small Optical Package are nearing completion.

Once all of the above studies have been completed, the Eumetsat Council will select its preferred options. In order to achieve a launch in 1998, the Phase A feasibility study must start before the end of 1990.

Polar Platform

The kick-off meeting for the Phase A study of the first Polar Orbit Earth Observation Mission using the Columbus Polar Platform was held in July with Dornier (D) and the 12 instrument sub-contractors charged with the study of the candidate Core Research Facility instruments.

In parallel, a number of supporting activities have been performed, including:

- meeting of the ESA scientific consultancy groups for the MERIS, HRIS and ATLID instruments
- interface meetings with the seven selected instrument teams to initiate their Phase-A studies
- interface meetings with Eumetsat/NOAA for the operational payload
- actions on integration of the MIPAS instrument activities within the Phase-A study
- continuation of the critical technology development activities.

Aircraft campaigns

Two aircraft campaigns have been successfully completed. Between 16 May and 15 July an imaging spectrometer campaign collected extensive data over sea and land target areas. In August an agreement with NASA provided for airborne data collection over land test sites, using the NASA/JPL three-frequency quadri-polarised DC8 SAR facility. Data from both campaigns will be made available to a wide number of research centres.

Earthnet

The satellite missions handled by Earthnet (Landsat, MOS-1, Tiros and Spot) continue to perform nominally. The Kiruna, Fucino, Maspalomas and Tromsø stations continue to process the data from these missions successfully.

A joint ESA-CEC project to process all the CZCS European data (acquisitions performed at Dundee, Lannion and Maspalomas in the period 1978-1986) has been proposed.

The ESA-EEC agreement for Spot and Landsat operations at Maspalomas has been extended to the end of 1990.

The ESA-Eurimage agreement for the commercial distribution of Landsat data has been extended for two years.

Progress is continuing on the establishment of the Earthnet ERS-1 Central Facility and ground stations at Fucino, Gatineau and Maspalomas. The German project for an Antarctic station is underway.

Work on the French, German and British Processing and Archiving Facilities (PAF) continues. Contractual actions have been initiated by the Italian Space Agency for the Italian PAF at Matera. Proposals are being prepared for the expansion of the ERS-1 Phase E activity to cover the operation of the PAFs and the promotion of ERS.

Earthnet

Les satellites dont les données sont traitées par Earthnet (Landsat, MOS-1, Tiros et Spot) continuent de fonctionner normalement. Ce sont les stations de Kiruna, Fucino, Maspalomas et Tromsø qui assurent ce traitement.

L'ESA et la CCE ont proposé de mener en commun un projet relatif au traitement de toutes les données européennes du CZCS (acquises à Dundee, Lannion et Maspalomas pendant la période 1978–1986).

L'accord conclu entre la CEE et l'ESA pour le traitement de données Spot et Landsat à Maspalomas a été prolongé jusqu'à la fin 1990.

L'accord ESA-Eurimage sur la distribution commerciale des données Landsat a été prolongé de deux ans.

On poursuit la mise en place de l'installation centrale ERS-1 d'Earthnet et des stations sol de Fucino, Gatineau et Maspalomas. Le projet allemand de station antarctique est en cours.

Les travaux sur les installations française, allemande et britannique de traitement et d'archivage (PAF) se poursuivent. L'Agence spatiale italienne a engagé des procédures contractuelles pour la PAF italienne de Matera. On prépare des propositions relatives à l'élargissement des activités de phase E d'ERS-1 pour couvrir l'exploitation des PAF et la promotion d'ERS.

Météosat

Programme pré-opérationnel

Depuis sa mise en service en août 1988, Météosat-3 (P2) a assuré les activités météorologiques opérationnelles, à titre de satellite principal, jusqu'au 19 juin 1989, date à laquelle Météosat-4 (MOP-1) a pris le relais. Cela a mis un terme à la mission de P2 qui a assuré la transition entre les programmes pré-opérationnels et opérationnels. Ce satellite est actuellement parqué 3°W en renfort de Météosat-4. Il sera ultérieurement placé à 50°W où il comblera le vide causé par la défaillance du satellite américain GOES-East.

Météosat-2, lancé en juin 1981, va manquer d'ergols et sera retiré de l'orbite géostationnaire dans les prochains mois. Son système imageur est vérifié régulièrement et ne montre aucun signe de détérioration au bout de huit années de fonctionnement en orbite.

Programme opérationnel

Après son lancement réussi et sa recette en orbite, le satellite MOP-1 a été mis en service le 19 juin 1989 et rebaptisé Météosat-4. Les réserves d'ergols sont suffisantes pour les cinq années de durée de vie prévues et le fonctionnement est nominal.

MOP-2 a été intégré dans les locaux de l'Aérospatiale à Cannes et les essais d'ambiance ont débuté. Le lancement est maintenant prévu pour avril 1990. Le troisième modèle, MOP-3, sera lancé en septembre 1993.

A la demande d'Eumetsat, on prépare une proposition de prolongation du programme au-delà de 1995. Elle portera notamment sur le lancement et l'exploitation d'un satellite supplémentaire.

Eureca

L'intégration de l'unité de vol d'Eureca chez MBB/ERNO (Brême) se déroule de façon satisfaisante. Le système de micropulsion par gaz froid et le système de transfert interorbital à hydrazine ont satisfait aux essais d'étanchéité et de timbrage. On se concentre maintenant sur l'intégration initiale et les essais de fonctionnement des sous-systèmes électroniques, à l'exception du sous-système de commande d'orientation qui ne sera pas disponible avant le début de l'année prochaine. Sur les quinze instruments qui doivent être intégrés dans la première mission, sept sont déjà à Brême et les essais initiaux sont sur le point de commencer.

On travaille activement avec l'ESOC et la NASA à la mise au point définitive des accords d'interface et à la préparation du planning des opérations en vol.

Le modèle d'expérience RF d'Eureca a été assemblée et mise à l'essai; elle est actuellement au Centre spatial Johnson de la NASA où elle subit des essais de compatibilité avec la Navette dans le laboratoire d'essais des sous-systèmes électroniques. Il est prévu de procéder en octobre à d'autres essais de compatibilité à l'ESOC.

Eureca est actuellement inscrit au manifeste pour un lancement en mai 1991 avec le satellite captif italien.

Station spatiale internationale/ Columbus

Après que l'industrie ait annoncé fin mai que la soumission de la proposition de phase C/D du secteur spatial de Columbus serait repoussée à la fin août, le Conseil directeur du Programme Columbus et le Comité de la politique industrielle (IPC) ont été informés de ce glissement en juin lors de leurs réunions respectives. Afin de ne pas retarder la décision du Conseil de l'ESA, fixée à octobre 1989, des dispositions spéciales ont été arrêtées avec l'industrie en vue de soumettre une proposition anticipée pour les options A et B de plate-forme polaire. La proposition officielle de phase C/D du secteur spatial de Columbus a été soumise pendant la période comprise entre le 31 août et le 4 septembre.

La date de soumission de la proposition ayant été modifiée, l'ESA a révisé son planning d'évaluation. L'évaluation principale doit avoir lieu entre septembre et novembre et, après une série initiale de négociations, ses conclusions devraient être présentées à l'IPC en mars 1990.

Le Comité ESA de la Revue des impératifs préliminaires (PRR) de Columbus s'est réuni en juin pour examiner les résultats des revues complémentaires de la PRR 1 qui se sont terminées au début de l'année. Le Comité a conclu que l'achèvement de ces revues complémentaires mettait un point final à la PRR 1 de Columbus. Après réception de la documentation technique, qui fait partie de la proposition de phase C/D, on a entamé les préparatifs de la PRR 2 qui aura lieu dans la deuxième moitié de l'année.

L'équipe Columbus a également participé à la PRR d'Hermès en juin. Aucun problème important n'a été décelé au cours de la revue en ce qui concerne les exigences d'interface entre l'avion spatial Hermès et le module

Meteosat

Pre-operational Programme

Meteosat-3 (P2) was used as the primary spacecraft for operational meteorological activities from the end of its commissioning in August 1988 until 19 19 June 1989 when operations were switched to Meteosat-4 (MOP-1). This ended the role of P2 as a bridge between the Pre-operational and Operational Programmes. The spacecraft is now on stand-by at 3°W as back-up for Meteosat-4. It will later be moved to 50°W, where it will fill the gap caused by the failure of the American satellite GOES-East.

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

Operational Programme

After successful launch and in-orbit commissioning, the MOP-1 spacecraft was placed in service on 19 June 1989 as Meteosat-4. The on-board fuel is sufficient to support the five-year lifetime and performance is nominal.

MOP-2 has been integrated at the Aerospatiale facilities in Cannes, and environmental testing has started. The launch is now scheduled for April 1990. The third model, MOP-3, will be launched in September 1993.

At the request of Eumetsat, a proposal for extension of the programme beyond the end of 1995 is being prepared. This would include launch and operation of one more spacecraft.

Eureca

Integration of the Eureca flight unit at MBB/ERNO in Bremen is progessing well. Full pressure testing and leak verification of the cold gas reaction control system and the hydrazine orbital transfer system has been completed successfully. Emphasis is now on initial integration and function testing of the electronic subsystems, with the exception of the attitude-control subsystem which will not be available until early next year. Of the fifteen instruments to be integrated for the first mission, seven are already at Bremen and initial testing is about to commence.

Very active discussions are underway with ESOC and NASA to finalise interface agreements and to prepare the flight operation planning.

The Eureca RF 'Suitcase' model has been assembled and tested and is now at NASA's Johnson Space Center for Shuttle compatibility testing in the Electronic Systems Test Laboratory. Subsequent compatibility testing is scheduled for October at ESOC.

Eureca is currently manifested for launch together with the Italian Tethered Satellite in May 1991.

International Space Station/Columbus

Following Industry's announcement at the end of May of a delay in submittal of the Columbus Space Segment Phase C/D proposal to late August, the Columbus Programme Board and the Industrial Policy Committee (IPC) were informed of the slippage at their respective meetings in June. In order to safeguard the October 1989 ESA Council decision milestone, special advanced proposal-delivery arrangements related to the Polar Platform Options A and B offers were agreed with Industry. The formal Columbus Space Segment Phase C/D proposal was actually submitted over the period 31 August to 4 September.

ESA's evaluation planning was revised as a consequence of the changed proposal delivery date. The main evaluation is planned for the period September to November, and will be followed by an initial negotiation round, with the aim of presenting the conclusions to the IPC in March 1990.

The ESA Columbus Preliminary Requirements Review (PRR) Board convened in June to review the results of the 'delta' PRR 1 reviews completed in the early part of this year (a 'delta', or follow-on, review is held to verify that the recommendations of the original review have been carried out). The Board concluded that, with completion of the delta reviews, all Columbus PRR 1 objectives had been met. Having received the technical documentation, as part of the C/D proposal, preparation for PRR 2 in the latter part of the year is underway.

Columbus also participated in the Hermes PRR in June. No major problems were identified during the review with respect to the Hermes spaceplane/Columbus Free Flyer interface requirements. A delta PRR review is planned towards the end of the year, after completion of the Hermes spaceplane concept preliminary design review.

In early July ESA was informed by NASA that a critical internal NASA Space Station Freedom review had been initiated in response to anticipated budget cuts over the next few years. At the beginning of August NASA informed the international partners about a significant reduction of the International Space Station (Freedom) capabilities, at least in the early years of operation. ESA has expressed its concerns to NASA, and consultations on how to resolve the issues are in progress.

A Multilateral Utilisation Study supported by all International Space Station (Freedom) partners will be completed in September. The study team has elaborated a detailed list of candidate payloads for all Space Station Modules, including information on their resource requirements. This information has enabled the study team to perform an analysis of the integration and operation of this complement.

A hardware contract has been placed with Industry for the development of a Microgravity Measuring Assembly to be flown initially on Spacelab D-2 and then developed further for use in both the Attached and the Free-Flying Laboratory. Phase-A Studies for additional common laboratory equipment (such as coolers, freezers, payload video system, a vacuum pump and a general purpose workbench) are being initiated for completion at the end of Phase 1 of the Columbus Programme.

Ariane

ELA-3 site status

Civil engineering works on the Ariane-5 launch complex, ELA-3, at Kourou, French Guiana, have progressed despite a particularly wet season earlier this year.

autonome Columbus. Une revue PRR complémentaire doit avoit lieu vers la fin de l'année, lorsque que la Revue de conception préliminaire de l'avion spatial Hermès aura été achevée.

Début juillet, la NASA a fait savoir à l'ESA qu'elle avait entamé une revue interne et critique de la Station spatiale internationale (Freedom) en prévision des réductions budgétaires attendues pour les prochaines années. Début août, la NASA a informé les partenaires internationaux qu'il y aurait une réduction substantielle des ressources de la Station spatiale internationale (Freedom), tout du moins pendant les premières années de son exploitation. L'ESA a fait part de sa préoccupation à la NASA et des consultations sont en cours afin de résoudre ces problèmes.

Une étude d'utilisation multilatérale réalisée avec le concours de tous les partenaires de la Station spatiale internationale sera achevée en septembre. L'équipe d'étude a dressé une liste détaillée des charges utiles candidates pour tous les modules de la Station spatiale, dans laquelle figurent des renseignements sur les besoins en matière de ressources. Ces renseignements ont permis à l'équipe d'étude d'analyser l'intégration et l'exploitation de cette charge utile.

Un contrat a été passé avec l'industrie pour la réalisation d'un ensemble de mesure de microgravité qui doit tout d'abord être embarqué sur le Spacelab D-2 puis, après d'autres travaux de développement, être utilisé dans le Laboratoire raccordé et dans le Laboratoire autonome. On entame des études de phase A portant sur des équipements supplémentaires communs aux deux laboratoires (par exemple, réfrigérateurs, congélateurs, système vidéo de charge utile, pompe à vide et établi polyvalent), qui seront achevées à la fin de la phase 1 du Programme Columbus.

Ariane

Site ELA-3

En Guyane, les travaux de génie civil se sont déroulées, en début d'année, dans un climat particulièrement humide. La structure en béton, d'une hauteur de 55 m, du bâtiment d'intégration propulseurs (BIP) a été achevée et peut maintenant accueillir les équipements secondaires (plates-formes, installation d'air conditionné, etc.).

La structure du bâtiment d'intégration lanceur (BIL), qui est en cours de construction, doit être achevée d'ici la fin de l'année pour que l'on puisse procéder à l'assemblage des structures métalliques et des équipements au début de 1990.

Les travaux de construction du bâtiment d'assemblage final (BAF) commenceront en 1990. Les fondations du centre de lancement (CDL) et de l'aire de lancement sont terminées (zone avant).

La fabrication en Europe de la structure métallique de la table de lancement a débuté en août et se poursuivra jusqu'à la fin de l'année; l'expédition et l'installation des systèmes fluides et électriques pourront donc avoir lieu début 1990.

Les travaux sur le banc d'essais P230 ont bien avancé, et la pyramide de soutien en béton est presque achevée. L'assemblage des structures métalliques devrait également commencer début 1990.

Photo: Bernard Paris

ELA-3 Booster Integration Building (BIP) under construction (May 1989)

Le Bâtiment d'intégration propulseurs de l'ELA-3 en cours de construction (mai 1989)

Photo: Bernard Paris

ELA-3 P230 Test Stand under construction (August 1989)

Le banc d'essai P230 de l'ELA-3 en cours de construction (août 1989)

The 55 m high Booster Integration Building (BIP) concrete structure has been completed and is now ready to receive the secondary equipment (platforms, air conditioning, etc.)

The Launcher Integration Building (BIL) structure is under way, with completion scheduled for the end of the year in order to start assembly of the metallic structures and equipment in early 1990.

The Final Payload Assembly Building (BAF) works will start in 1990. Foundations have been completed for the Control Centre (CDL) and the launch pad (forward area).

Manufacture of the metal structure for the Table started in August in Europe and will last until the end of the year, enabling shipment and installation of fluid and electrical systems to take place in early 1990.

The P230 teststand is well under way, with the concrete support pyramid near completion. Assembly of the metal structures is also scheduled to start in early 1990.

TDP

Experiments
For the Gallium Arsenide Solar Array (GaAs) experiment the flight unit panel and the experimental patch have been manufactured and tested, and the Flight Acceptance Review was held in August. The experiment will be integrated aboard UoSAT-E in September. Phase-2, focussing on 2 × 4 cm cells with welded interconnectors, has been initiated.

The Solid State Microaccelerometer flight unit has successfully completed environmental testing and the Flight Acceptance Review is scheduled for September. The Transputer and Single Event Upset flight unit completed its Flight Acceptance Review in August and will also be integrated on UoSAT-E in September.

In July Phase-B activities for the Collapsible Tube Mast (CTM) were completed. The decision as to whether to proceed to Phase C/D will be taken in October.

The Liquid Gauging Technology experiment development contract will start in September and will last 18 months.

Common Support Subsystems
Development of the Payload Control Unit has been delayed and is now scheduled for completion by the end of this year. The first operational unit of the Hitchhiker-G simulator has been manufactured.

ESA/NASA Cooperative Experiments
Regarding the In-Flight Contamination Experiment (IFCE) the NASA Phase-B was completed in July (the ESA Phase-B having been completed earlier). Discussions on Phase C/D are awaiting the outcome of the CTM decision.

The NASA Phase-B for the Solar Array Module Plasma Interaction Experiment (SAMPIE) will be completed in September. ESA is again awaiting the CTM decision.

Flight opportunities
With regard to the Hitchhiker experiments, the Altitude Sensor Package is now manifested on STS-49, on 30 September 1991, the Collapsible Tube Mast with the IFCE on 22 February 1993 (STS 64).

The final safety review cycle for the Solid State Microaccelerometer will be completed by the end of this year. It is expected to be launched in 1990 (Shuttle Get-Away Special G21).

UoSAT-E will be launched on 9 November on an Ariane 4 as piggy-back to Spot-2. The TDP experiments on board are the Transputer and Single Event Upset 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) is in progress.

TDP Next Phase Preparation
In the framework of the preparatory activities for Phase 2 of the Technology Demonstration Programme (TDP), the preliminary evaluation of proposals received in reply to the Announcement of Opportunity has been completed and the detailed evaluation should be completed by the end of this year.

Hermes

Since the last Bulletin two major Hermes reviews have been held. Although Industry's involvement was limited to the spaceplane main contractor and Avion Marcel Dassault (AMD), these reviews will have a strong impact on the rest of the Phase 1 activities.

The objective of the first review, the Preliminary Requirements Review (PRR), was to prepare the Hermes requirements' baseline at top system level for space, crew and ground segments. With the Hermes System Requirements Document as reference, a number of key documents were examined in detail. The PRR Board issued a number of recommendations dealing with these documents and their architecture; it will formally be closed in October.

The second review, the Preliminary Spaceplane Definition Review (RDP-A), was organised by CNES and Aerospatiale and started at the end of June. Its main objective was to assess the spaceplane 'Stage 0' configuration against the requirements cleared at the PRR. It also aimed to approve the 'level 1' documentation, including Aerospatiale's spaceplane specifications, the spaceplane development plan and the general specifications which will form the basis of the future industrial development phase. The Review Board and the six review panels, made up largely of independent external experts, participated in two weeks of intensive discussion at Aerospatiale in Blagnac, during which over 4000 pages of documentation were reviewed. A number of presentations were made by Aerospatiale and AMD, as well as by the Technology Panels appointed by CNES and ESA.

Over 100 recommendations were made, dealing with major issues such as crew safety and the use of the ejectable cabin, the spaceplane mass budget, critical technology and aerodynamics, the qualification plan, and the Ariane-5 interfaces. They will be submitted to a Steering Board in mid-September and, once approved, will enter into force in October.

TDP

Expériences
Pour l'expérience de générateur solaire à l'arséniure de gallium (GaAs), la fabrication et les essais du panneau du modèle de vol et des plaquettes expérimentales sont terminés et la Revue d'acceptation au vol s'est tenue en août. L'expérience sera intégrée à bord d'UoSAT-E en septembre. La phase-2, qui porte principalement sur des piles de 2 cm × 4 cm avec interconnecteurs soudés, a été engagée.

L'unité de vol du microaccéléromètre à l'état solide a satisfait aux essais d'ambiance. La Revue d'acceptation au vol est prévue pour septembre. L'unité de vol de l'expérience transordinateur et pertubations sous l'effet de particules élémentaires a déjà passé cette revue en août et sera elle aussi intégrée à UoSAT-E en septembre.

En juillet, les activités de phase B portant sur le mât à tube enroulable (CTM) ont été menées à bonne fin. On décidera en octobre s'il convient de passer à la phase C/D.

Le contrat de développement de l'expérience de technologie de jaugeage des liquides démarrera en septembre et durera dix-huit mois.

Sous-systèmes de soutien communs
La réalisation de l'unité de commande de la charge utile, qui a été retardée, devrait être achevée d'ici la fin de l'année. La première unité opérationnelle du simulateur Hitchhiker-G a été fabriquée.

Expériences en coopération ESA/NASA
En ce qui concerne l'expérience de contamination en vol (IFCE), les travaux de la NASA sur la phase B se sont achevés en juillet (les travaux correspondants de l'ESA sont déjà terminés). On attend pour reprendre les discussions relatives à la phase C/D de connaître la décision du CTM.

La NASA achèvera en septembre ses travaux sur la phase B de l'expérience d'interactions entre le module de générateur solaire et le plasma (SAMPIE). Là encore, l'ESA attend une décision du CTM.

Occasions de vol
Pour les expériences Hitchhiker, l'ensemble de détection d'orientation est inscrit au manifeste de vol de la Navette pour le 30 septembre 1991 (STS-49) et le mât à tube enroulable avec l'IFCE pour le 22 février 1993 (STS 64).

Le cycle de la Revue finale de sécurité pour le microaccéléromètre à l'état solide sera achevé à la fin de l'année. Le lancement doit avoir lieu en 1990 (Get-Away Special G21 sur la Navette).

UoSAT-E sera lancé le 9 novembre 1989 sur Ariane-4 en tandem avec SPOT-2. Il emportera les expériences transordinateur et pertubations sous l'effet de particules élémentaires et panneau solaire à l'arséniure de gallium avec des plaquettes de photopiles expérimentales. On procède au choix définitif du satellite qui emportera le panneau à l'arséniure de gallium avec des photopiles de plus grandes dimensions (phase 2).

La prochaine tranche du TDP
Dans le cadre des activités préparatoires de la phase-2 du Programme de démonstration technologique, on a achevé l'évaluation préliminaire des propositions reçues en réponse à l'avis d'offres de participation et l'évaluation détaillée devrait être terminée d'ici la fin de l'année.

Hermès

Depuis la parution du dernier bulletin, deux revues importantes ont été tenues. Bien que la participation de l'industrie soit limitée au contractant principal de l'avion spatial et aux Avions Marcel Dassault (AMD), ces revues auront de fortes répercussions sur le reste des activités de la phase 1.

La première revue, la Revue des exigences préliminaires (PRR), avait pour objet de dresser le catalogue de référence des exigences d'Hermès au plus haut du niveau système pour les secteurs spatial, terrien et des équipages. Le document 'exigences du système Hermès' a servi de référence à l'examen détaillé de bon nombre de documents clés. Le Comité de la PRR a fait un certain nombre de recommandations au sujet de ces documents et de leur structure; la revue sera officiellement clôturée en octobre.

La deuxième revue, la Revue de définition préliminaire de l'avion spatial (RDP-A), organisée par le CNES et l'Aérospatiale, a commencé fin juin. Elle visait essentiellement à évaluer la configuration de 'stade 0' de l'avion spatial, compte tenu des exigences approuvées lors de la PRR. Elle portait également sur l'approbation des documents de 'niveau 1', notamment les spécifications de l'Aérospatiale pour l'avion spatial, le plan de réalisation de l'avion spatial et les spécifications générales qui constitueront la base de la future phase de développement industriel. Le Comité de la revue et les six groupes d'études, constitués en grande partie d'experts extérieurs indépendants, ont participé à une session d'étude intensive de deux semaines à l'Aérospatiale, à Blagnac, au cours de laquelle ils ont examiné plus de quatre mille pages de documentation. Des présentations ont été faites par l'Aérospatiale et AMD, ainsi que par les groupes technologiques désignés par le CNES et l'ESA.

Plus de cent recommandations ont été formulées, traitant de questions essentielles telles que la sécurité de l'équipage et l'utilisation de la cabine éjectable, le bilan de masse de l'avion spatial, les technologies critiques et l'aérodynamique, le plan de qualification et les interfaces d'Ariane-5. Elles seront soumises à un Comité directeur à la mi-septembre et, si elles sont approuvées, entreront en vigueur en octobre.

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