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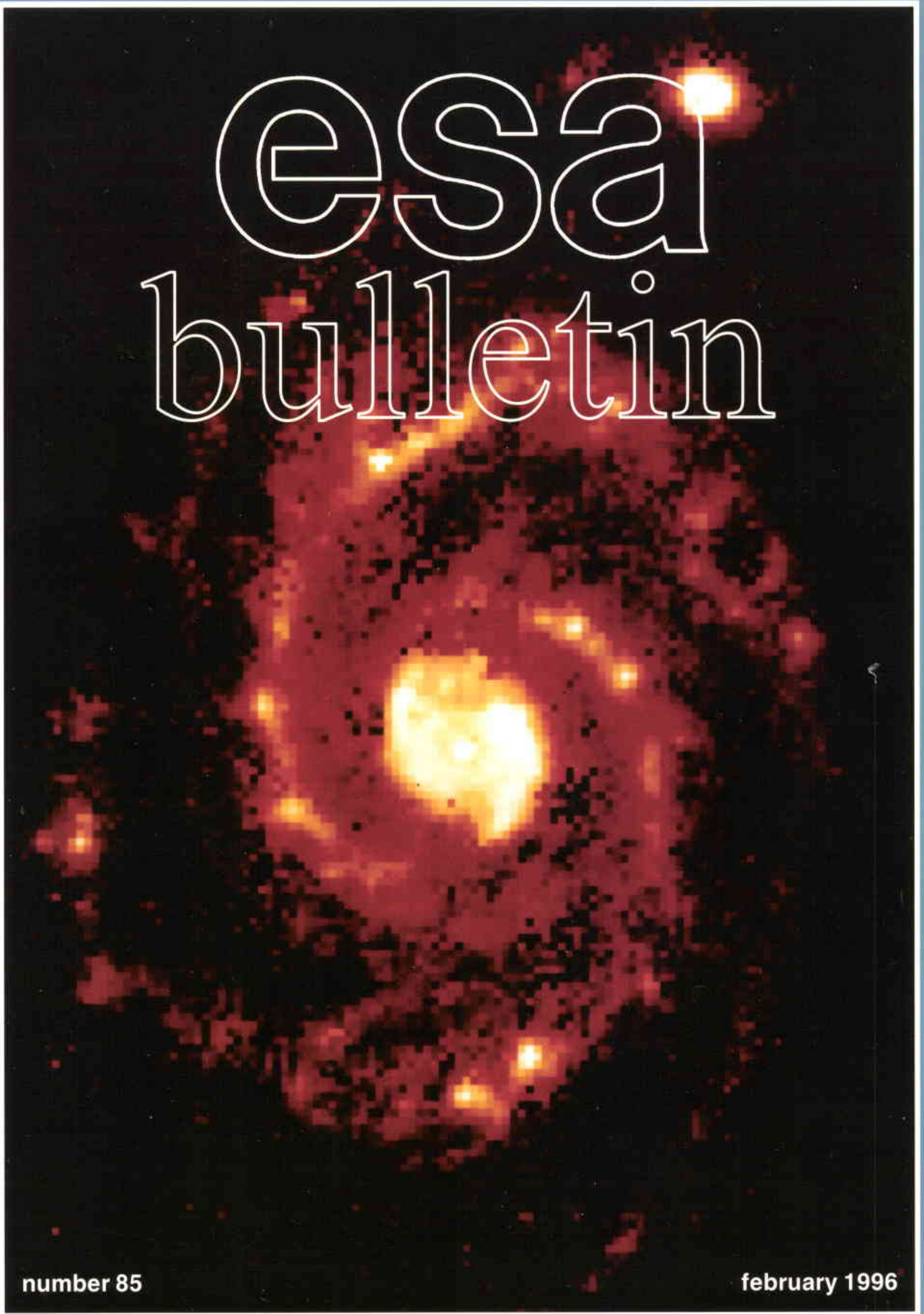

number 85

february 1996

esa

european space agency

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: P.G. Winters

Director General: J.-M. Luton.

agence spatiale européenne

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

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

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

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

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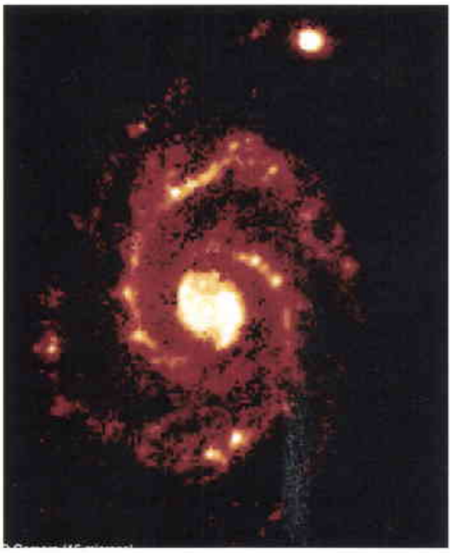

Cover: The 'Whirlpool Galaxy' as imaged by ESA's new Infrared Space Observatory (ISO), launched on 17 November 1995 (see page 104 for more details)

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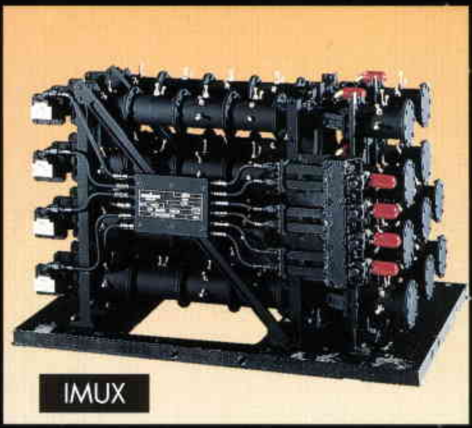
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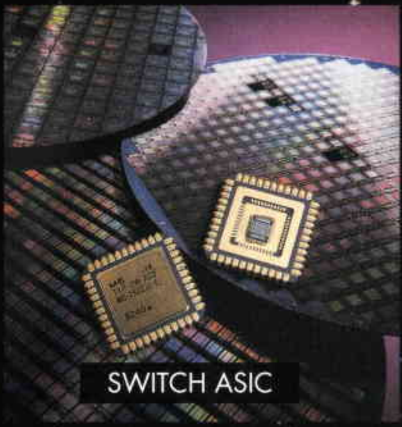
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Weight:	16 lbs (7.3 kg)
Power:	18 Watts @ 28VDC
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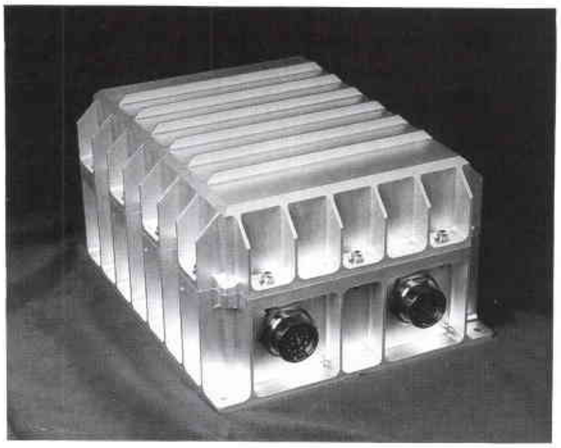
	(300mm x 229mm x 152mm)
Interface:	RS-422



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The newest member of the FDR-8000 family is the FDR-8500C. The capacity of the FDR-8500C is 5 Gigabytes of uncompressed data. Hardware compression is typically 2:1, yielding 10 Gigabytes of storage space. Depending on data content, compression rates of 50:1 are attainable. Peak data rates are 10 Mbit/s per channel into a 4 Mbit buffer. Multiple input models are available. Total sustained data rates from combined channels are from 4 Mbit/s to 12 Mbit/s depending on compression efficiency. The error rate is less than one in 10^{13} bits read.

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The FDR-8000 enclosure is a sealed box purged with nitrogen. The inert gas provides an air cushion around the recording head and protects the tape from common corrosive gases during long term storage. Internal heaters activate below +10°C. During initialization, recording is disabled until heaters can stabilize the internal environment above 0°C. Shock and vibration isolation allow the tape transport assembly to surpass Shuttle launch and landing requirements.

The recorder's footprint measures 11.8" x 9" (300mm x 229mm), with a height of 6" (152mm). The mounting hole pattern is on 70mm centers for easy interfacing with ESA cold plates and Hitchhiker pallets. Total weight is 16 lbs (7.3 kg).

Electrical

Power dissipation is 18 Watts at 28V. Each recorder contains its own DC/DC power converter. An internal controller supports serial data transfer, file structures, error recovery, and regulation of the recorder's operating environment.

Interface

Communication with the FDR-8000 is provided via RS-422 compatible channels. The command channel is asynchronous at 1200 baud. The data channel is synchronous from DC to 10 MHz.

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Involved in most of the major European space programs, AEROSPATIALE has extented its experience to the development of pressurization subsystem components. Their function is the accurate positionning of satellites or the pressurization of launcher propellant circuits.

PRESSURIZATION SUBSYSTEM COMPONENTS AND GAS STORAGE TANKS THE RESULTS OF EXPERIENCE

This has not been achieved by chance. For more than 20 years, Aerospatiale has developed a large number of pressurization subassembly components for bi-propellant systems: valves, regulators and gas storage tanks. These capabilities added to a systems experience naturally led to development and production of pressurization subsystems for the "Symphonie" satellite or the Huygens probe (development).

MASTERING FLUID CIRCUITS

Developing a pressurization subsystem component also requires knowing how to adjust component size optimising the fluid circuit. For this, Aerospatiale owns a computer program for pyrotechnical components which:

- carries out digital simulations in steady state and especially transient regimes ;
- performs these simulations for studying downgraded operating modes;
- selects the optimum pressure;
- achieves the most suitable structure for improving system reliability.

Aerospatiale's pressurization subsystem components are flight proven, and 100 % successful.

- The bi or monostable valves control the attitude correction circuits. Monostable valves are already operational on the TV-SAT, TDF, EUTELSAT II, ARABSAT, TURKSAT, SPOT 1 & 2, ERS 1 and HELIOS satellites.
- The pyrotechnical valves open and close the HP and LP circuits. These pyrotechnical valves ensure perfect sealing Aerospatiale patent between the pyrotechnical chamber and the HP or LP fluid circuits, they operate on DFS, EUTELSAT II, ARIANE IV and TURKSAT.
- The mechanical regulators reduce and regulate fluids from more than 350 bar to below 20 bar (Helium) or 2 bar (Xenon), one is already used on TV-SAT, TELE-X, TDF, DFS, EUTELSAT II. TURKSAT, ARABSAT...
- Aerospatiale has also developed a range of high pressure gas storage tanks for 18.35 to 51 litres and even 300 litres for ARIANE 5.

TANKS DESIGNED FOR AEROSPACE REQUIREMENTS

For more than 10 years, Aerospatiale has applied its know-how in winding filaments of reinforcing fibres to the manufacture of spherical gas storage tanks, usually filled with helium. To reduce the weight by 30 to 50% with respect to all-metal tanks, Aerospatiale uses high performance materials: a thin metal liner provides air tightness and serves as a mandrel for a composite envelope, wound with Kevlar or carbon fibres, which supports pressures up to 400 bar.

To date, 220 tanks have been manufactured, with a hundred of these for ARIANE 4. They save about 80 kg in the weight of the second stage of this launcher, gaining aroung 18 kg for the payload. They also are used for ARABSAT, TV-SAT, EUTELSAT II and TELECOM 2. The new generation of carbon fibre tanks for ARIANE 5 will allow a 10% further weight reduction. These 300-litre capacity tanks are designed for a service pressure of 400 bar. Due to their size and working pressure, Aerospatiale has redefined the winding algorithms. 25 tanks will be delivered for the various ground tests and first launches of ARIANE 5.

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ESA's Earth-Observation Strategy

R. Bonnefoy & H. Arend
Earth Observation Programmes and Plans Department,
Directorate for Observation of the Earth and Its Environment, ESA, Paris

The strategy for ESA's post-2000 Earth observation activities was approved at the ESA Council Meeting at Ministerial Level in Toulouse (F) on 18 – 20 October 1995. This 'Dual Mission Strategy' is based on two categories of missions, known as 'Earth Explorer' and 'Earth Watch' missions. The Earth Explorers are research/demonstration missions designed to advance our understanding of planet Earth, whilst the Earth Watch missions will serve specific Earth-observation applications.

Introduction

Earth observation from space has clearly demonstrated its growing scientific, social, economic and political importance in recent years by contributing to regular monitoring and hence a better understanding of the Earth and its environment, by supporting a wide range of applications, and by providing essential data for geopolitical purposes. Over the past 25 years, Europe has achieved a high level of expertise and experience in this sector, both at a national and on a cooperative European level. Within ESA, the development and operation of the Meteosat series of satellites (Fig. 1), followed by ERS-1 and ERS-2 (Fig. 2), are well-recognised examples of those achievements (Figs. 3 – 5).

Earth observation is also evolving rapidly, with a growing community of users from different sectors – public and private, and research as well as applications oriented – with increasingly varied and often incompatible requirements. Against this background of market growth, and in view of the increasing strategic importance of Earth observation from space, there is more than ever a need for a coordinated approach between the European players. Consequently, the Agency, in close cooperation with the European Commission, Eumetsat and the Member States, has developed a proposal for a European Policy for 'Earth Observation from Space' for the next 25 years.

Within this policy framework, the Agency has developed a strategy for its post-2000 Earth-observation activities (beyond Envisat which is currently under development), known as the 'Dual Mission Strategy'. It involves two specific types of missions, known as 'Earth Explorer' and 'Earth Watch' Missions, in order to best address both the existing and anticipated requirements of the scientific and operational applications users.

Both the policy proposal and the Agency's Dual Mission Strategy were well-received by Ministers at the ESA Council Meeting at Ministerial Level in Toulouse last October, and the Agency is now in the process of elaborating concrete proposals for its implementation.

The objectives

Earth observation from space has the unique advantage of providing continuous global coverage with the temporal and spatial resolutions required by the scientific and operational applications user communities for improving our understanding, monitoring, prediction and management of the Earth's environment and resources.

In taking account of evolving research as well as applications (operational and commercial) interests, the four fundamental objectives that underlie the Agency's present Earth-Observation Programme need to be complemented by a fifth objective reflecting the growing importance of Earth observation for applications users. These objectives are directed towards:

1. The study and monitoring of the Earth's climate and environment on various scales, from local or regional to global.
2. The monitoring and management of the Earth's resources, both renewable and non-renewable.
3. The continuation and improvement of the service provided to the worldwide operational meteorological community.
4. The contribution to the understanding of the

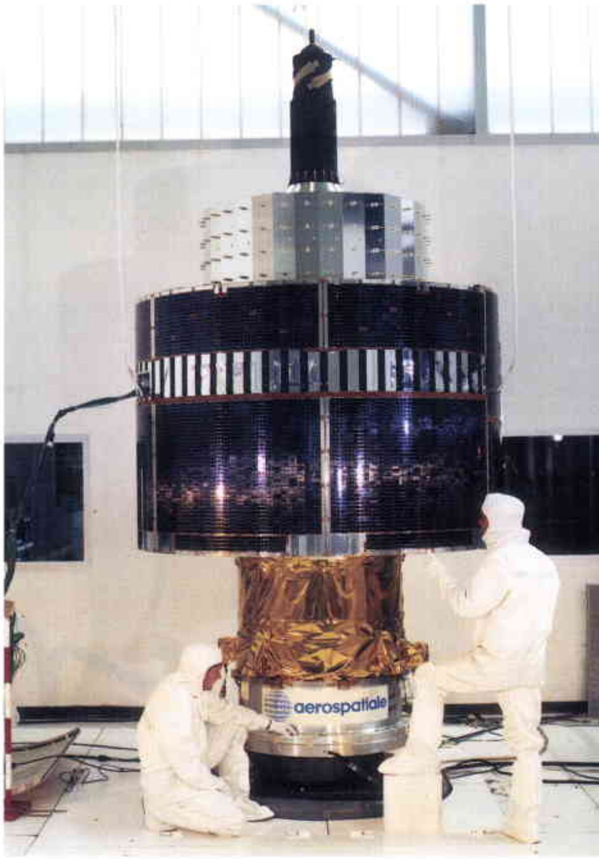


Figure 1. The first flight model of the operational series of Meteosat satellites, MOP-1

structure and dynamics of the Earth's crust and interior.

5. The initiation and consolidation of the services for application communities with emerging needs for space Earth-observation data.

As far as Earth-observation research in the post-2000 era is concerned, the Agency's Earth-observation programme must take full account of the worldwide scientific and public concern related to the environment, climate change and Earth resources. It must therefore duly consider the associated scientific data requirements which span climatology and atmospheric dynamics, atmospheric chemistry and climate change, geodesy and geophysics, ocean, ice and land surfaces. It is also important to consider the interactions spanning conventional disciplines, such as atmosphere/ocean or land/ocean interactions.

Beyond the research aspects, it is becoming increasingly important to address operational Earth-observation applications, spanning well-established and demonstrated domains like operational meteorology, crop forecasting, land use and cartography, as well as emerging areas like the monitoring of coastal zones. Furthermore, there are a variety of other groups of operational/commercial users with wide-spread but less well developed/formulated needs. It is clear, however, that there are many areas of high economic importance which will benefit in the long term from these Earth-observation data.

The Agency will therefore be aiming on the one hand at increasing user awareness and preparedness, which in most cases takes many years to come to maturity, and on the other at ensuring the provision from space of Earth-observation data that match the current and anticipated needs of the various operational user communities in terms of accuracy, spatial and temporal sampling, and timeliness and continuity of delivery. These needs must be identified carefully through close consultation with the user communities at all levels.

The Dual Mission Strategy

In order to achieve the above objectives, and in line with the proposed European Policy for Earth Observation from Space, ESA intends to depart from the multi-objective programme approach leading to large satellites, and to follow a 'Dual Mission Strategy' more suited to the needs of both scientific and operational users. This strategy comprises:

- Earth Explorer Missions: These are research/demonstration missions with the emphasis on advancing our understanding of the different Earth system processes. The missions will primarily support scientific research, but could also address the research needs of operational entities. Each mission will focus on a particular research field, or re-group a limited number of research fields. The demonstration of specific new observing techniques and associated technologies could also fall into this category.

  The Earth Explorer Missions will be entirely funded by ESA and will have mission durations tailored to the specific mission requirements. They will include the possibility of providing instruments through Announcements of Opportunity and with separate funding.

- Earth Watch Missions: These are pre-operational/operational missions addressing the requirements of specific Earth-observation application areas related to well-identified user communities and/or operational entities.

  Beyond the development/pre-operational phase to be funded by ESA together with users and/or operational entities, the responsibility for this type of mission will be transferred to (European) entities providing operational services. The timing of this transfer will depend on the maturity of the

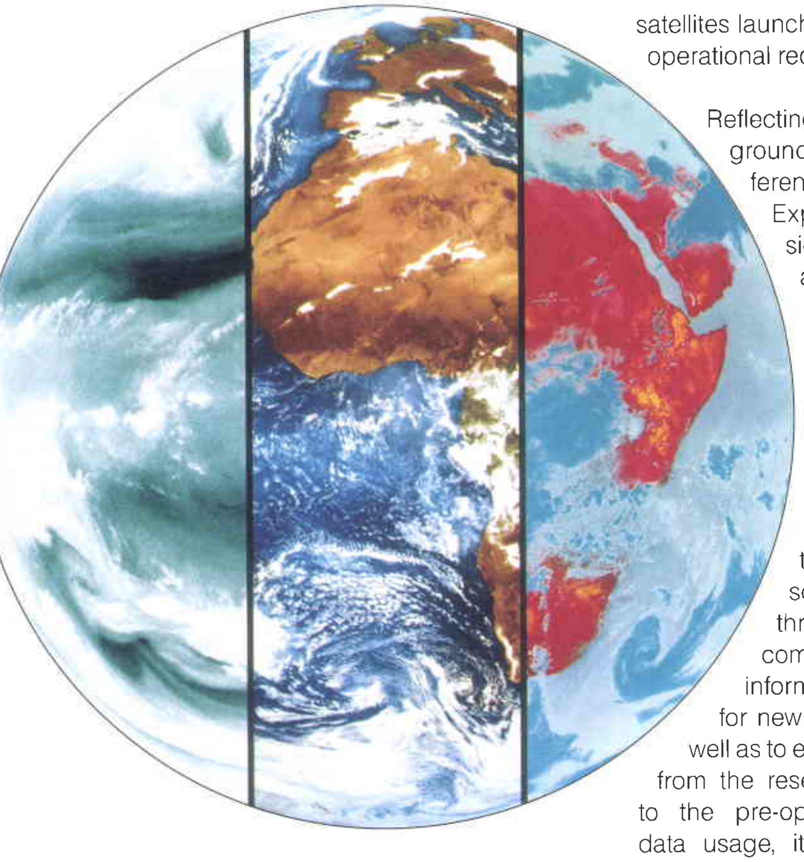


Figure 2. The Earth as seen (left to right) by Meteosat's water-vapour, visible and infrared channels

user community involved and the related status of the operational entity. Data continuity over a period of about ten years will be required to ensure the success of such a scenario.

The two categories of missions will cross-fertilise each other in so far as Earth Explorers could demonstrate new technologies which could be used later on for routine operational applications, whilst Earth Watch missions could provide data that also support scientific activities, e.g. long-term monitoring of specific processes or parameters.

Implementation

To provide the stability and continuity needed by the users, the Earth Explorer missions are to be implemented through a specific framework programme, the Earth Explorer Programme, in which the selection of the individual missions is to be based on the research needs and priorities of the scientific user community. This will allow scientific criteria to be separated from technological and industrial criteria.

The Earth Watch missions will be implemented as optional programmes in successive phases. They will be carried out in association with partners who will ultimately assume long-term responsibility for these missions and will involve close cooperation with the European Commission. Earth Watch will imply a series of satellites launched at regular intervals to meet operational requirements.

Reflecting this strategy, the future ground segment will follow different approaches for the Earth Explorer and Earth Watch missions and will evolve towards a homogeneous framework of decentralised facilities. This evolution will take due account of both present and forthcoming investments, both at national and European level.

Users of Earth-observation data and information span the spectrum from individual scientists and research institutes through operational entities to commercial companies. In order to inform users about and prepare them for new Earth-observation services, as well as to ease and speed up the transition from the research and development stage to the pre-operational stage in terms of data usage, it is essential that ESA plans appropriate promotional and support activities focussed in three main directions:

- Information and training for both on-going and future ESA missions.
- Expanding data usage through monitoring of activities performed by Principal Investigators and within Pilot Projects for ESA missions and, in specific cases, support up to the derivation of thematic information.
- Harmonisation of User Information Services to ensure better access for users to ESA missions and associated products through the various ESA and national facilities.

International coordination

Earth observation from space is by its very nature global and goes beyond national limits and continental boundaries. Therefore, international coordination needs to be considered at two different levels, namely the European level and the worldwide scene.

Within Europe, the close coordination between the ESA Earth Observation Programme and the national programmes of Member States to harmonise both missions and data usage with a view to maximising synergy and complementarity will be pursued and enhanced. In addition, ESA will strengthen its cooperation in Earth observation with European entities such as Eumetsat, the European Commission and the European Environment Agency (EEA).

Figure 3. The ERS-2 spacecraft being readied for launch in Kourou, French Guiana

On the worldwide scene, the Agency intends to pursue and strengthen its relations with, in particular, the USA, Japan, Russia, Central and Eastern Europe, China and India. Due account will be taken of the needs of Developing Countries.

ESA will continue to play a major role in international forums such as the Committee on Earth Observation Satellites (CEOS) and will take due account of initiatives such as the International Geosphere-Biosphere Programme (IGBP), the World Climate Research Programme (WCRP) and the Global Ocean Observing System (GOOS).

The next steps

Following the successful outcome of the Toulouse Ministerial Council Meeting, ESA is now preparing detailed proposals for the Earth Explorer Programme and the first Earth Watch mission for decision by its Member States in the 1997/1998 time frame. The identification, study and assessment of the corresponding mission candidates is well underway.

An initial list of nine potential candidates for the first Earth Explorer mission has been identified in close consultation with the scientific user community, in particular through the User Consultation Meeting held at ESTEC in Noordwijk in October 1994 (Table 1). These candidates are presently being studied and assessed by eminent European scientists, with the support of ESA staff, with respect to their scientific justification, research objectives, observation requirements, and their corresponding mission elements, system concept and programmatics. This assessment will be presented to the user community at a workshop to be held on 29 – 31 May 1996 in Spain. Its outcome will form the basis for a selection in the second half of 1996 of three or four missions for Phase-A study.

Concerning applications, two Earth Watch-type missions are currently in preparation by ESA, namely Meteosat Second Generation (MSG), the successor to the current Meteosat geostationary satellites, and METOP, a series of polar-orbiting operational meteorological satellites. Both are being undertaken in cooperation with Eumetsat, which will ultimately assume responsibility for both missions.

Beyond these missions, five other groups of potential Earth Watch communities have been identified by the users (Table 2). These fields are presently under study with respect to their economic importance, the related user

Table 1. Candidates for the first Earth Explorer mission

Earth Radiation Mission – to advance understanding of the Earth's radiation balance, which is of fundamental importance to the Earth's climate.

Precipitation Mission – to observe precipitation especially in tropical regions.

Atmospheric Dynamics Mission – to observe three-dimensional wind fields in clear air in both the troposphere and stratosphere.

Atmospheric Profiling Mission – to observe temperature profiles in the troposphere and stratosphere for climate research.

Atmospheric Chemistry Mission – to advance understanding of the chemistry of the atmosphere, including the study of active chlorine species and the hydrogen oxides.

Gravity Field and Ocean Circulation Mission – to derive a highly accurate global and regional model of the Earth's gravity field and its geoid.

Magnetometry Mission – to observe the Earth's magnetic field.

Surface Processes and Interactions Mission – to advance understanding of biospheric processes and their interactions with the other processes that occur in the Earth/atmosphere system.

Topographic Mission – to observe the topography of the oceans, the land and the polar ice sheets.

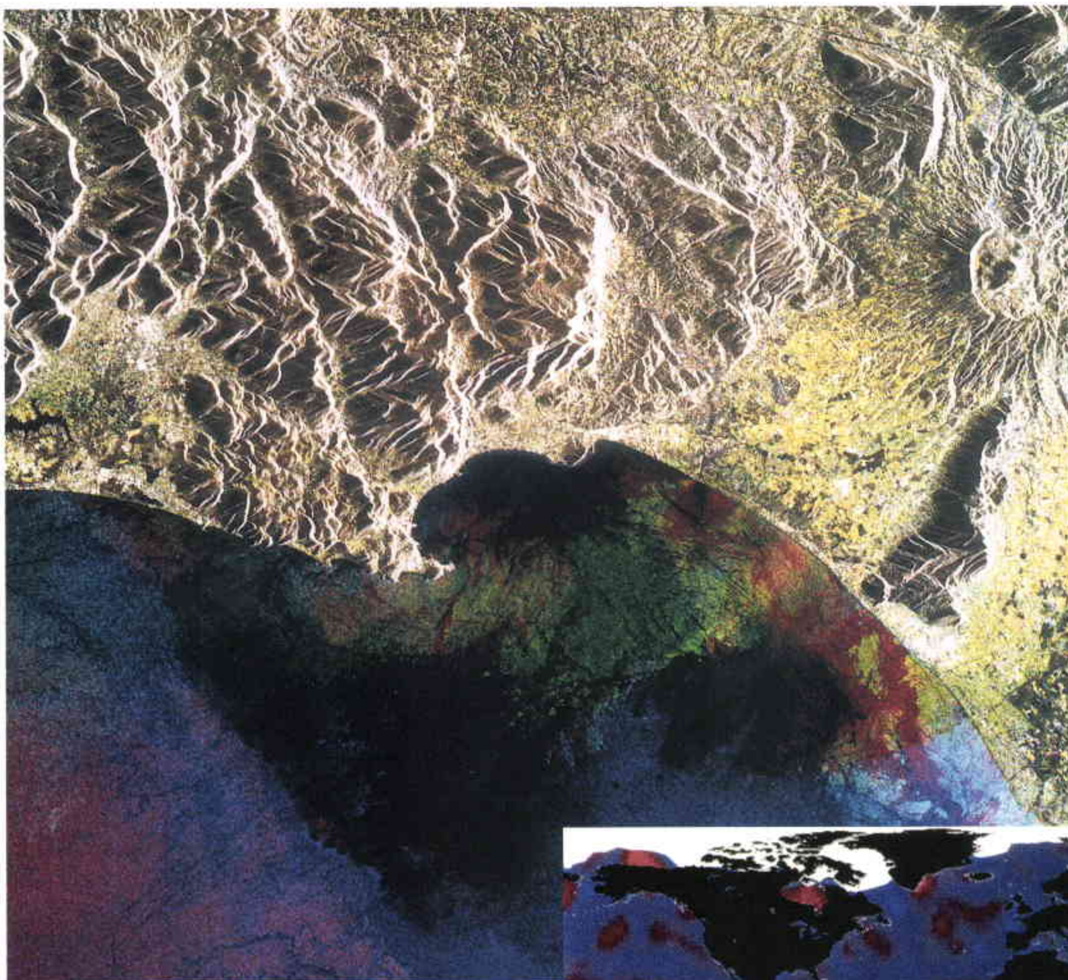


Figure 4. ERS-1/2 SAR multitemporal image of a 96 x 96 km² area around Gulf of Gaeta (Italy)

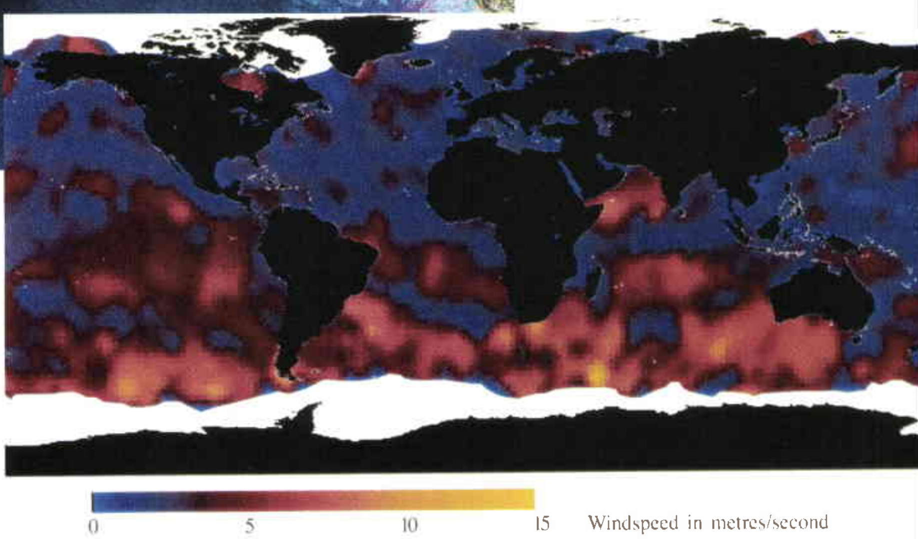


Figure 5. Global wind speeds derived from ERS Scatterometer data. The ice edges were added using the satellite's Radar Altimeter data

communities, the corresponding maturity of usage of Earth-observation data and information, and the potential macro-economic impact of Earth observation. Selection of the most promising area(s) for further, more detailed study is envisaged in the second half of 1996.

Table 2. Candidate fields for the first Earth Watch mission

Coastal Zones – this covers a wide field of applications, including bathymetry, oil-spill monitoring, sea-state monitoring and forecasting, mineral and hydrocarbon exploration, flood surveillance and prevention, inland waters, fisheries, coastal erosion and surveillance, river discharge, coastal land use, etc.

Ice Monitoring – this includes both the operational monitoring of sea ice fields and the forecasting of their evolution.

Land Surface – this spans a variety of uses on a national and a European level, including crop forecasting, crop-damage assessment, forestry, land use, cartography, etc. Some of these relate directly to the enforcement of regulatory measures.

Atmospheric Chemistry – the long-term need for atmospheric-chemistry monitoring is only partially addressed by the ozone instrument on METOP. It is also necessary to consider the monitoring of halogens in the stratosphere.

Open Oceans – this includes ship routing and sea-state monitoring and forecasting.


ERS-1/ERS-2 tandem SAR image of Amsterdam

Achieving, Assessing and Exploiting the ERS-1/2 Tandem Orbit Configuration

J.M. Dow, M. Rosengren, X. Marc, R. Zandbergen*, R. Piriz & M. Romay Merino****

Orbit and Attitude Division, European Space Operations Centre (ESOC), Darmstadt, Germany

Although the ERS-1 spacecraft, launched on 17 July 1991, had exceeded its specified nominal lifetime when ERS-2 was launched by an Ariane-4 on 21 April 1995, it continues to function very successfully and, thanks to the decision by the contributing ESA Member States to extend ERS-1 operations beyond the end of the ERS-2 Commissioning Phase, the 'tandem mission' has become a reality. Both spacecraft are currently orbiting the Earth in almost the same orbital plane, with a spacing between them of about one third of an orbital period.

This article reviews the requirements for the dual orbit configuration of the two spacecraft, how it was achieved, and how it is being exploited.

Introduction

The advantages of being able to fly the ESA Remote-Sensing Satellites ERS-1 and ERS-2 in parallel, at least for a limited period, have long been recognised. In fact, during the evaluation of the several hundred research proposals received by ESA in answer to the Announcement of Opportunity for the exploitation of ERS-2 payload data, the utility of a 'tandem' mission was identified as a factor common to a significant proportion of the proposals.

In particular, the rapidly expanding field of Interferometry using Synthetic Aperture Radar (INSAR) requires that the projection of the orbital path on the Earth's surface repeat to within a few hundred metres after a fixed number of days. If two radar images, separated in time by one or more cycles of the ground-track repeat period, are superimposed, the interference fringes generated in those parts of the image area in which some change has taken place can be used to detect very small displacements (at the centimetre level). Thus, for example, movements caused by earthquakes and by volcanic activity can be analysed in considerable detail using INSAR techniques.

A number of applications of ERS's Radar Altimeter data, notably the cross-calibration of the ERS-2 and ERS-1 Altimeters, require that the repetition of the ground track should be close enough for cross-track variations in the sea surface, averaged over the beam width of the Altimeter, to be essentially negligible. For optimal use of the Altimeter's height measurements for oceanographic applications, a very high orbital accuracy is required. This is achieved firstly by using (in appropriate computer software) the best possible models for the orbital motion and measurement processes, and secondly by using high-precision tracking measurements , viz. laser ranging, and in the case of ERS-2, data from the PRARE (Precise Range and Range-rate Equipment). The accurate orbits obtained also provide an excellent means of assessing the quality of the operational orbit, which is used for mission-control purposes and for the computation of fast-delivery data products from the payload instruments.

Preparing for ERS-2's launch

While ERS-1 has spent time in various orbits during the past four and a half years in order to satisfy the requirements of the different applications for the payload, it had been decided before the launch of ERS-2 that the latter should remain in a fixed repeat cycle throughout its mission. With this fixed cycle, every point on the ground track will be overflown every 35 days.

The ERS orbits are Sun-synchronous. This means that the choice of orbital height and of the orbital plane's inclination with respect to the equator are such that the precession in the orbital plane due to the Earth's equatorial bulge is equal to one revolution per year, or about 1° per day, the same as the apparent motion of the Sun around the Earth. The requirement set for the tandem configuration was that both spacecraft should be in a 35 day repeat cycle, with a time difference of exactly one day between overflights of the same ground point (with either spacecraft leading). Since the ERS satellites orbit the Earth approximately 14 1/3 times per day, by separating the spacecraft in their orbital planes by about one third of an orbital period the trailing spacecraft can be made to pass over the track of the leading spacecraft exactly one day later.

* With Logica, London, UK

** With GMV, Madrid, Spain

Owing to the unexpected launch delays which affected its sister satellite, ERS-1 was able to make two complete cycles of its Geodetic Phase orbit, in a ground-track repeat cycle of 168 days, before manoeuvres started on 19 March 1995 to bring it into the 35 day orbit. Its orbital inclination was first adjusted by means of two orbital node manoeuvres 50 min apart. Two days later, a drift was initiated, and at the same time in-plane elements were corrected, with two manoeuvres separated by 1½ revolutions. The drift was stopped on 24 March by two tangential burns separated by half an orbit, giving ERS-1 the desired orbit [passing over a particular point on the equator (0.1335°E) and making 501 revolutions in exactly 35 days ($14^{11}/_{35}$ orbits per day)] whilst awaiting the arrival of ERS-2.

This orbit was higher than the nominal initial ERS-2 orbit, for which no constraints emanating from the planned tandem mission were placed on Arianespace. Hence, in order to reach the final tandem configuration, and particularly to achieve the in-plane separation of 31.6 min, a sequence of post-launch manoeuvres would be needed which would depend on ERS-2's exact time of launch within the assigned 10 min window. A further constraint was that the separation between the two spacecraft after ERS-2's launch should be at least 30 min, to facilitate the handling of both spacecraft by a single prime ground station. This constraint was, however, relaxed to 15 min in order to open a launch window on some days on which launch would not otherwise be possible. Consequently, the launch window was open on two days, then closed on the third, with a near repetition of this pattern every three days, due to the ground track almost repeating after three days ($42^{33}/_{35}$ revolutions in three days).

The ERS-2 Launch and Early Orbit Phase (LEOP)

ERS-2 was launched on an Ariane-4 (flight V42) at the beginning of the 10 min launch window at 01:44 UTC on 21 April 1995. Its separation from the launcher occurred over NASA's Wallops Island station close to Washington, DC. Deployment of the spacecraft's solar-array arm took place shortly after separation, and the sequence of transitions in the Attitude and Orbit Control System from launch mode, through rate-reduction mode and coarse acquisition mode to fine acquisition mode, took place within about 5 min of spacecraft separation, suggesting very nominal attitude, and low attitude rates. By the time the first tracking data from Wallops Island and the Poker Flat (Alaska) station became available (the satellite went below the horizon at Poker Flat at 02:22 UTC), it was clear that the injection orbit provided by Ariane was extremely close to that planned, with the height of ERS-2's orbit only about 1 km too low, and its inclination just 0.003° away from nominal.

One consequence of this very nominal orbit was the small inclination manoeuvre needed, which was in fact about one tenth of that expected on the basis of the normal launcher injection uncertainties. Moon blinding constraints on the spacecraft earth sensor used for attitude determination meant that the inclination manoeuvre, which required a 90° rotation of the spacecraft before and after the burn, could not take place before 25 April. The date and time of the ERS-2 launch meant that ERS-1 was the lead satellite by some 47 min (just less than half the orbital period), and so the first manoeuvres executed on 22 April were a pair of in-plane thrusts designed to initiate the drift to provide the proper separation between the two spacecraft. Orbit calibrations showed that the manoeuvres were implemented with better than 1% accuracy.

The spacecraft attitude rates during the inclination manoeuvre are shown in Figure 1. The manoeuvre started at 02:57:08 and lasted 46 s. The large rotations are apparent and the convergence afterwards is rapid. A further pair of relatively large in-plane manoeuvres on 27 April, 50 min apart, followed by a pair of small touch-up manoeuvres a day later, provided the correct starting conditions for the Commissioning Phase, which could then begin on 28 April 1995.

The commissioning and routine-phase orbits

The Commissioning Phase orbit requirements, derived from the need to cross-calibrate the Radar Altimeters, were that the spacecraft should pass over a point on the equator at 0.1335°E longitude in a 35 day repeat cycle, with exactly 501 revolutions per cycle. Each ground track should repeat within ±1 km of the nominal ground track, defined using a reference orbit model, including the JGM-3 gravity model. A 1 day separation between the overflights of a given point by ERS-1 and ERS-2 was specified. Furthermore, between latitudes 65°N and 65°S over ocean zones, the relative tracks of the two spacecraft should be within 200 m of each other. This phase lasted 130 days, or nearly four repeat cycles.

During the Routine Exploitation Phase, which has been in progress since 7 September 1995 when the Commissioning Phase was

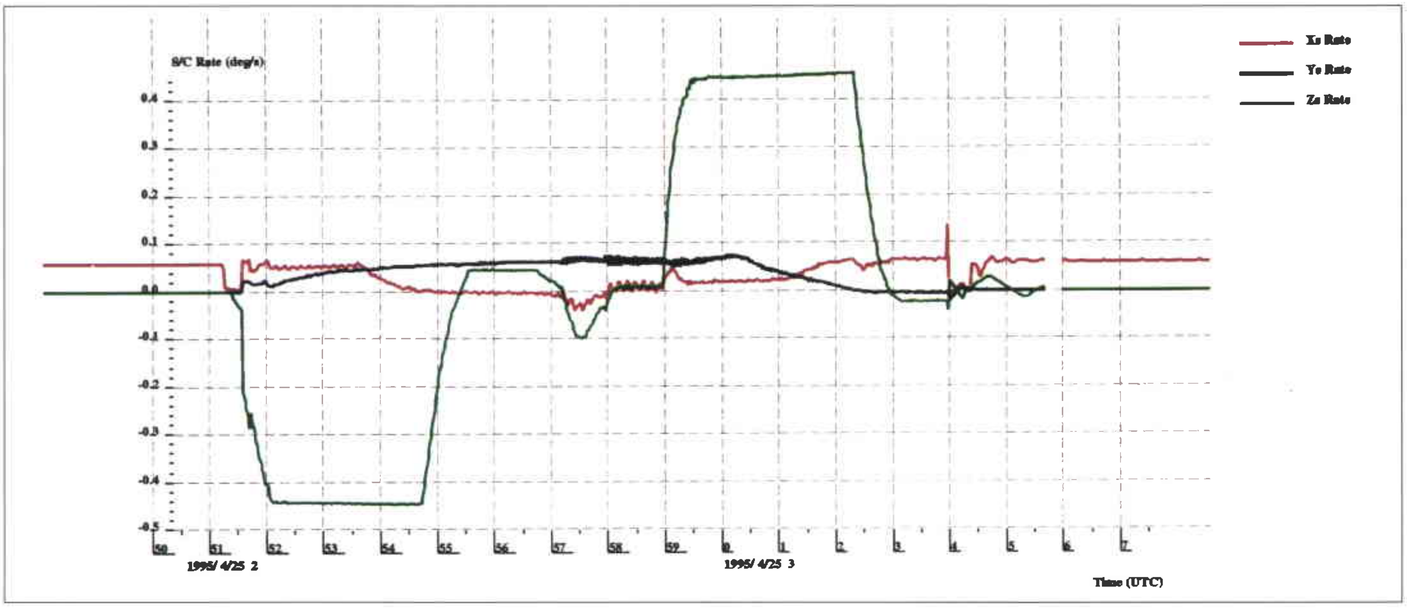


Figure 1. ERS-2 attitude rates during the first inclination manoeuvre

completed, the above requirements still apply, except that the 200 m between the two ground tracks has been relaxed to 80 – 250 m. This leeway is needed for the SAR Interferometry, for which a minimum baseline is necessary in order to generate interference fringes. As was the case for the Commissioning Phase, the individual ground tracks of each spacecraft must repeat to within 1000 m around the equator and to within 400 m at high latitudes. ERS-1's ground track crosses that of ERS-2 at high latitudes twice per orbit, so that the lower limit of 80 m is briefly violated there.

The histories of the ERS-1 and ERS-2 ground tracks since the beginning of 1995 are shown in Figure 2, from which it can be seen that the rather severe requirements for the Commissioning Phase were consistently achieved.

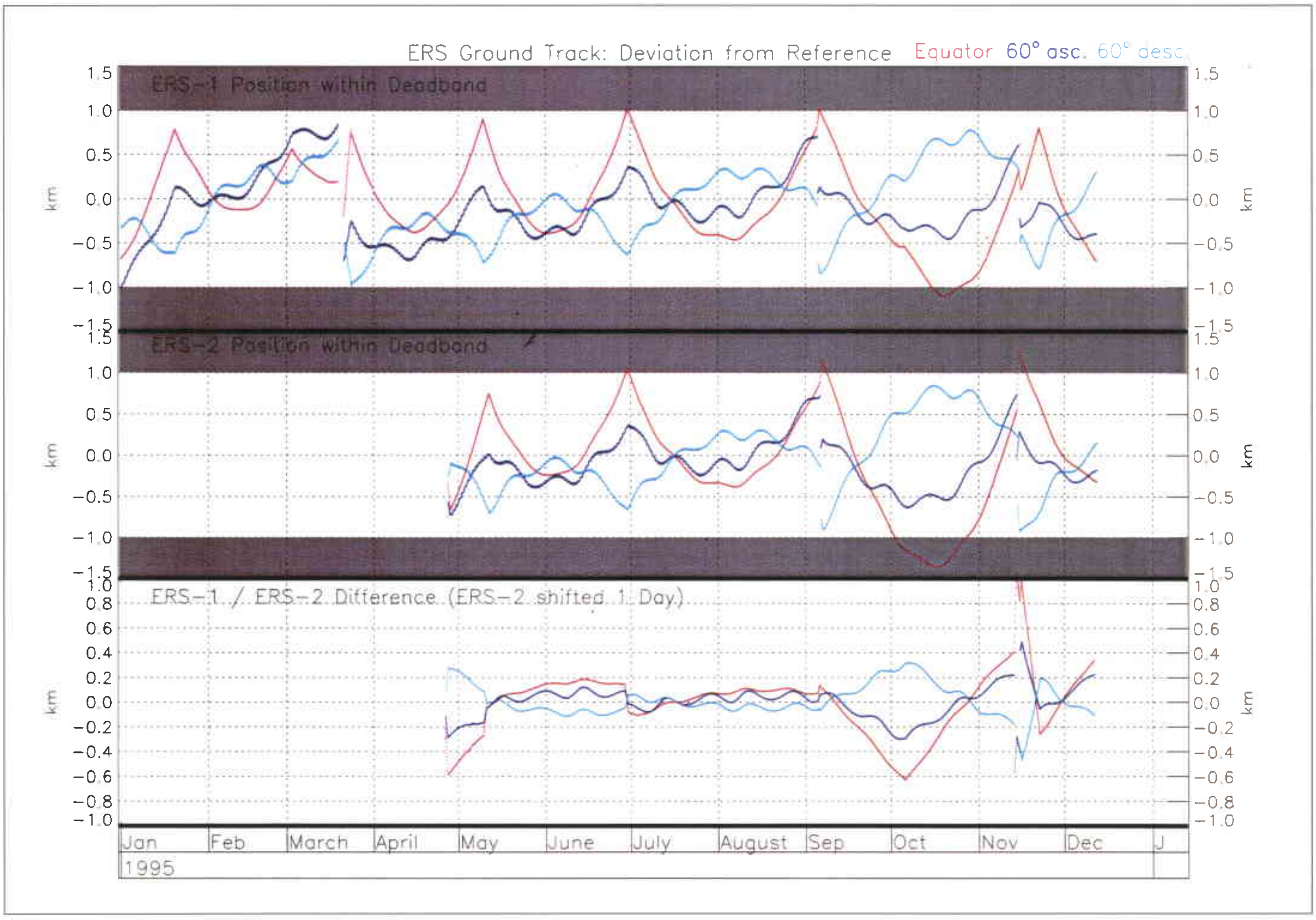


Figure 2. ERS ground-track offsets from reference

In contrast to the inclination manoeuvres during the earlier ERS-1 mission (two per year, in spring and winter), those for the ERS-2 mission, and consequently for ERS-1 in tandem, are now being carried out at fixed phases of the repeat cycles, with a maximum of five per year. This helps both to reduce the dispersion in the ground tracks and to increase the probability of obtaining interferometric images.

Assessment of orbit accuracy

One of the main purposes of the operational orbit determination is to provide the ERS-1 and ERS-2 ground segment with the latest orbit determinations and predictions, for satellite-acquisition (at the ground stations), mission-planning and fast-delivery data-processing purposes. This determination relies on S-band tracking and fast-delivery Altimeter height data, with various corrections applied. The S-band data consist of range and range-rate measurements from the Multi-Purpose Tracking System (MPTS) installed at the Kiruna ground station in Sweden. An automatic software sequence checks the data's arrival in the ESOC computer after each planned pass, and sends warning messages to the spacecraft controller's console if anomalies are detected.

Table 1. Models used in ERS operational and precise orbit determination

Reference frame
- mean equator and equinox of J2000.0
- Station coordinates computed from a Topex/Poseidon and Lageos multi-arc solution

Dynamics
- JGM-3 (36,36) gravity model (operational), JGM-3 (70,70) (precise)
- MSIS density model (Hedin 1983); detailed CD modelling; 1 daily (operational) or sub-daily (precise) drag scale factor estimation
- luni-solar gravity
- frequency-dependent solid-Earth tides, Wahr model
- detailed ocean tide model, augmented Schwiderski (precise)
- direct solar radiation pressure model (operational), taking into account spacecraft geometry (precise)
- albedo, infrared perturbations (precise)
- modelling of manoeuvre accelerations, estimation of corrective factors
- one cycle per revolution accelerations

Measurement processing
- Hopfield tropospheric correction (S-band), Murray-Marini (laser)
- Rawer-Bent ionospheric correction (S-band)
- spacecraft transponder delay, and ground calibrations
- centre of mass correction (precise)

Altimeter data processing
- fast-delivery dry tropospheric corrections
- Rawer-Bent ionospheric correction (precise)
- sea-state bias: fast-delivery correction plus an additional percentage of the SWH (precise), currently 0.0%
- ESOC wet tropospheric correction model (precise)
- ERS-1/ESOC Preliminary Mean Sea Surface, 0.3 deg resolution. Reference ellipsoid $a = 6378.1367$ km, $f = 1/298.257$
- solid tide correction, including permanent tides (precise)
- NSWC ocean tide models, including ocean loading (precise)
- ESOC Dynamic Ocean Topography model to degree and order 20: previous month's solution (precise)

Once per day, the full sequence of programs is run to process tracking data from the last three days, and to update the orbit file, including a prediction for the next nine days. The central day of the three-day moving window provides the final orbit. Consequently, the operational orbit is available to users with just one day's delay.

In parallel with this process, precise orbit determination is performed using more complete models and all the available data: quick-look laser, S-band range and Doppler, and corrected fast-delivery altimetry from Kiruna (16 s normal points). The precise orbit determination is also performed automatically outside normal working hours, including the retrieval and pre-processing of tracking data and the generation of residual and orbit-comparison plots. Solutions are being generated in 4-day arcs, with a delay of typically one week necessary to collect most of the laser tracking data.

The models used in generating both the operational and precise orbits are listed in Table 1. Comparison of the operational and precise orbits allows the accuracy of the operational orbit determination to be estimated. This is currently 2 – 3 m along-track, 1 m across-track and 30 – 50 cm radially (30 cm for ERS-2; see Fig. 3).

The quality of the orbit prediction provided by the operational orbit solution is monitored constantly, by comparing each day's predicted orbit with the final orbit determined afterwards. Statistical information on the 1-day, 3-day and 6-day prediction errors for the period May to October 1995 is presented in Table 2. The relatively high prediction accuracy reflects the low solar activity (near the minimum of the 11-year solar cycle). High levels of solar activity experienced after the ERS-1 launch (and to be expected during the Envisat mission) led to prediction errors of 1 km after a day, and up to 5 km after 3 days.

The quality of the individual tracking data types is summarised in terms of the amount of data available and the root-mean-square (rms) residuals from the precise solution. The 'residuals' are the differences between the actual measurements and those computed with the best models available after the solution has been obtained. Individual statistics are plotted for the laser data (including a detailed breakdown per laser station), for the MPTS S-band tracking data, and for the Altimeter data in Figure 4. Typical fitting accuracies are 6 cm for laser, 14 cm for altimetry, 60 cm for MPTS ranging and 2 mm/s for MTPS Doppler (30 s sampling).

Precise orbits for ERS-1 and ERS-2 are generated at the German Processing and Archiving Facility (D-PAF) in Oberpfaffenhofen, in support of refined ERS Altimeter products. A regular comparison is made between the ESOC and D-PAF precise orbits, showing a radial consistency between both solutions at about the 9 cm level during 1995 (Fig. 5). Overlap tests made by differencing short common arcs in consecutive four-day solutions show an internal radial consistency in the ESOC orbits of better than 5 cm. The objective of providing orbits with sub-decimetre radial accuracy for ERS is therefore certainly being achieved.

ERS-2 Altimeter calibration

Calibration campaigns involving near-overflights of laser stations have been the most commonly used method of calibrating a radar altimeter. The recent improvements achieved in orbit determination, together with the fact that several altimetric missions are currently flying simultaneously, have opened up new calibration possibilities. They are mainly based on relative calibration between two or more satellites. A special working group, including experts from a number of European institutes working on altimetry, has been set up by ESRIN for the purpose of cross-calibrating the ERS-2 Altimeter with respect to that of ERS-1.

As noted earlier, radial orbit errors are no longer a limiting factor in calibrating a radar altimeter using global techniques. More important limitations are the corrections to the altimeter measurements themselves. The latter need to be corrected for various propagation effects in order to determine the height of the satellite above the instantaneous mean sea surface accurately. The instantaneous height of the sea above the reference ellipsoid can be determined by applying accurate corrections

Table 2. ERS orbit prediction errors

	ERS-1/ERS-2 (metres) after 1 day	after 3 days	after 6 days
October '95	30/20	111/98	326/274
September '95	13/18	50/53	148/106
August '95	14/14	58/57	201/200
July '95	14/12	50/51	173/165
June '95	17/16	71/72	197/227
May '95	23/18	105/97	202/199

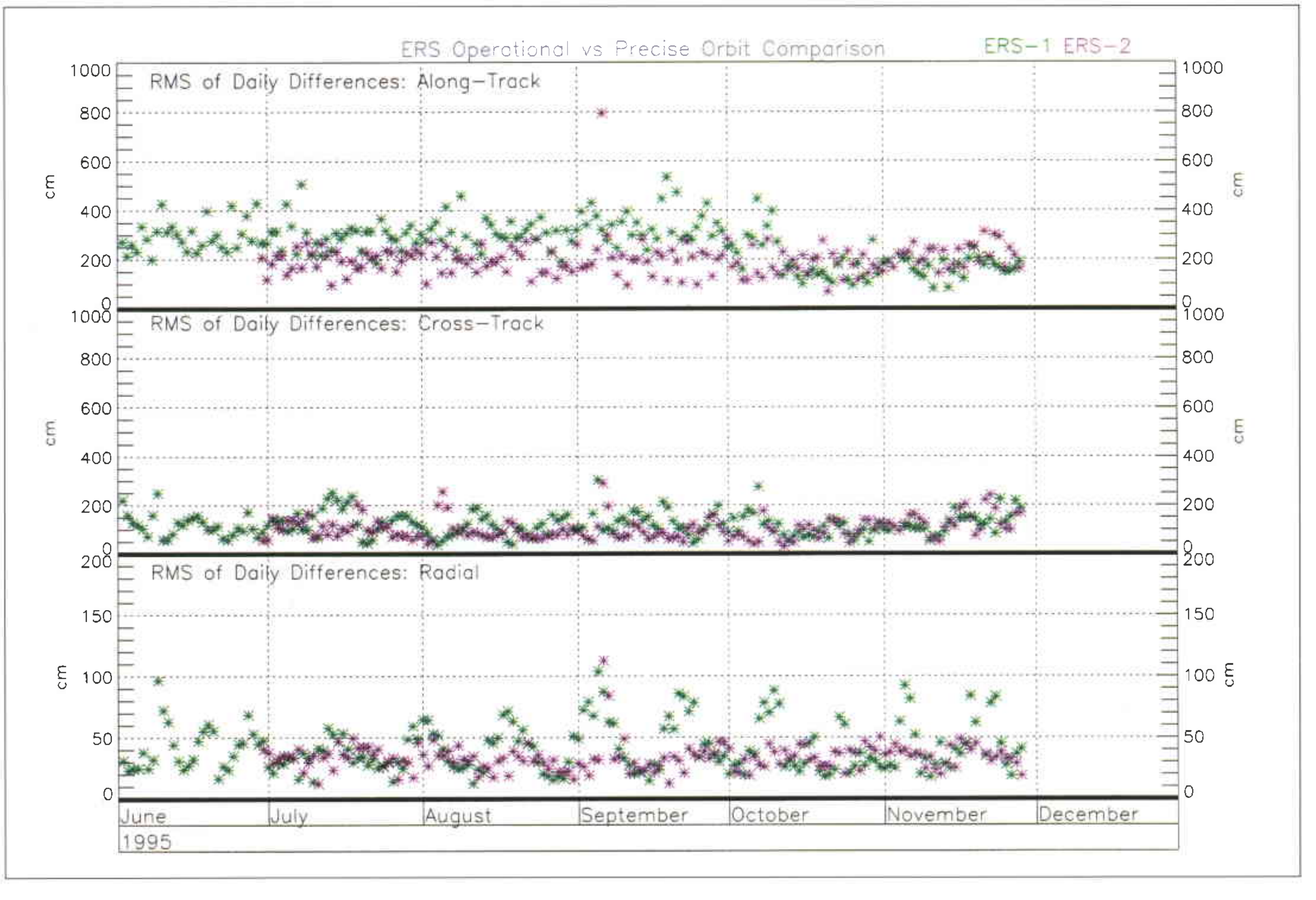


Figure 3. ERS operational versus precise orbit comparison

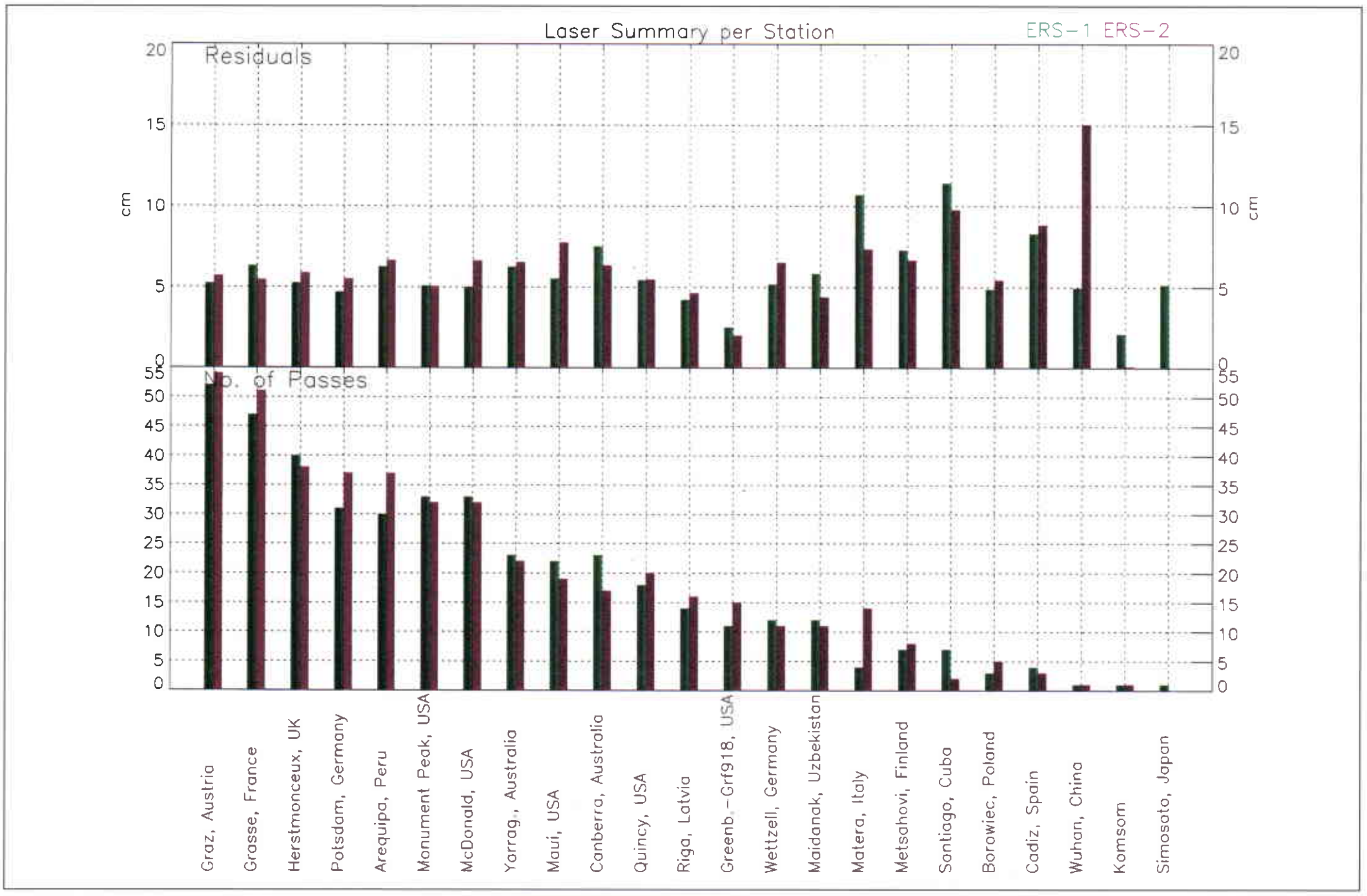


Figure 4a. Laser tracking of ERS during October 1995

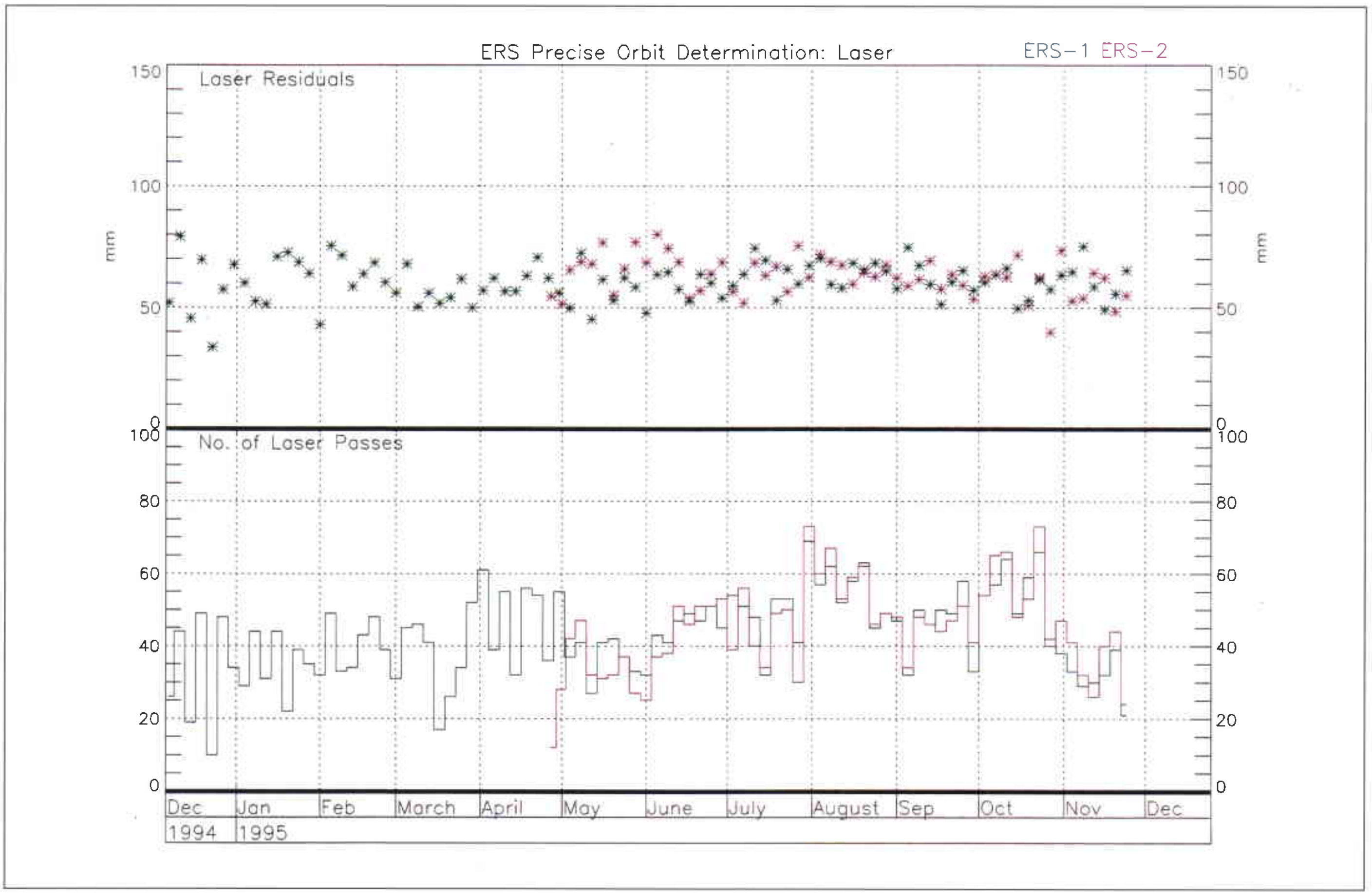


Figure 4b. ERS laser processing since December 1994

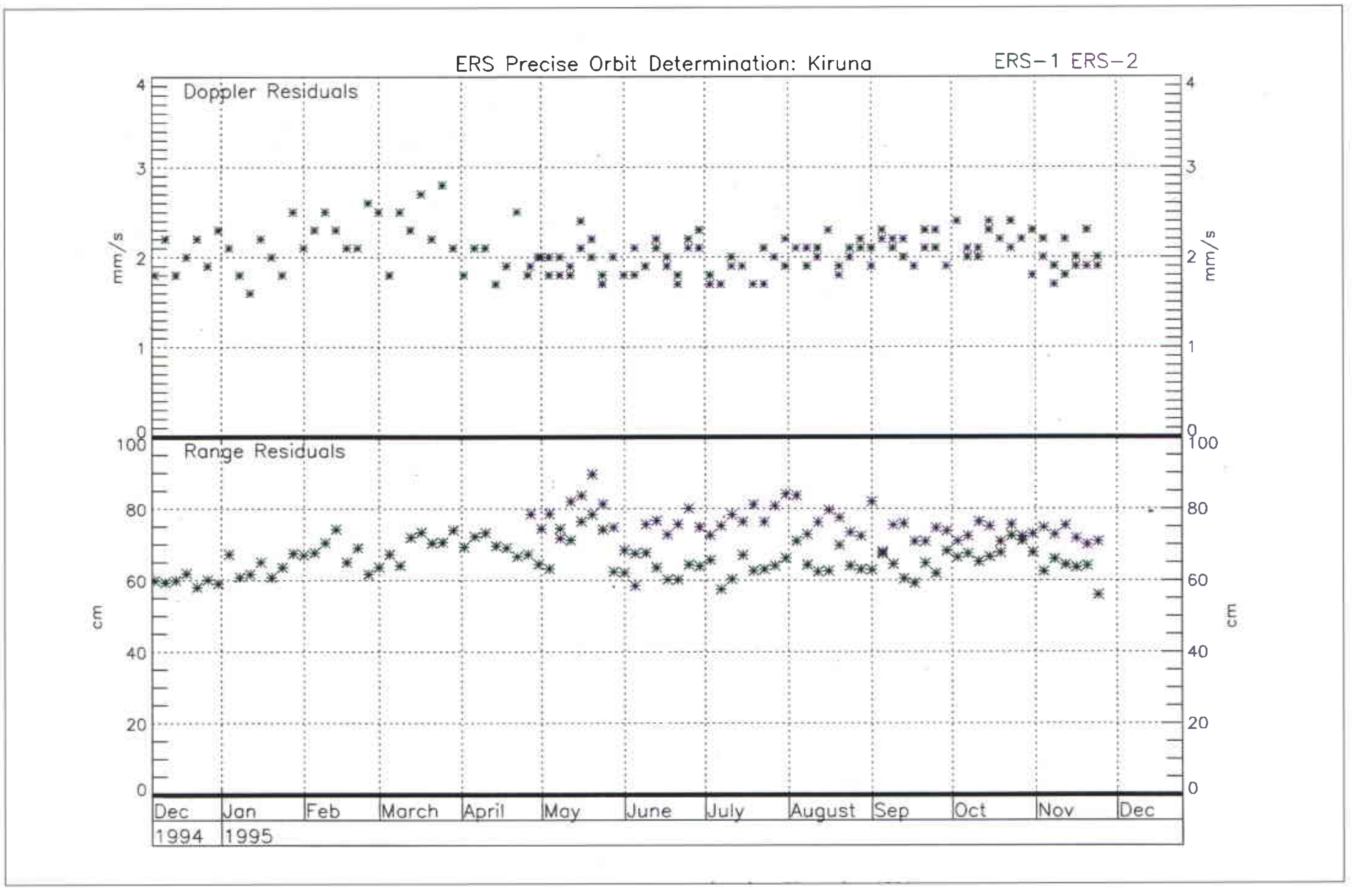


Figure 4c. Kiruna range and Doppler processing since December 1994

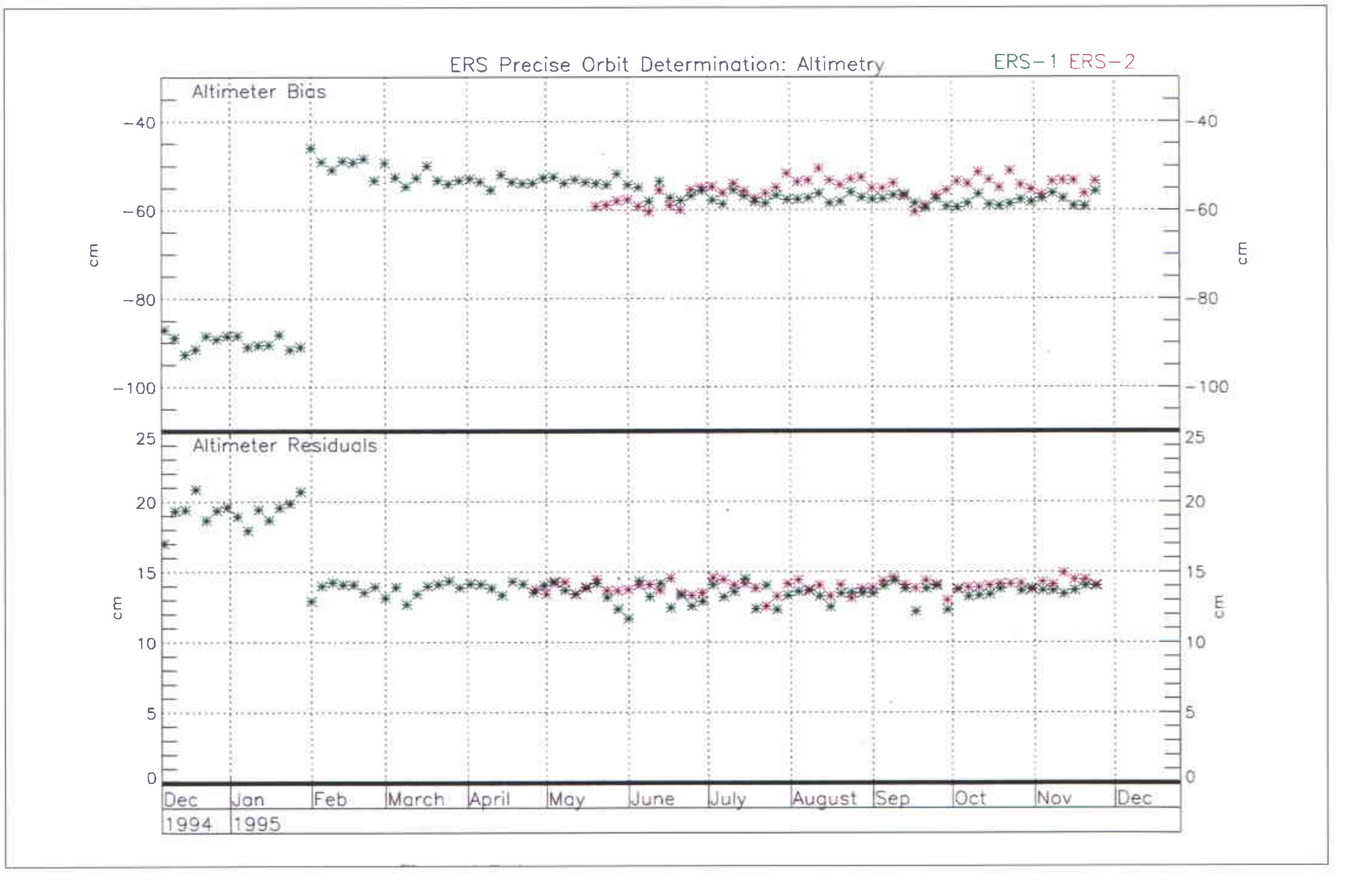


Figure 4d. ERS Altimeter processing since December 1994

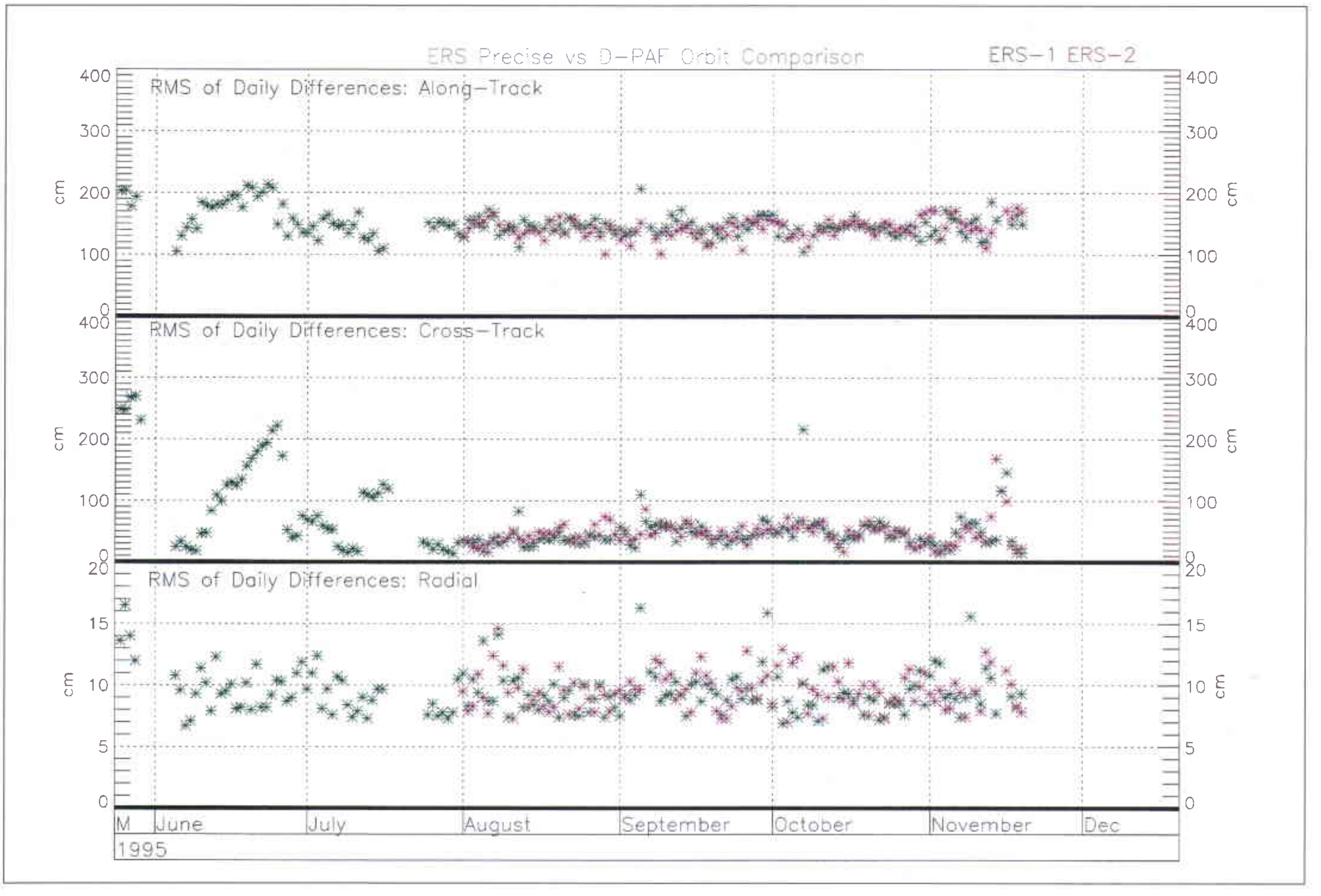


Figure 5. ERS precise orbit comparison (ESOC minus D-PAF)

to account for the geoid, tides, currents, etc. Once the orbit has been determined, the height of the satellite above a reference ellipsoid can be computed; the difference between that height and the corrected measurement is then the Altimeter bias.

Over the last few years, ERS-1 and Topex/Poseidon data have been used at ESOC to improve the corrections applied to altimeter measurements, and models for the following corrections have been developed: sea-surface topography (Fig. 6), mean sea surface (Fig. 7 highlights the differences between the new model and the OSU 91A model used previously), wet tropospheric correction, electromagnetic bias, and ocean tides. The combination of very precise orbits and very accurate corrections to the Altimeter measurements has allowed the relative calibration of the ERS-2 Altimeter's bias to be performed with an uncertainty of only about 2 cm.

The Fast Delivery (FD) data from the ERS Altimeter have been enhanced at ESOC. All necessary corrections are applied to the data as soon as they become available, typically within 24 hours. The fit of these enhanced FD data with the precise orbits computed at ESOC is within about 13 – 14 cm (Fig. 4d).

To estimate the relative Altimeter bias between ERS-2 and ERS-1, four different techniques have been considered:
- Global calibration
- Local calibration in the Mediterranean sea
- Global calibration, orbit solution
- Sea surface differences.

The use of four different techniques permits quantification of the error involved in the bias estimation. Errors in the corrections applied to the Altimeter data will affect all global methods in almost the same way, but can be expected to influence the local calibrations in a different manner. Therefore, the difference between the value computed from the global analysis and that computed from the local analysis provides an indication of any systematic errors introduced by the corrections.

A high degree of consistency has been found between the relative Altimeter bias values obtained with each of the techniques, as is apparent in Table 3. Figure 4d shows the Altimeter bias values found using the 'orbit solution' method. They are computed every four days with a typical delay of less than ten days.

A weighted fit between all the methods considered provides the final value of the bias, as well as the associated error which represents the combination of the non-systematic errors. This then has to be combined with the estimate for the systematic error, derived from a set of local calibrations. The relative Altimeter bias has been solved for in 30° x 30° regions. The systematic error's contribution will be different in each region, and the standard deviation will therefore provide an upper limit for the total remaining or systematic error.

The final value of the relative bias determined by these methods is then 1.02 $\pm$ 2.18 cm. This uncertainty value can be considered pessimistic because there is quite a large uncertainty associated with each 30°x30° Altimeter bias determination which is not really due to the systematic error contribution.

Conclusion

The stringent requirements set for maintaining the tandem ERS-1 and ERS-2 mission configuration are being met, except for some brief excursions around inclination corrections. Both the 'operational' and 'precise' orbit determinations for the two spacecraft are being performed with a high degree of accuracy and autonomy at ESOC. The operational solutions, based on S-band tracking from the Kiruna station and fast-delivery altimetry, have typical accuracies of 2 m overall and 30 – 50 cm radially, with a delivery delay of just one day. Precise orbit determination, relying additionally on quick-look laser data, is available after about 10 days (time lapse needed to guarantee the acquisition of sufficient laser data), and provides a radial orbit accuracy of 5 – 8 cm.

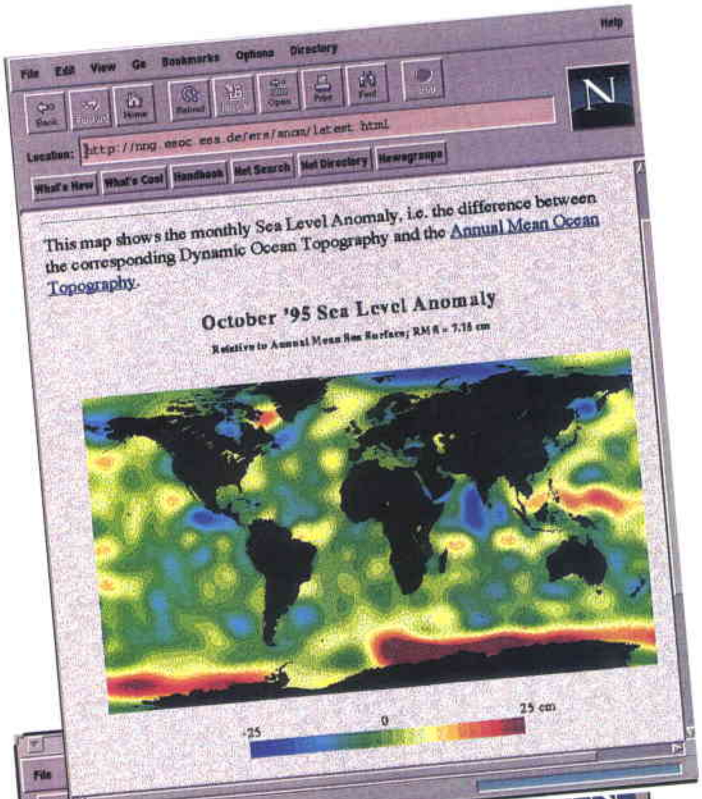
One of the major advantages of the tandem orbit configuration during the Commissioning Phase was the possibility to cross-calibrate the Radar Altimeters on ERS-1 and ERS-2 without the need for a dedicated field campaign of the sort conducted for ERS-1. Several groups have shown that both Altimeters have essentially the same measurement bias, within the approximately 2 cm uncertainty of the estimation.

The latest status of the ERS orbits and their evaluation (Figs. 6 & 7) by ESOC is available via our Home Page on the World Wide Web:

http://nng.esoc.esa.de

Table 3. ERS-2 Altimeter bias calibration, relative to ERS-1

Method	Relative bias (cm)	Sigma (cm)
Global solution	1.20	$\pm$1.90
Mediterranean solution	0.30	$\pm$3.30
Orbit solution	1.40	$\pm$2.00
Sea-surface differences	0.90	$\pm$1.20



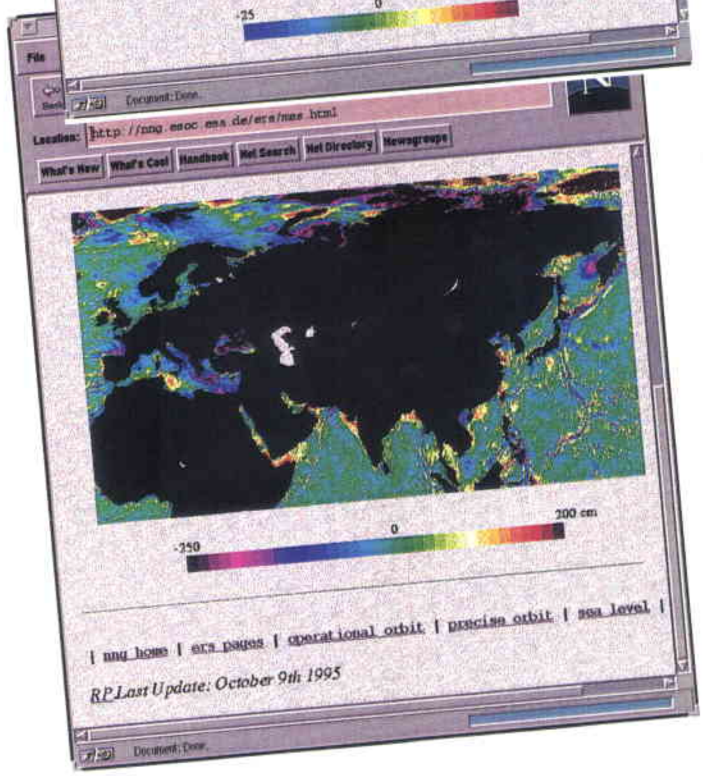
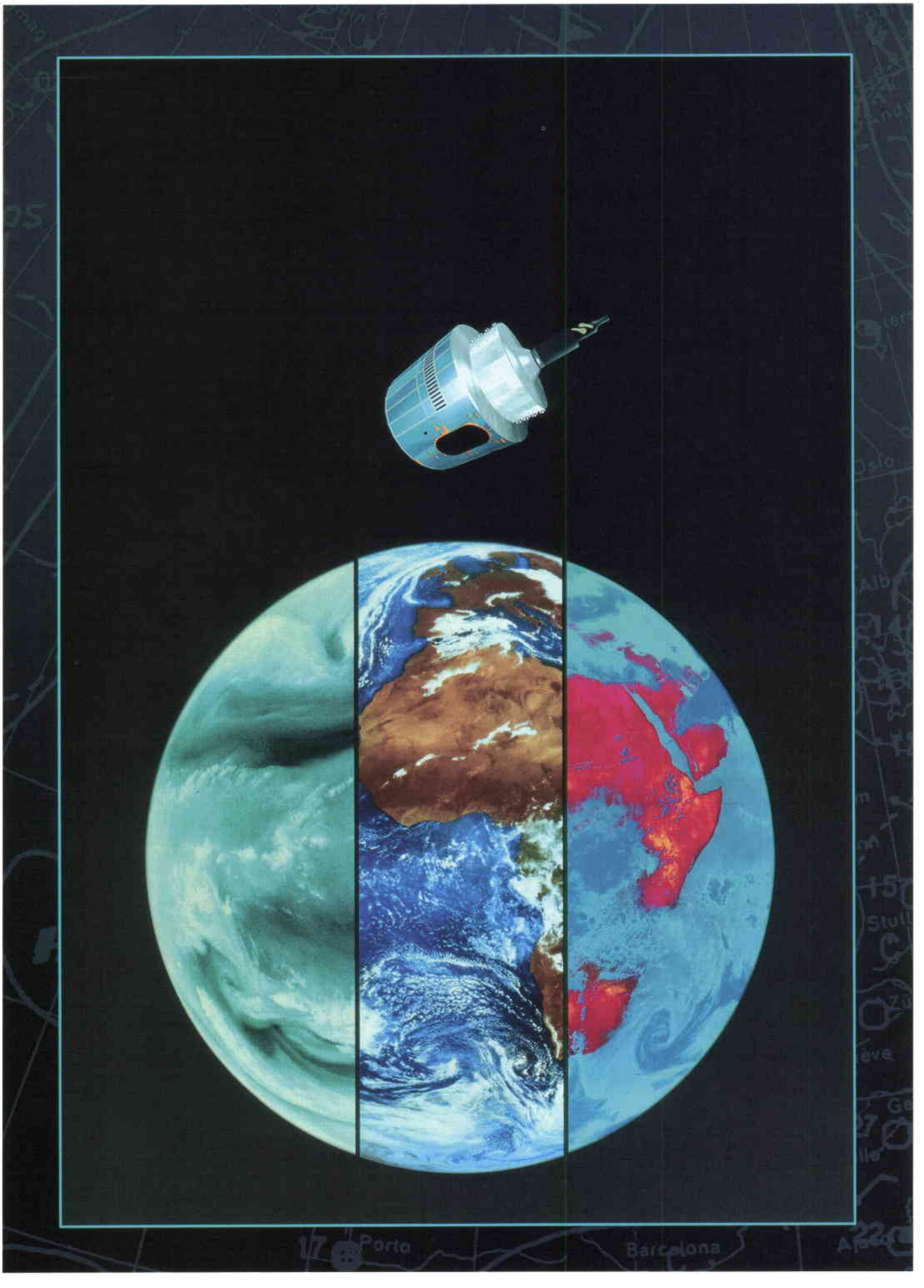


Figure 6. October 1995 sea-level anomaly from ERS altimetry

Figure 7. Preliminary mean sea surface from ERS-1 geodetic phase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Météosat – un programme d'actualité

G. Ferrand
Département Projets Observation de la Terre, Division Météosat,
ESTEC, Noordwijk, Pays-Bas

Comment rester pendant 18 ans le programme spatial européen le plus connu, non seulement des spécialistes mais aussi du grand public? Rester à l'écoute des utilisateurs, perfectionner l'outil de production et améliorer le service, ces trois recettes de marketing qui ont fait leurs preuves dans le secteur privé ont été appliquées avec succès au programme Météosat.

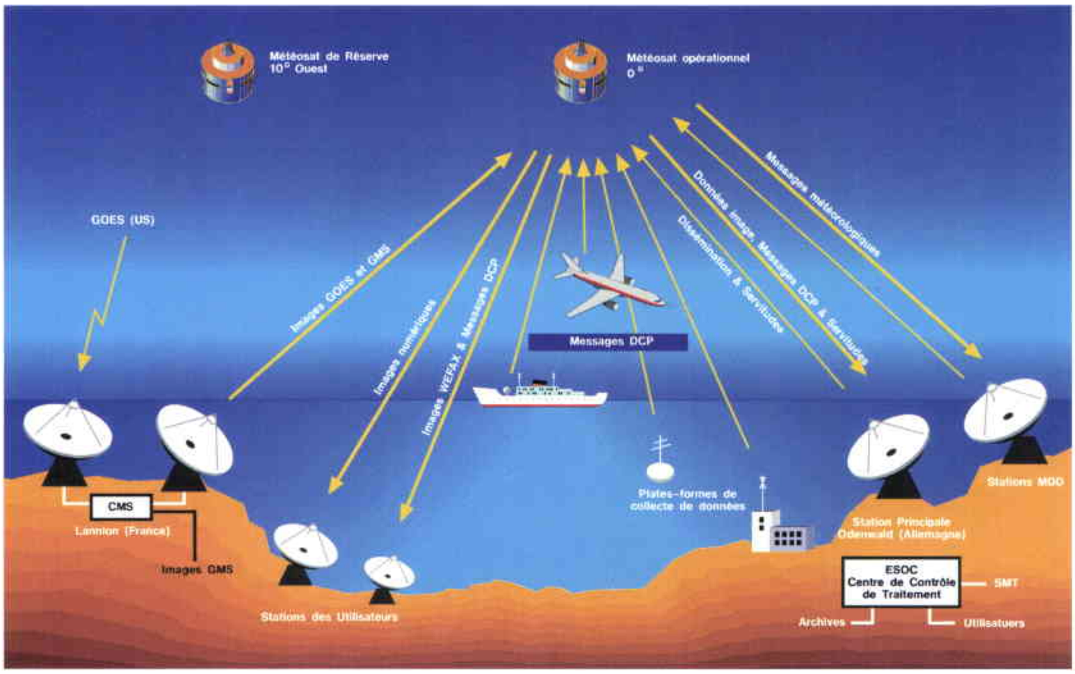
Le système Météosat est un système autonome et indépendant, conçu pour les météorologues. Un satellite géostationaire, stabilisé par rotation à 100 tours/minute, est équipé d'un radiomètre qui prend des images de la Terre toutes les demi-heures. Le satellite embarque également une charge utile de télécommunications pour la transmission des données image à la station sol principale, la diffusion des images traitées aux utilisateurs et la collecte de données. En plus de la station principale située dans l'Odenwald en Allemagne, les installations au sol comprennent essentiellement le centre de contrôle des opérations et le centre de traitement des données, tous deux à l'ESOC. Une station complémentaire pour la mesure de distance est installée à Kourou en Guyane française. Ce système permet l'observation de la Terre et de sa couverture nuageuse, le traitement des images pour en extraire les informations météorologiques, la diffusion d'images et la collecte de données sur l'environnement.

Dialogue avec les utilisateurs

L'expérience acquise sur la série des satellites Météosat et le dialogue continuel avec les utilisateurs ont permis d'affiner les missions du système Météosat au cours des années.

La prise d'image, mission essentielle

A l'origine, il était prévu d'observer la Terre et sa couverture nuageuse dans le spectre visible (0,4 – 1,1 μm) et dans le spectre infrarouge thermique (10,5 – 12,5 μm). De cette manière, on disposait d'un jeu de deux images, l'une correspondant à ce que voit l'oeil humain et l'autre sensible à la température de la scène observée. Peu après l'approbation du programme, les météorologues ont demandé à disposer d'une image infrarouge supplémentaire correspondant à la bande

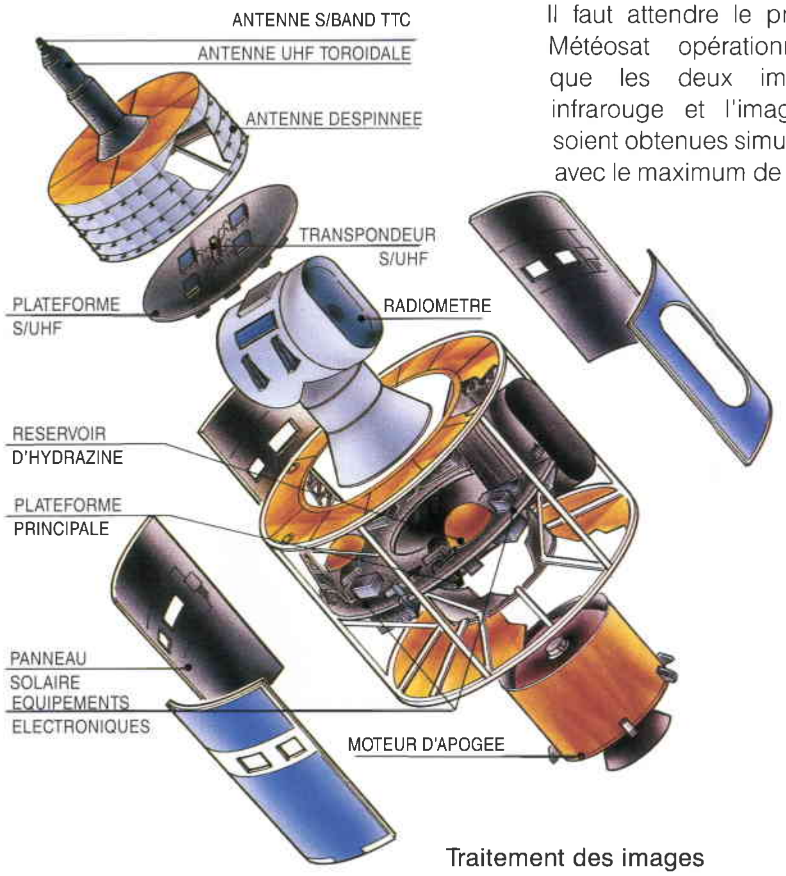


Le système Météosat

d'absorption de la vapeur d'eau (5,7 – 7,1 µm). Après des études de faisabilité concluantes, le radiomètre est modifié pour inclure le canal vapeur d'eau et fournir trois images.

L'image visible, la plus détaillée, consiste en une mosaïque de 5000 points par 5000 lignes. Les images en infrarouge thermique et vapeur d'eau comprennent chacune 2500 points par 2500 lignes. Cependant, lorsque le canal infrarouge vapeur d'eau est en fonctionnement, l'image visible est réduite de 5000 à 2500 lignes.

Il faut attendre le programme Météosat opérationnel pour que les deux images en infrarouge et l'image visible soient obtenues simultanément avec le maximum de définition.



Vue explosée du satellite

Traitement des images

Les images reçues du satellite par la station sol de l'Odenwald sont transmises à l'ESOC. Là, elles sont d'abord traitées pour corriger les déformations géométriques. En effet, le satellite n'est pas parfaitement géostationnaire, il ne tourne pas exactement à 100 tours à la minute et son axe de rotation n'est pas rigoureusement perpendiculaire au plan de l'équateur terrestre. Les données image sont ensuite calibrées pour prendre en compte le gain optique du radiomètre et la sensibilité des détecteurs. Après corrections géométriques et radiométriques, les images sont prêtes à la diffusion aux utilisateurs.

Les données images sont aussi traitées pour en extraire les paramètres météorologiques: champs de vents à différentes altitudes, températures de surface de la mer, cartes de la hauteur des sommets des nuages, cartes de distribution des nuages, cartes du contenu en vapeur d'eau de la haute troposphère et bilans radiatifs.

Diffusion des images

Images et informations météorologiques sous forme de cartes sont transmises aux utilisateurs de Météosat. Pour cela, la charge utile du satellite offre deux canaux de diffusion dont la couverture radioélectrique est quasi-hémisphérique (42% du globe terrestre).

Les images retransmises par la station de l'Odenwald en direction du satellite sont diffusées, soit en numérique à destination des services météorologiques, soit au standard WEFAX (Weather facsimile) pour une utilisation beaucoup plus large (560 utilisateurs étaient recensés en Europe et en Afrique dès 1983).

A la demande des utilisateurs, les images du satellite américain GOES-Est (70° Ouest), et du satellite japonais GMS (150° Est) sont également retransmises par le Centre de Météorologie Spatiale (CMS) installé à Lannion en France; l'ensemble des images retransmises couvrent les deux tiers du globe.

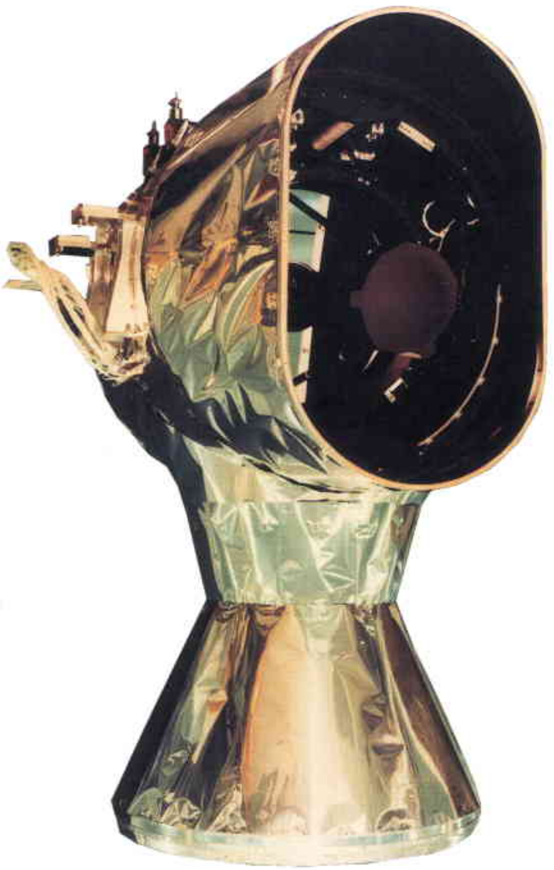
A partir d'octobre 1983, cette mission est étendue à la retransmission des messages météorologiques en provenance des plates-formes de collecte de données et toute station de réception WEFAX peut alors recevoir ces messages collectés et relayés par le satellite.

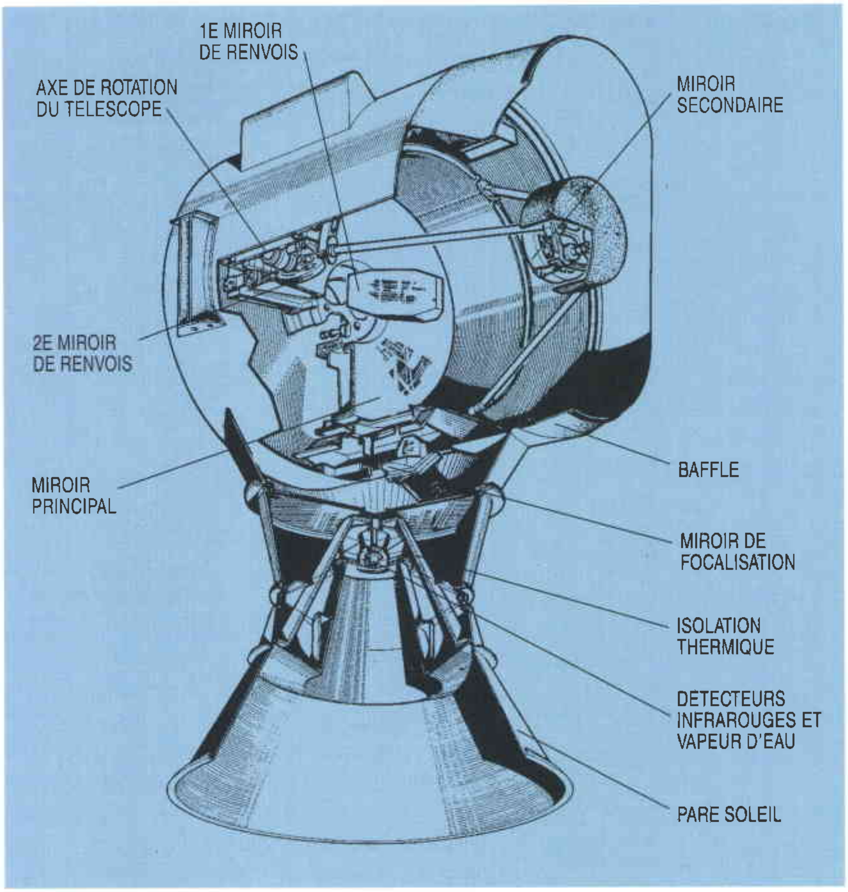
L'orbite géostationnaire est soumise à de multiples perturbations qui obligent à mesurer régulièrement la distance du satellite aux stations sol. Jusqu'en 1989, ces mesures utilisent les techniques classiques de modulation et mobilisent les deux canaux de diffusion huit fois par jour. Les nouvelles techniques, modulation à bande étalée et code pseudo-aléatoire, permettent d'effectuer les mesures de distance sans avoir à interrompre la mission de diffusion, sa disponibilité devient permanente, le gain obtenu est supérieur à une heure par jour.

En septembre 1995, à la demande d'Eumetsat, la nouvelle organisation chargée d'établir, maintenir et opérer les systèmes européens opérationnels de météorologie satellitaire, la diffusion des images numériques est partiellement encryptée.

Collecte des données

Les données d'environnement mesurées localement sont transmises automatiquement par des plates-formes de collecte de données





Vue du radiomètre

Vue explosée du radiomètre

(DCP) et relayées par le satellite. Après leur acquisition par la station de l'Odenwald et leur remise en forme par le centre de traitement installé à l'ESOC, elles sont envoyées aux utilisateurs par lignes téléphoniques, télex ou encore par courrier. Ces modes de distribution bien adaptés à l'environnement européen présentent de nombreuses déficiences pour certains utilisateurs non européens dont les moyens de télécommunications sont moins développés. L'introduction de la retransmission des messages météorologiques aux stations WEFAX, en 1983, remédie à cette situation.

Les plates-formes peuvent être soit fixes, soit mobiles. Les plates-formes fixes, situées à l'intérieur de la zone de couverture Météosat, assurent une couverture régionale; les mobiles, installées sur bateau, bouée, ballon stratosphérique ou avion, font appel au système international CGMS (Coordination of Geostationary Meteorological Satellites) comprenant les satellites américains GOES-Est et GOES-Ouest, japonais GMS et européen Météosat, assurent la couverture mondiale.

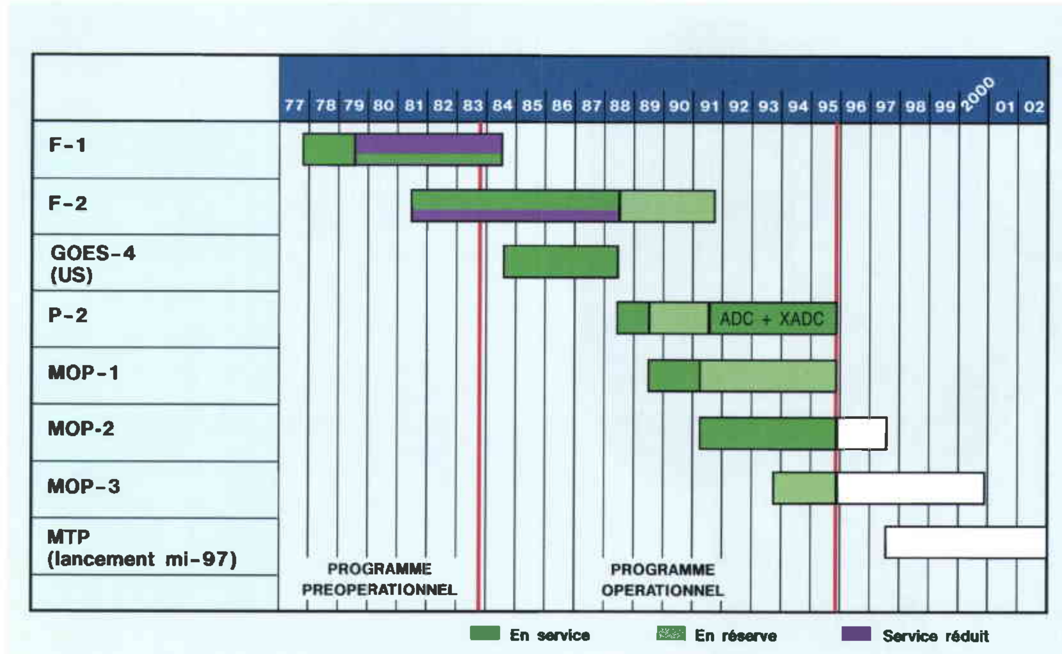
Les plates-formes les plus courantes transmettent leurs messages à heure fixe; d'autres, dites d'alerte, envoient un message d'alarme dès que certaines conditions d'environnement sont atteintes, sans attendre leur créneau horaire. D'autres encore peuvent être interrogées pour transmettre leurs messages à la demande, ces dernières furent rapidement abandonnées car trop chères.

La mission s'est donc développée autour des plates-formes à heure fixe. Aujourd'hui, près de 1100 plates-formes sont enregistrées auprès de Météosat.

Distribution des données météorologiques

L'Organisation Météorologique Mondiale dispose de son propre système de télécommunication, le SMT (Système Mondial de Télécommunications) qui relie tous les services météorologiques du monde entre eux. Une étude effectuée en 1983 révèle que ce système présente certaines lacunes et identifie les besoins de moyens complémentaires pour la distribution des données météorologiques (MDD) en Afrique.

Considérant la position privilégiée du satellite au-dessus du golfe de Guinée et les relations étroites entre les météorologues européens et africains, la mission du programme Météosat opérationnel est élargie pour fournir huit canaux réservés à la distribution des messages météorologiques. Actuellement, trois canaux sont utilisés par les services météorologiques de France, d'Italie et du Royaume-Uni pour distribuer leurs messages météorologiques à leurs homologues africains.



Planning

Archivage des images

Il ne faut pas oublier la source de données météorologiques et d'environnement que constitue les archives Météosat grâce aux images qui se sont accumulées au cours des années. Fin novembre 1995, plus d'un million d'images enregistrées sur bande magnétique et plus de 50 000 images sur film photographique sont disponibles.

Perfectionnement de l'outil de production

L'un des objectifs du programme préopérationnel est de vérifier la viabilité du satellite et son adéquation aux missions qui lui sont dévolues. En effet, Météosat est le premier satellite géostationnaire d'observation de la Terre construit par l'industrie européenne; les solutions techniques retenues pour sa réalisation demandent à être confirmées avant de s'engager dans un programme opérationnel.

Météosat F1, F2 et P2

Météosat F1 lancé le 23 novembre 1977 répond positivement à la question essentielle que l'on peut raisonnablement se poser, en fournissant sa première image seize jours plus tard, le 9 décembre. Cette performance demande cependant à être confirmée par le comportement à long terme du satellite.

Les performances du satellite en orbite sont donc analysées pour détecter les défauts patents aussi bien que les imperfections non décelables lors des essais au sol. De même, certaines faiblesses de conception sont mises en évidence lors de l'utilisation intensive du satellite. Corrections et améliorations sont étudiées et éventuellement introduites sur les modèles suivants.

Météosat F1 met en évidence l'impact du vent solaire sur les satellites géostationnaires, phénomène qui n'avait pas encore été étudié par les scientifiques européens. Les protections thermiques du satellite sont composées de couches de mylar aluminisé qui se chargent électrostatiquement sous l'effet du vent solaire. Lorsque les charges accumulées sont trop importantes, une décharge électrique se produit et les interférences électromagnétiques ainsi générées perturbent le bon fonctionnement du satellite. Leurs conséquences sont facilement corrigées par télécommande mais une ou deux images sont perdues et ce comportement n'est pas acceptable pour un système opérationnel. Les satellites suivants sont corrigés en conséquence: toutes les parties métalliques sont mises à la masse, le blindage du câblage est renforcé et les circuits électroniques sont modifiés pour les rendre tolérants aux perturbations électromagnétiques.

Sur Météosat F1, quelques lignes d'image sont systématiquement perdues à des instants bien précis. Cette anomalie, sans influence sur la valeur météorologique des images obtenues, est due à la coïncidence entre l'impulsion solaire qui pilote l'horloge interne et la phase du signal d'horloge reconstitué. Il est à noter qu'aucun essai effectué au sol n'avait permis de détecter cette perturbation qui dépend de la conjonction de plusieurs paramètres dont la position exacte du satellite sur son orbite. Les satellites suivants sont équipés d'un circuit d'anticoïncidence pour éviter la répétition de ce dysfonctionnement.

La panne de Météosat F1 qui réduit la mission du satellite à la collecte de données le

Lancement de Météosat-F1 en novembre 1977.

24 novembre 1979, soit deux ans et un jour après son lancement, est encore dans toutes les mémoires. Le disjoncteur électronique du circuit de puissance principal se met à osciller, ce qui rend vaine toute tentative pour le réenclencher. Tous les satellites ultérieurs sont équipés de sécurités supplémentaires destinées à court-circuiter chaque disjoncteur. Cette interruption prématurée de deux des trois missions ne remet pas en cause la conception du satellite dont la durée de vie spécifiée est de trois ans avec une probabilité de survie de 50%. Le satellite continue d'assurer la mission de collecte de données jusqu'à ce qu'il soit mis définitivement hors service en octobre 1984, soit après plus de 6 ans en orbite.

Météosat F1 est équipé d'une batterie qui fournit l'énergie électrique nécessaire pour traverser les éclipses lorsque les panneaux solaires du satellite sont dans l'obscurité. Une amélioration notable apportée aux satellites suivants est l'ajout d'une deuxième batterie qui permet de laisser sous tension tous les sous-systèmes pendant les éclipses et ainsi de reprendre plus rapidement la mission en sortie d'éclipse. De plus, cette deuxième batterie offre une marge de sécurité appréciable pour le contrôle thermique pendant les éclipses. Une autre amélioration est l'introduction d'un mode de charge lent pour maintenir les batteries normalement chargées sans l'intervention des opérateurs.

Alors que Météosat F1 est lancé par la fusée américaine Thor-Delta 2914, les satellites suivants sont mis en orbite par le lanceur européen Ariane. Ce changement nécessite le renforcement de la structure du satellite, l'abandon du moteur d'apogée américain Aérojet pour le moteur européen Mage et une nouvelle optimisation des tuyères du système de contrôle d'attitude.

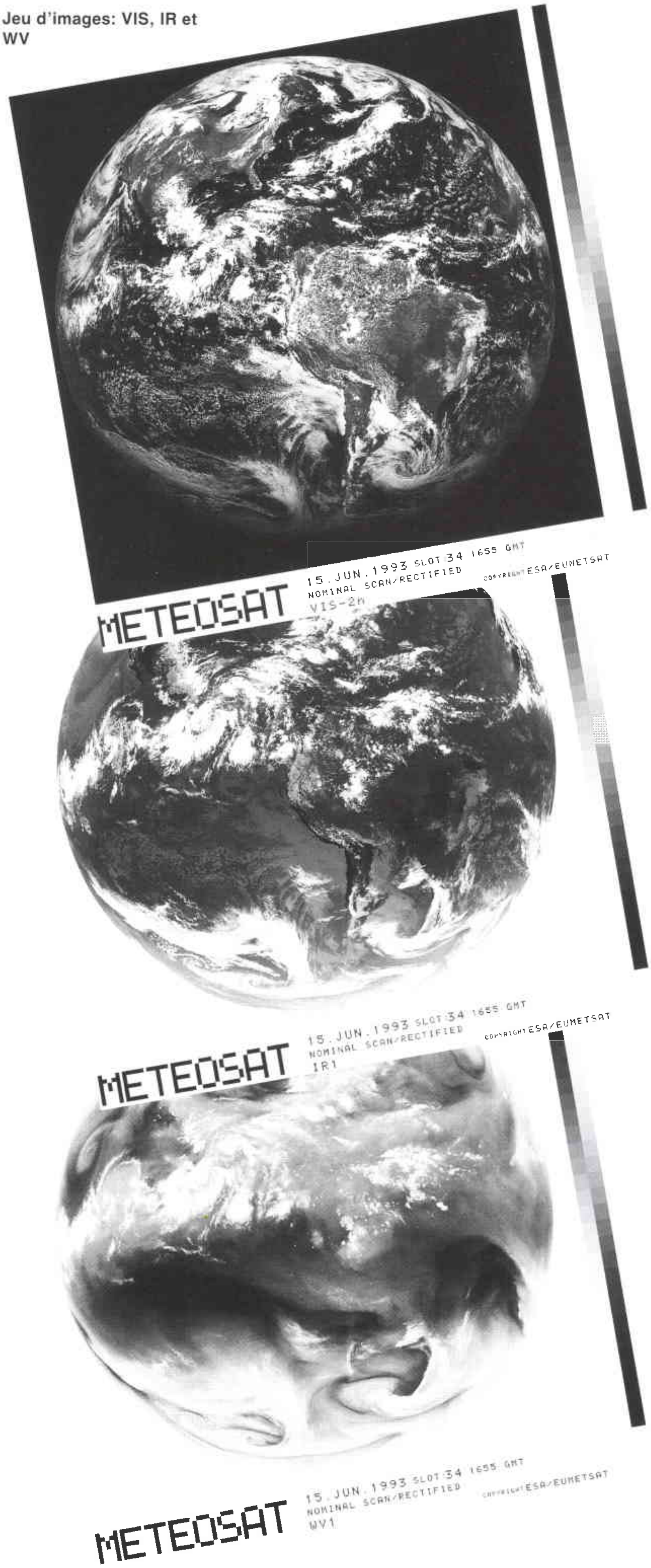
Pour étudier plus en détail le phénomène de décharges électrostatiques observé sur Météosat F1, deux expériences sont embarquées sur Météosat F2. L'une permet de mesurer le flux d'électrons et leur énergie dans la gamme de 50 eV à 20 keV, l'autre de surveiller le niveau du bruit radioélectrique et d'identifier les décharges électrostatiques.

Météosat F2, lancé en juin 1981, assure les missions de prise d'image et de diffusion pendant sept ans, jusqu'à la mise en service de Météosat P2 en juin 1988. La mission de collecte de données, défaillante sur ce satellite, est poursuivie par Météosat F1 et reprise plus tard par le satellite américain GOES-4. Météosat F2 est mis hors service et retiré de l'orbite géostationnaire en décembre 1991, soit plus de dix ans après son lancement.

Le satellite Météosat P2 ne bénéficie pas entièrement du programme d'amélioration puisque ce deuxième modèle de qualification a été intégré avant même le premier modèle de vol Météosat F1. Par contre, il embarque l'expérience LASSO qui permet la synchronisation d'horloges atomiques avec une précision meilleure que 10 nanosecondes.

Lancement de Météosat P2 (Ariane 401)

Jeu d'images: VIS, IR et WV



Son principe est la détection d'impulsions laser contrôlées par les dites horloges et la mesure du temps qui sépare les impulsions successives. Il embarque aussi une expérience (le premier modèle était monté sur Météosat F2) pour mesurer le flux d'électrons et leur énergie dans la gamme de 30 à 300 keV.

Météosat P2 est lancé le 15 juin 1988. Il assure la mission Météosat jusqu'au lancement de MOP-1, premier satellite du programme opérationnel, en 1989, puis est gardé comme satellite de réserve. En collaboration avec l'agence américaine NOAA (National Oceanic and Atmospheric Administration), il est déplacé en juin 1991 à 50° Ouest, puis pour pallier le manque d'un de leurs satellites GOES, est repositionné à 75° Ouest en janvier 1993. Les opérations correspondantes effectuées par l'ESOC sont connues sous les sigles de ADC (Atlantic Data Coverage) et XADC (Extended Atlantic Data Coverage). Il est finalement mis hors service et retiré de l'orbite géostationnaire en novembre 1995, à la fin du programme Météosat opérationnel.

MOP-1, MOP-2 et MOP-3

L'avènement du Programme Météosat opérationnel apporte des modifications importantes pour améliorer la qualité des images et permettre la mission de distribution de données météorologiques.

Une qualité essentielle d'un service opérationnel étant sa disponibilité, la redondance du radiomètre est augmentée: quatre détecteurs visibles au lieu de deux, deux détecteurs vapeur d'eau au lieu d'un seul et les électroniques des chaînes images ainsi que celles qui commandent le balayage sont doublées.

L'amélioration des données images porte sur les trois types de résolution: spatiale, temporelle et radiométrique. L'image visible est toujours à résolution maximum, l'image vapeur d'eau est disponible en permanence et les données des images visibles et vapeur d'eau sont codées sur 256 niveaux de gris au lieu de 64. Ces modifications nécessitent en outre le doublement de la cadence numérique des données image.

Pour profiter au maximum de l'amélioration des images, le contrôle des interférences électromagnétiques devient plus sévère.

Le système de calibration comprend maintenant deux corps noirs pour obtenir une calibration vraie, plutôt que relative, y compris en cas de pollution sévère de l'optique froide.

La mission MDD conduit à introduire un troisième canal de diffusion qui est obtenu par le partage d'un des deux canaux originels.

Pour permettre le maintien en orbite de plusieurs satellites et leurs opérations, chaque satellite utilise des fréquences différentes pour ses liaisons de servitude. Par contre, pour assurer la transparence vis-à-vis des utilisateurs chaque liaison de mission ne doit avoir qu'une seule fréquence, et pour éviter tout risque d'interférences chaque liaison peut maintenant être mise en marche ou arrêtée à la demande.

MOP-1 est lancé le 6 mars 1989. Suite à certaines difficultés observées pour synchroniser l'ensemble des convertisseurs de tension du système d'alimentation, un relais est rajouté sur les satellites suivants. Il permet de sélectionner le mode de fonctionnement, synchronisé ou non, des alimentations qui est optimum pour la qualité des images. En 1992, après la mise en service de MOP-2, MOP-1 devient satellite de réserve puis est mis hors service et retiré de l'orbite géostationnaire à la fin du programme Météosat opérationnel en novembre 1995.

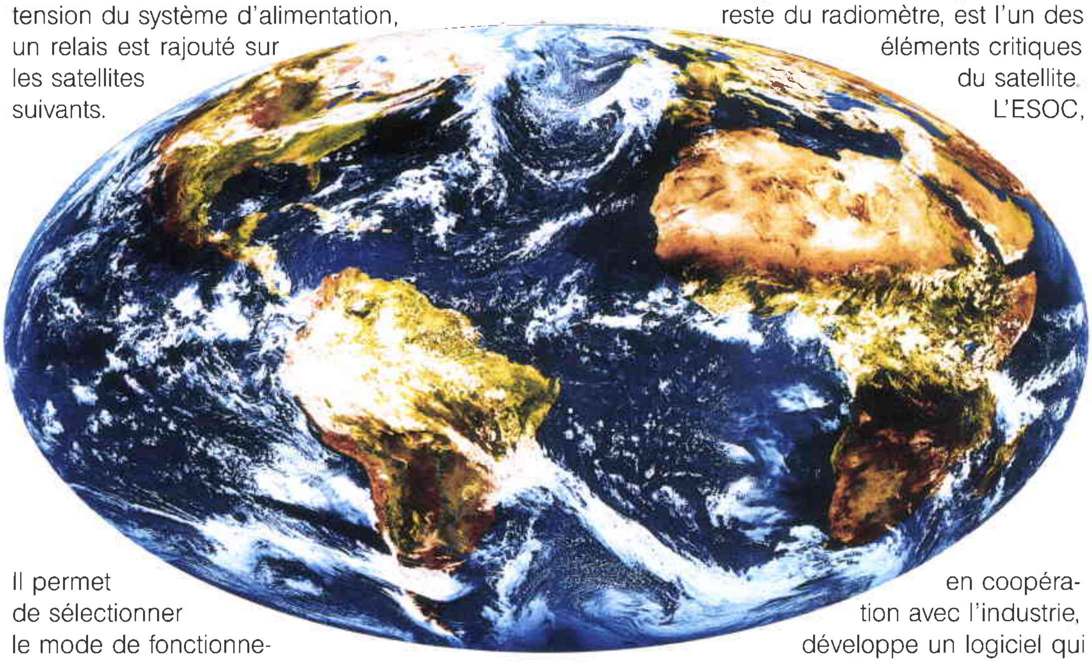


Image composite: MOP-2 et ADC

On observe sur MOP-2, lancé le 2 mars 1991, une déformation géométrique variable des images infrarouges et vapeur d'eau. La recherche de l'origine de ce défaut oblige à développer de nouveaux algorithmes dont la précision est le centième de pixel (élément d'image); à titre de comparaison le traitement de l'image se fait alors avec une précision de l'ordre d'un tiers de pixel. L'anomalie est due aux microvibrations induites par le mécanisme de balayage du radiomètre qui font tourner l'une des trois lentilles du bloc optique. Le mode de fixation des lentilles par sertissage, procédé classique en optique, est alors remis en cause, bien qu'il ait fait ses preuves sur les quatre satellites précédents. En parallèle, l'ESOC développe et met en oeuvre un logiciel qui corrige les effets de l'anomalie. Fin novembre 1995, MOP-2 est toujours le satellite principal qui assure la mission Météosat, sa fin de vie nominale est actuellement prévue pour avril 1997, soit après plus de six ans en orbite.

On vérifie que le sertissage des lentilles du radiomètre est satisfaisant sur MOP-3 (lancé le 20 novembre 1993). Les images infrarouges et vapeur d'eau sont géométriquement correctes mais présentent une instabilité radiométrique. L'analyse de l'anomalie qui a duré presque deux ans conclut à la rupture de la suspension du bloc optique refroidi. Cette suspension, réalisée en fibres de verre pour assurer l'isolation thermique entre le bloc optique et le reste du radiomètre, est l'un des éléments critiques du satellite. L'ESOC, en coopération avec l'industrie, développe un logiciel qui compense les effets de l'anomalie. MOP-3 est considéré comme satellite de réserve, sa fin de vie nominale est actuellement prévue pour mars 2001, plus de sept ans après son lancement.

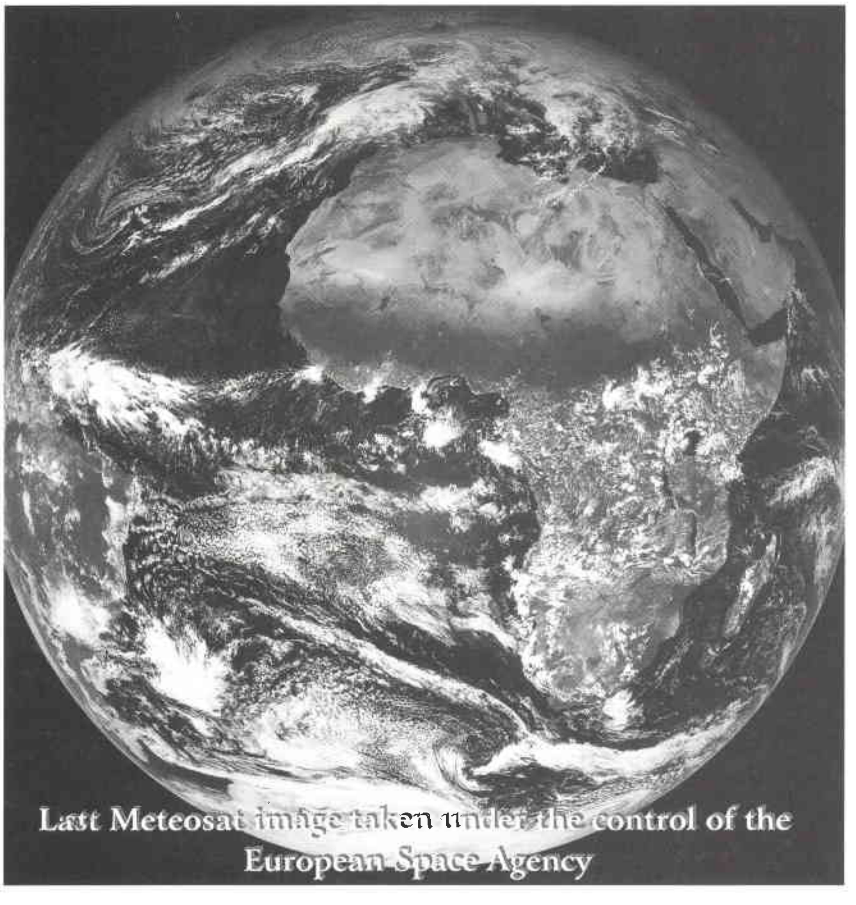
Programme de transition Météosat (MTP)

MTP, réplique des satellites de la série MOP, bénéficie de lentilles serties et collées pour éviter l'anomalie de MOP-2; en outre, les procédures de fabrication des brins de suspension du bloc optique refroidi sont revues et leurs critères d'acceptabilité sont modifiés pour éviter la répétition de l'anomalie de MOP-3. Ce satellite doit être lancé mi-1997.

Amélioration du service

Finalement, l'ESOC chargé des opérations et de l'extraction des paramètres météorologiques est en fin de chaîne en contact permanent avec les utilisateurs et à ce titre responsable du service rendu. Au cours des années Météosat, il a toujours su réagir en temps réel pour maintenir les missions. Il a adapté ses moyens de contrôle au nombre et type de satellites en orbite, perfectionné sans cesse ses moyens de calcul ainsi que l'expertise de son personnel pour fournir régulièrement les paramètres météorologiques en quantité et qualité croissantes et ce malgré les particularités propres à chaque satellite.

Il n'est malheureusement pas possible dans cet article de décrire de manière exhaustive tout ce travail d'améliorations effectué par l'ESOC. Seulement trois exemples sont rapportés ci-dessous pour en illustrer la compétence et le professionnalisme.



Dernière image reçue par l'ESA

La station de l'Odenwald est équipée originellement d'une antenne de 15 m pour contrôler le satellite Météosat F1. Après le lancement de Météosat F2 en juin 1981, quand il est clair que ce nouveau satellite ne peut pas supporter la mission de collecte de données, une nouvelle antenne de réception, de 10 m, est installée en quelques mois, elle permet de poursuivre la mission de collecte de données grâce à Météosat F1. Plus tard, quand ce satellite qui ne peut plus être maintenu à poste est définitivement retiré du service, en octobre 1984, cette antenne est adaptée pour recevoir les messages de collectes de données via le satellite américain GOES-4 prêté à l'ESA par la NOAA.

En préparation à la mission ADC, une nouvelle antenne de 13,5 m est installée début 1991. A partir de ce moment, l'ESOC avec trois antennes peut assurer la mission Météosat sur l'Europe, opérer un deuxième satellite au-dessus de l'Atlantique et maintenir jusqu'à deux satellites supplémentaires en réserve.

Le traitement des données images devient subitement inadéquat lorsque l'anomalie du satellite MOP-2 est détectée. L'ESOC en collaboration avec l'industrie, développe un nouveau logiciel opérationnel qui corrige les effets de la rotation de la lentille, ses performances sont telles que les images MOP-2 ainsi traitées sont de meilleure qualité que les images des satellites précédents traitées avec l'ancien logiciel. Paradoxalement, on peut dire que cette anomalie se traduit par l'amélioration de la qualité géométrique de l'image.

L'anomalie de MOP-3 oblige de nouveau l'ESOC à faire développer un nouveau logiciel qui compense les variations radiométriques des images infrarouges et vapeur d'eau; les images ainsi corrigées permettent l'extraction des paramètres météorologiques avec une qualité comparable à ceux extraits des images des autres satellites. De même que l'anomalie de MOP-2 a conduit à de meilleures images, on s'attend à des retombées bénéfiques de l'anomalie de MOP-3 pour la calibration des images infrarouges et vapeur d'eau.

Dix-huit ans après le lancement du premier satellite, le programme Météosat opérationnel s'achève

Souhaitons à Eumetsat, qui reprend le contrôle et l'exploitation des satellites, le même succès que l'ESA qui a su défricher et faire fructifier, au profit des utilisateurs, les capacités des satellites.

Que MTP, le prochain et dernier satellite de la série Météosat, en soit le premier par le mérite et fournisse les bons et loyaux services auxquels nous sommes habitués.

Enfin, que les prochains satellites Météosat Seconde Génération, en cours de développement, soient les dignes successeurs des satellites actuels et perpétuent le succès de la famille Météosat.

The Second Parabolic Flight Campaign for Students

W.J. Ockels
Automation and Informatics Department, ESTEC, Noordwijk, The Netherlands, and Faculty of Aerospace Technology, Delft University of Technology, The Netherlands

In conjunction with the European Commission's 'European Week for Scientific and Technological Culture' in November, ESA organised the second parabolic flight campaign for students. Students selected through a competition, were again given the unique opportunity of experiencing weightlessness as they performed their own scientific experiment during a parabolic flight. The experiments covered a wide variety of disciplines. Some illustrated well the effect of microgravity while others may offer new and far-reaching scientific results.

The primary goal, however, is to educate and motivate the students rather than to obtain new research. It is hoped that the campaign will stimulate the next generation to think about space and the potential of microgravity. It is in that way that an innovative future user community for the International Space Station Alpha can be built. The great enthusiasm shown by many students and the wide coverage provided by the media also demonstrate the interest in space and the promotional value of the campaign.

Introduction

Although it is always important that the next generations are well aware of the opportunities that space offers, it is now of the utmost importance. Europe is entering into the era of the International Space Station, a long-term programme extending well into the next millenium, and ESA will also begin implementing its outreaching vision defined by the Long-Term Space Policy Committee, which expresses the need for innovation and new technologies. Today's young people will be the ones who eventually take over and become responsible for implementing much of today's plans. Action is therefore required now to ensure that they are made interested in space-specific technologies early enough and are aware of the unique potential for research that the Space Station will offer. Only by giving young people the opportunities now, will innovative R&D in Europe be guaranteed for the future.

One aspect of that, to give students the opportunity to develop an understanding of weightlessness and how it can be used aboard the Space Station, is already being addressed: ESA has now organised two parabolic flight campaigns dedicated to students and their experiments. The first one was held in 1994 and the second one in 1995. Attempts are now being made to make it an annual activity.

The Aerospace Students Association of the Delft University of Technology (NL) first proposed the idea to hold a parabolic flight campaign for students. ESA accepted to organise such a campaign. The participants are selected through a competition based on their proposal for an experiment that can be carried out in 25 seconds of zero gravity, including the experiment's originality, its demonstration value for microgravity research and its educational value. They are then invited to carry out their experiment aboard a special parabolic flight. This year's competition was launched in March with a deadline for submissions in June. An international jury, under the author's chairmanship, selected 23 experiments covering a wide variety of disciplines (Table 1). The 55 students chosen represented 11 countries (Table 2).

The campaign was held in the week of 20 – 24 November as part of the European Commission's 'European Week for Scientific and Technological Culture'. The time remaining for the selected students to prepare their experiments was extremely short, much shorter than is normally given for the preparation for a professional experiment. In spite of the tight deadline, all experiments were ready on time.

Preparing for the campaign

The student campaigns are set up like regular ESA parabolic flight campaigns although they must take place in Europe, in keeping with the philosophy of the European Week for Scientific andTechnological Culture. The 1994 campaign was performed from the CEV base in Brétigny, south of Paris, with CNES's 0-g Caravelle aircraft. This year's campaign was held at the Valkenburg Naval Air Station in The Netherlands. NASA's KC-135 aircraft was

Table 1. Experiments performed

Scientific field	Experiment and experimenter	Reference
General physics	Convection of vibrated granular material under the influence of microgravity Volkhard Buchholtz & Jan Freund (Technical University of Berlin)	G-12
	Three-dimensional visibility of a magnetic field Lutz Kunath (Technical University of Berlin)	G-19
	Orbital simulation model Zaky El Hamel & Paolo Sabatini (University of Milan)	I-3
	Modes of vibration and control of bobbing on a tethered system Danielle Innorta & Luca Soli (University of Milan)	I-4
	Wave-movements in a free-hanging rope without gravitational force Evert-Jan de Theije, Femke de Theije & Koen Koustaal (Universities of Nijmegen and Eindhoven, The Netherlands)	NL-4
	Visual gravity by measurements experiments, & Space table Bjorn Ottar Elseth, Laurent Van Ham (Delft University, The Netherlands)	N-1/3
	Synchronous picosecond sonoluminescence Thomas J. Matula (University of Washington, Seattle, USA)	US-1
Fluid Physics	Capillary effects in two-phase flow in porous media for enhanced oil recovery and contaminant in soil transport modelling Nicolas Boseret & Eric Istasse (University of Brussels)	B-2
	Capillary waves without the disturbing effects of gravity Tamim Sidiki & Christian Berg (Bergische University of Wuppertal, Germany)	G-7
	Experimental confirmation of thermo-vibrational convection in a fluid cell Achille Cicalla & Massimo Piccirillo (University of Naples)	I-6
	Study of a liquid mirror under microgravity Alexandre Cuva (University of Geneva)	CH-1
	Thin liquid film experiment Thomas Gribovszki & Raghuram Tumkur (Utah State University and Mullard Space Science Laboratory, Surrey, UK)	UK-6
Combustion	Diffusion flames in hyper- and microgravity Ahmed Abatorab & Piotr Podobinski (Warsaw University)	P-1
Material processing	Solidification of hypermonotectic Al-Pb-Bi alloys in aerogel crucibles Gudrun Korekt & Stefan Hofacker (Cologne University, Germany)	G-18
	Fabrication of a metal matrix composite in microgravity Jason Maroothynaden (Imperial College London)	UK-4
Crystals and glass	Structural relaxation in microgravity Christophe Le Deit & Benedicte Friot (University of Rennes, France)	F-3
	Behaviour of a heap of marbles in microgravity Olivier Savin, Guillaume Faure (ENSAE Toulouse, France)	F-1
Optics	Focussed by air: large air lenses Manuel Reiter & Robert Holzer (Linz University, Austria)	AU-1
Biology	Microgravity as a release of nastic reactions explored on the example of rapid leaf movements by *Mimosa pudica* Wolfgang Neumann (Munster University and Bonn University, Germany)	G-22
	Investigation into the behaviour of invertebrates in microgravity F.J. Bell (Guildford Grammar School, UK)	UK-2
Technology	Welding in microgravity Thomas Kluge & Oliver Kropla (Technische Hochschule Aachen, Germany)	G-9
	Test of the Rapunzel deployer and the Star Track project Michiel Kruijff, Eric-Jan van der Heide, Dieter Sabath & Manfred Krischke (Delft University, The Netherlands, and Munich University, Germany)	NL-6
	Artificial cat Roland Vissers, Quirien Wijnands, Bastiaan Willemse, Jeroen Deweerd & Robin Biesbroek (VSV, Delft University)	NL-7

used; it was ferried from Houston because the Caravelle is no longer available. It was the first time that the NASA plane had made parabolic flights abroad. The company Novespace which had made the arrangements for the Caravelle was responsible for the arrangements for the KC-135 with NASA.

The company Orbitics had been contracted to oversee the accommodation of the experiments on the aircraft and their safety. They visited each experiment development site to inspect the experiment and to advise where necessary. The student teams managed, with strong enthusiasm and professionalism, to get their experiments ready in time while satisfying the safety regulations. Each of the students, who ranged from 17 to 31 years of age, also had to undergo medical examinations and physiological testing before they could be accepted for flight.

The flight week

The campaign took place during the week of 20 – 24 November 1995. The students, some with additional 'ground support' in the form of family and friends, gathered in a hangar at the air base to ready their experiments for flight.

Before the actual flight programme started, a safety review was held and extensive flight briefings were given to address the emergency procedures. Participants were given optional medication against motion sickness.

Table 2. Geographic distribution of the experiments performed — 11 countries were represented

Austria	1
Belgium	1
France	2
Germany	6
Italy	3
Netherlands	3
Norway	1
Poland	1
Switzerland	1
United Kingdom	3
USA	1

On each of the five days of the campaign, the NASA KC-135 conducted a two-hour flight, which provided at least 30 parabolas. Up to 15 students flew on each flight along with the campaign manager, a medical doctor, two photographers and up to four journalists. The NASA crew was very experienced and efficient.

The various experiments were accommodated on the different flights in such a way that each experiment could fly twice if necessary. If an experiment encountered problems during its first flight, it could be improved and flown again on a second flight. In that way, all experiments had a fair chance and each of the 55 students could experience at least one flight.

The more than 100 participants in the second parabolic flight campaign for students, in front of NASA's KC-135 which is specially-equipped for parabolic flights

Students working during a parabolic flight

The payload had to be reconfigured after each flight. The students did not spare their efforts and energy to work until late to be ready for the flight the next day. A very strong team spirit evolved, not least due to the fact that the day's video footage was shown and discussed each evening.

The students proved to be an excellent work force. During the flights, about a quarter of them became sick (which is typical for first-time flyers), but that did not hinder them from performing their experiments enthusiastically. All students were greatly impressed by the effect and the experience of weightlessness. Such an experience cannot be fully anticipated. They became aware of a new environment and started to think differently about what microgravity is and how it can be used.

There was much media interest in the campaign. More than 30 journalists from TV, radio and the printed press, from 10 European countries, visited the base to cover the campaign. Some 19 journalists also participated in the flights.

The experiments performed

In spite of the fact that scientific results were not the prime objective of the campaign, the level of research undertaken could well withstand the criticism of professionals. As was the case in the first campaign, the students showed their limitless creativity and great enthusiasm. Many proposals received were unique and the experiments selected covered a wide range of disciplines. The experiments are described below.

General physics

To study the convection process in microgravity, two students from Berlin made sand grains of different sizes and colour shake, which causes the grains to move in an upward motion called convection. They demonstrated that this process is different in weightlessness. The samples, which are fixated in an emulsion, will be cut in slices back in the laboratory to observe the convection process, indicated by the coloured layers that formed.

Another student from the same university looked at how small magnets float around a large magnet in weightlessness and the shape of the magnetic field lines. It required some negative g impulses, which the pilot specially provided, to make all the small magnets come loose from the floor and show very clearly the field. Several good photos were taken.

Despite the many experts who doubted that the quality of the zero-g would be sufficient, students from the University of Milan successfully simulated the solar system (Fig. 1). They were able to make a small ball make a full elliptical orbit around a sphere, attracted by the high electric voltage of the sphere (3 kV).

Italians are known for their interest in tethered satellites and two students, again from the University of Milan, are no exception. They were able to simulate a tethered satellite system in the aircraft. They subjected a small (10 cm) satellite with an elastic tether to a magnetic force that simulated the gravity gradient.

One of the multinational teams, consisting of a Norwegian and a Dutch student, designed a 'pizza table' that uses air suction to hold the pizza on the table in microgravity and, just as importantly, to collect the crumbs. Such a table has drawn quite a lot of interest from Space Station engineers.

A team from the US undertook a definite first. They observed for the first time the variations of the light emitted by a small cavity created by ultrasound in water. The accoustically-excited cavity was expected to be brighter in weightlessness. The 2-g phase, however, showed the brightest bubble, an effect that the team will now need to explain.

Fluid physics
A team of Belgian students observed how water drives out another fluid (isotane) by capillary forces in a stack of small glass spheres. This is a model for the cleaning of oil-contaminated soil. Contrary to their calculation, the surface of the water did not move in zero-g. A second try with water only, fortunately, confirmed the theory that they had learned from their professor. They returned home with good data and a puzzle to solve.

A student from Wuppertal, Germany, was very pleased with his results. He was able to take photos of gravity-free waves on the surface of silicon oil in zero-g.

Students from the University of Naples heated a fluid cell on one side to create so-called Marangoni convection. Small particles or tracers allowed the currents that formed four cells, two clockwise and two counter-clockwise, to be seen just as the students had learnt in the classroom.

The production of a mirror by rotating liquid mercury did not reach the desired shape although interesting photos were taken. The enthusiasm of the students, from Switzerland, was not hampered. On the contrary, they are now eager to analyse the pictures and learn why the shape turned out to be different.

A team of students from Surrey, UK, and Utah State University, USA, were able to pull very thin films of soapy water from a dish. They were studying the possibility of making thinner films in weightlessness. Thin films will eventually be needed for solar sail propulsion.

Figure 1. Two Italian students perform an orbit simulation using a small mass attracted by the high electrical potential of a central sphere

Combustion
A team from Warsaw studied flames and showed how the slow burning in weightlessness can allow part of a flame to break off and float away, eventually burning itself out. This is very relevant research for the fire protection of future space laboratories.

Material processing
Students from London worked with a special composite that melts in boiling water, to determine its reaction in weightlessness. The experiment had to be discontinued on its first flight because the water container leaked so badly. Back in the hangar, the students worked hard to resolve the problem and, the next day, on the second flight, they successfully melted and solidified samples (using a jet of cold water). Few others in the world are able to claim the posession of a so-called metal matrix composite sample that is 'space-made'.

Figure 2. Students from Austria attempt to produce a large air lens inside a hot tube and observe it with a laser

Students from Cologne were able to make new alloys from aluminium, lead and bismuth, using rapid cool-down and solidification within the 25 seconds of zero-g. They now have many samples to analyse in their laboratories.

Crystals and glass
Students from France used a furnace to melt glass and then dropped pieces into a cooler during the zero-g phase, such that new samples of glass are formed, to determine how the crystallisation of glass differs in microgravity. They had some bad luck. First, they were not aware that only the American airplane had a 110-volt power supply and that the hangar, where preparations were made, did not. Then, during the experiment's second flight, a glass sample got stuck in the cooler and the team could not make anymore samples. Whether the few samples of glass they were able to obtain will satisfy their objective will have to be seen.

Some other French students carried out a rather theoretical study of the order of many small ball-bearings held between two transparent plates as a model of a crystalline structure. After difficulties adapting to the somewhat wild environment in the airplane, the students finally managed to obtain some results on the amount of disorder that the balls show when in reduced gravity.

Optics
An Austrian team attempted to test their novel idea of using the mirror effect created by hot air, like one sees on a hot road ('fata morgana'), to produce an air lens inside a hot tube (Fig. 2). Despite some problems with the optical bench, a laser produced a clearly visible beam and, for the smaller diameter tubes at least, the lens effect was indeed witnessed.

Biology
A German student attempted to study the possible rapid motion of mimosa leaves in microgravity. Mimosa plants are particularly sensitive, their leaves open and close rapidly when disturbed. The plants proved however not to be 'relaxed' enough, the student found, as their leaves stayed folded from the outset.

British students flew a small aquarium containing tropical fish. The students were surprised to see the fish swimming in nose-down loops when in weightlessness. What once was a professional and costly experiment in Skylab, was now repeated by students in a simple and cheap manner.

Technology
A team from Aachen, Germany, tested the well-designed setup that they had developed for welding steel pipes together in weightlessness (Fig. 3). Many welds were made. The students have a wealth of material to investigate.

Another international team, from Munich and Delft, investigated quite a new approach for orbit transfer, the use of long tethers. They looked at the initial deployment of a re-entry

Figure 3. A student from Aachen, Germany, places two steel tubes together, ready to be welded in weightlessness

Figure 4. Students from Delft practise rotating an artificial 'cat' in weightlessness, by remotely controlling its feet and body

capsule attached by a tether. A journalist with a tether attached to her belt was 'deployed' as a replacement for the capsule. After being giving a slight push, she floated through the airplane, and the students were able to measure the tension of the tether and observe the characteristics of its deployment.

The students from the Delft University of Technology who organised the competition also flew an experiment. Using a mechanical 'space cat' that they had created, they successfully demonstrated the cat's ability to turn itself while in free fall (Fig. 4), a capability that cats use to always land on their feet.

All students are now analysing their data. Many of the experiments will undoubtedly show interesting results. The participants will meet in the near-future to discuss their latest findings.

Conclusions

This year's ESA student parabolic flight campaign was again a great success. The 55 European students who participated experienced for themselves the weightlessness in which they performed their experiments. They demonstrated the potential of tomorrow's microgravity science community. These young European researchers proposed innovative ideas and implemented them in an unusually short time. The cooperative spirit that they displayed was very encouraging, not only for themselves but, just as importantly, for the supporting technicians, operators, managers and pilots.

For many of the students, the campaign was a significant experience in their life and should have a positive impact on their future careers. The experience has increased their interest in science and technology, made them aware of a large variety of other scientific disciplines, and has given each one valuable contacts with European partners.
It is highly recommended to repeat such an event in the following years. With new students entering university each year, it is in fact justified to create an annual student parabolic flight campaign programme as an activity to enhance Europe's scientific culture.

Acknowledgement

The campaign was sponsored by ESA and the European Commission. Its success was a result of the hard work of many professionals, i.e. engineers, technicians, pilots, and companies. The efforts of the students, particularly of the initiators and organisers of the competition represented by the chairman of the Delft Aerospace Students Association, Querien Wijnands, were also invaluable.

The generous contributions of the Netherlands Minister of Defence, namely the use of the Valkenburg Naval Air Station and the required airspace, and the air traffic control services provided, were an essential part of the success. The NASA crew also showed an excellent spirit of cooperation, which bodes well for future cooperation in Space Station activities.

The Dynamic Behaviour of Fluids in Microgravity

W. Teichert
Product Centre Engineering, IKOSS GmbH, Stuttgart, Germany

M. Klein
Structures and Mechanisms Division, ESTEC, Noordwijk, The Netherlands

The increasingly large volumes of fluid that have to be carried aboard satellites designed for long operating lifetimes, but which often must also deliver high-accuracy pointing, mean that special attention has to be paid to the behaviour of fluids in low gravity. Several novel methods are being used at ESTEC to model the influence of the fluids on the satellite's dynamic behaviour in orbit.

Low gravity and fluid dynamics

There are several methods for analysing the dynamic behaviour of fluids under normal gravity conditions on Earth. A common assumption in such methods is that the free surface of the fluid is flat and at right angles to the direction in which gravity is acting, i.e. normal to the gravity vector. In this case, surface tension does not contribute to the fluid's dynamic behaviour. However, this assumption is no longer valid if gravity is significantly reduced, as is the case for a satellite in orbit.

An indicator of the importance of the surface tension is the so-called 'Bond number', which is a measure of the relative magnitudes of the gravitational and capillary forces. It is proportional to the gravity level, the fluid density and the square of the characteristic length of the fluid's free surface, and is inversely proportional to the surface tension of the fluid. If the Bond number is much greater than 1, the surface-tension effects can be neglected; if it is much less than 1, the gravity forces can be neglected.

To take an example, the Bond number for water in a 2.7 mm-diameter tube subject to Earth's gravity is 1, and the fluid surface in such a tube is curved. If the tube diameter is much smaller, gravity forces have no significant influence on the fluid, and the water would not flow out when the tube is turned upside down.

The gravity level on an orbiting spacecraft is very low. On a spacecraft like ESA's Eureca retrievable platform, for example, drag results in a residual acceleration of just 5×10^{-6} m/s^2. Under such conditions, a fluid in a typical 1 m-diameter tank will have a Bond number of less than 1, which means that the free surface will be curved and surface tension has to be considered when modelling the fluid. In some cases, it might be possible to neglect gravity effects in the analysis, depending on the tank's diameter and the type of fluid that it holds. This would be true, for example, for a 0.6 m tank carrying nitrous oxide, for which the Bond number would be 0.1 under a Eureca-type residual acceleration.

Free-surface shapes in low gravity

Considering only surface-tension effects, the free-surface shape can be determined analytically for simple tank geometries. If the tank wall is a shell of revolution, the free-surface shape is spherical. The tank geometry, fluid volume and contact angle between tank wall and free surface are required to determine the shape of the fluid. The contact angle is mainly a property of the fluid and distinguishes wetting fluids such as water, and non-wetting fluids such as Mercury. The value of this angle is also influenced by the surface material of the tank, and it is usually difficult therefore to ascertain the contact angle exactly.

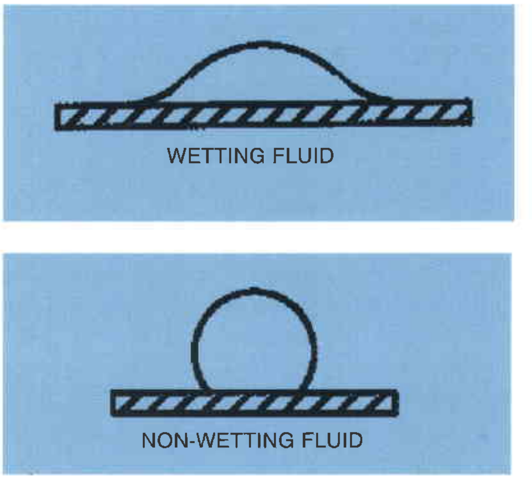


Figure 1. Typical contact angles for wetting (e.g. water) and non-wetting (e.g. mercury) fluids

So far we have been considering only tanks with an axi-symmetric inner surface. Tanks for microgravity applications often contain baffles and fluid-management devices and their effects need to be considered as a next step.

Fluid sloshing frequencies

The fluid sloshing modes of tanks subject to Earth's gravity exhibit frequencies that are usually far below the structural resonance frequencies. The first sloshing mode in a typical spacecraft tank has a frequency around 1 Hz. The frequency is approximately proportional to the square root of the gravity, and therefore decreases if the gravity level is reduced. If the Bond number becomes small, the frequency's dependence on the surface-tension increases. Analytical solutions are possible for simple problems of limited engineering value, but numerical methods are needed to model complex engineering problems.

Fluid sloshing mode frequencies in micro-gravity are generally very low, typically in the range 0.1 to 0.01 Hz. These low-frequency modes could interfere with the structural bending modes of large solar arrays, or with the satellite's Attitude and Orbit Control System (AOCS). As a result, such fluid effects in low gravity need to be determined as one of the more critical inputs when analysing the dynamic control of satellites.

Analysis methods

Appropriate analysis capabilities have been established at ESTEC to support evaluation of the performances of satellites with stringent pointing requirements. Facilities are available for the generation of a simplified dynamic model (few degrees of freedom) of the propellant fluid in low gravity for coupling with satellite mass and stiffness matrices as input to the satellite AOCS model. The analysis facility is based on the boundary-element program RAYON, and employs standard graphical software for model visualisation (PATRAN) and a general-purpose finite-element program (ASKA) for establishing the satellite's mass and stiffness matrices.

The analysis is conducted in three steps. As a first step, the shape of the fluid's free surface is determined. Subsequently, the mass and stiffness matrices are evaluated. Finally, the fluid modes and frequencies are computed and simplified models are derived, assuming a rigid tank. At present, the analysis of the tank geometry is limited to cylindrical tanks with elliptical end caps, a spherical tank being a special case of such a geometry.

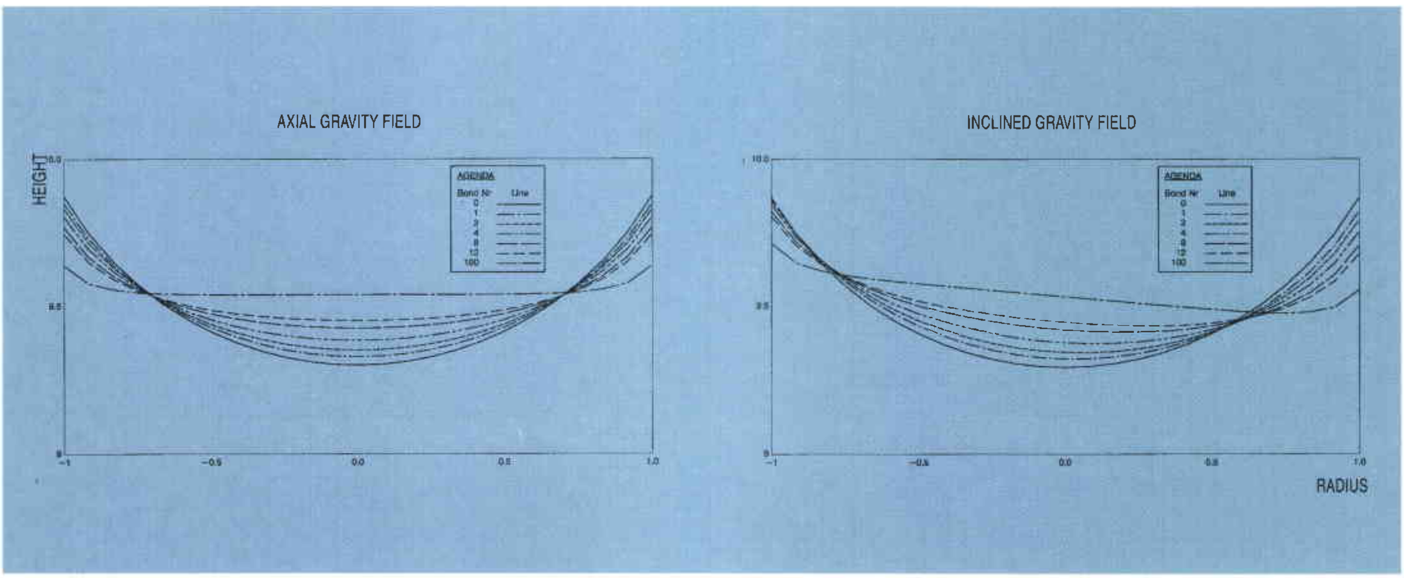
Free-surface shape determination

As mentioned earlier, the two shape extremes are the flat free surface obtained when the surface tension is negligible, and the spherical surface in zero gravity. Numerical analysis is necessary when gravity and surface tension are taken into account simultaneously, and in most cases a non-linear iteration process is required to derive the free-surface shape. The latter is discretized using finite elements, and this idealization is employed to describe the boundary of the fluid.

Figure 2 shows the different shapes of the free surface at different Bond numbers for fluid contained in a cylindrical tank. It is possible in the analysis to define an offset angle between the tank's axis and gravity vector. The surface shapes displayed in the right-hand figure are for an offset angle of 5°.

Once the free surface and its contact line with the tank wall have been established, it is easy to determine the fluid boundary necessary to establish the fluid dynamics.

Figure 2. Meridian of the free-surface for different Bond numbers, in a cylindrical tank



Generation of fluid mass and stiffness matrices

To account for the effect of the fluid on the satellite, the fluid mass and stiffness matrices are generated and implemented in the satellite mathematical model. In general, the latter is built up using the finite-element method (FEM). Similar finite-element representation of the fluid would involve a significant mesh-generation effort. Boundary-element techniques, however, facilitate the generation of the fluid matrices. A number of difficulties related to the usage of the boundary-element method (BEM) for this type of fluid processing have been solved. The combination of FEM and BEM techniques arrived at has been employed successfully to represent satellite propellant tanks, which have then been coupled into the satellite mathematical model for pointing-performance evaluations.

As an example of the analysis possibilities, Figure 3 shows the first mode of vibration of the fluid in a satellite tank.

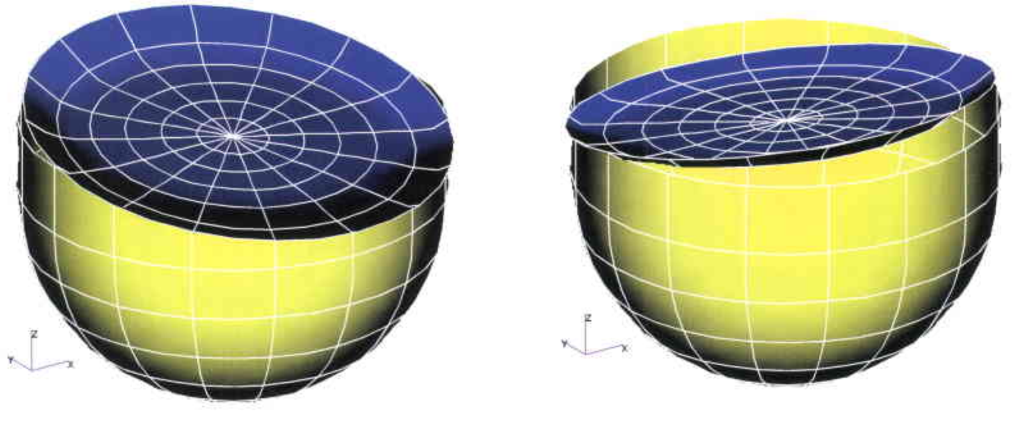


Figure 3. The first fluid sloshing mode at 0.02 Hz

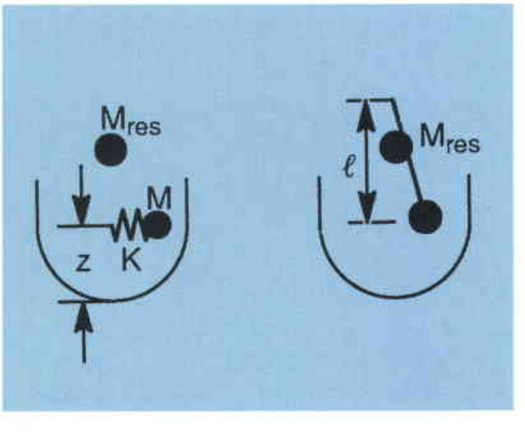


Figure 4. The mass-spring and pendulum models

Derivation of dynamically equivalent simple models

The importance of each mode of vibration depends on the load generated at the tank interface with the satellite. The interface force depends on the effective modal mass matrix of the vibrational modes. It is possible to derive from the latter single-degree-of-freedom models which have equivalent dynamic behaviours in terms of tank interface loads.

Mass-spring and pendulum models are two types of models which can be inserted directly into the satellite AOCS model (Fig. 4).

The simplified mass-spring models are determined by the vibrating mass and its location, the spring stiffness, and the residual mass and its location. The vibration characteristics of the pendulum model are determined by the pendulum length rather than the spring stiffness, and can be used for non-zero-gravity conditions.

Conclusion

The analysis of fluid effects in satellite propellant tanks that has been presented very briefly here can be employed to support stability and pointing-performance evaluations for spacecraft susceptible to fluid-driven perturbations in the microgravity environment.

The latter include missions such as Artemis, with its large low-frequency solar arrays, microgravity and observation-type platforms like Eureca and the Polar Platform, respectively, and technology-demonstration satellites such as Sloshsat (an ESA technology demonstration project), the results from which will be used to verify the analytical predictions against in-flight measurements.

Further work is planned to extend the evaluation capabilities that have been summarised above to complex tank geometries and to cover the effects of in-tank baffles and fluid-management devices.

The CSDS User Interface — A Technical and Programmatic Overview

F. Drigani
Cluster Project Office, ESTEC, Noordwijk, The Netherlands

S. Skogvold
Automation & Ground Facilities Division, ESTEC, Noordwijk, The Netherlands

P. Donzelli & S. Moulin
Information Systems Division, ESRIN, Frascati, Italy

The Cluster Science Data System (CSDS) is a network-based system established to assist in the distribution of the vast amount of data expected to be acquired during the Cluster mission. The User Interface (UI), a common software infrastructure, links National Data Centres and the scientific community and permits them to ingest, select and manipulate science data products.

The CSDS UI was developed by a team of ESA establishments and scientific institutes. To a large extent, it is based on existing software in order to minimise the risk and to ensure a rapid development cycle. It was developed over a period of two years. There have been five incremental deliveries, to allow early feedback to be obtained and to enable the development team to cope with requests for changes and new requirements in a controlled way. This method also contributed to the development being kept within the original 'cost at completion'.

Introduction

Cluster, which together with SOHO constitutes the first cornerstone of ESA's Science Programme's Horizon 2000 long-term plan, is a mission consisting of four identical satellites. It will be launched on the first Ariane 5 launch presently scheduled for Spring 1996. The four Cluster satellites will orbit in a tetrahedral formation, with the aim of building for the first time a 3-D picture of the physical processes occurring in the magnetosphere. The Cluster payload consists of 11 instruments on each satellite, each generating raw data to be acquired and processed on ground. The products will then be distributed to the Cluster scientific community.

To do so, a network-based system called the Cluster Science Data System (CSDS) was established. The CSDS includes:

- ESA's operations centre, ESOC in Darmstadt, Germany, as the operations control centre for command uplink and data acquisition
- National Data Centres (NDCs) located in the countries of the Principal Investigators and responsible for the data processing
- The Joint Science Operations Centre (JSOC), located at the Rutherford Appleton Laboratory (RAL) in the UK, and which supports the project scientists and the scientific community
- The CSDS User Interface, a common software infrastructure linking the National Data Centres and the scientific community and permitting them to select, ingest and manipulate the science data products.

For more information on the CSDS, see 'Collection and Dissemination of Cluster Data' in ESA Bulletin No. 84, November 1995.

The functionalities of the CSDS User Interface

The CSDS User Interface (UI) offers the NDCs and the scientific community a number of specialised data products and services.

CSDS data products

The NDCs will make several types of Cluster data available to the scientific community:

- *Primary Parameters (PP) and Summary Parameters (SP) data* for all Cluster instruments. This data is generated based on raw data coming from ESOC. The PP and SP data are made available as files, each covering one day of satellite operation. The PP data is instrument data at four-second resolution for all four spacecraft, while the SP data has a one-minute resolution and is provided for only one of the spacecraft. Thus, the PP data provides a more detailed view of the science data than the SP data. The PP data will be accessible to Cluster Principal Investigators and Co-Investigators only. The SP data will be accessible to all scientists within the International Solar Terrestrial Programme (ISTP) community.

The files are stored in the Common Data Format (CDF), which is a standard for all the projects within the ISTP. With this format, it is possible for the scientists to manipulate the data.

Each NDC is responsible for the 'pipeline process' that generates the PP and SP, i.e. the process used to convert the raw data to data products, for the NDC's own set of instruments. The PP and SP data files for the other instruments must be fetched from the other NDCs.

— *Summary plot files*
  These are files generated on the basis of the SP data for each day. They provide a 'quick look' at the PP/SP data, however, there is no means of manipulating the data. They are stored in Postcript format and will not be subjected to access restrictions. These files are generated by the German Data Centre (GDC), and all the other NDCs must fetch the files from the GDC.

— *Events catalogues*
  These are generated by the Cluster Joint Science Operation Centre. The catalogues provide data about the predicted and observed scientific events for the Cluster mission. They therefore give the scientists an indication of which time intervals to focus on in the PP and SP databases.

CSDS UI services to the NDCs
As mentioned above, each NDC will generate SP and PP CDF files for their own instruments. This data will then have to be validated by the instrument's PI before it is made available to the user community. The CSDS UI permits the PI to insert validation information into the CDF files. Once the CDF files have been validated, the NDC will perform two actions, both done with the use of the CSDS UI:

— Include the CDF files in their own PP/SP database
— Make the CDF files available for the other NDCs to fetch.

At this stage, the CDF files are actually available to the scientists that are served by the local NDC, but not to the scientists that are served by the other NDCs. Therefore, all NDCs will use the CSDS UI software everyday to look up the other NDCs, and to pick up the new PP/SP CDF files that are made available. These files are then included in the local SP/PP database, and thus made available to the local scientific community. When the German NDC is looked up, the CSDS UI makes sure to pick up also the new Summary Plot files.

As far as the events catalogues are concerned, the CSDS UI will automatically update the copies stored in the NDCs with the newest version from the master catalogues in the JSOC.

The CSDS UI permits the NDCs to manage their own user community. They can register users and give access rights. The access rights can be given both in terms of data type (PP and SP data), as well as instrument and observation time interval for the PP data.

Lastly, the CSDS UI provides utilities to manage the databases in the NDC (remove data, backup data, etc.) and to log user access.

CSDS UI services to the scientists
Once the data is in the NDC, the Cluster scientists served by the NDC can access it. The CSDS UI permits the scientist to:

— Search in the PP/SP data catalogues to identify data of interest in the PP and SP databases.

— Search in the events catalogues to identify events and time periods of interest.

— Fetch PP/SP CDF files to their own computer

— Fetch SP files from their local NDC

— Visualise and manipulate interactively the PP/SP CDF files. The data can be manipulated and plotted in many ways. Some examples are:

  — The selected data can be plotted as a simple time plot.

  — Plots can be made in which the y-axis is a mathematical function involving one or more parameters, or in which a parameter is a function of another parameter (or mathematical formulae).

  — The same tool can be used to access data directly residing on the NDC computer as well as on the local user's machine.

Technical description of the CSDS UI
In this section, the CSDS UI is presented on a technical level. A view of the environment in which the software will work is first presented,

and then the different modules that make up the system are explained.

The environment and general aspects of the CSDS UI

Figure 1 shows how the CSDS UI fits in with the pipeline process for generating science data in a local National Data Centre, and how the data flows through the system.

Data generated by the four Cluster spacecraft undergoes several stages of transfer and processing before being made available to scientific users as PP and SP databases through the NDCs. Raw data is distributed, on a regular basis, to NDCs. Each NDC generates the PP and SP CDF files for the instruments related to that NDC. These non-validated PP and SP CDF files constitute the interface between the local NDC pipeline process and the CSDS UI.

The events catalogues are regularly updated in each NDC from the master catalogues in JSOC. This is an unattended process which does not require any regular interaction by the NDC personnel.

Three categories of users, with different roles, make use of the CSDS-UI:

— Principal investigators and co-investigators (PI/CoIs)
— NDC systems managers
— Scientific users.

The PI/CoIs perform the data validation.

NDC system managers perform CSDS-UI system management tasks in the NDC and provide support to both PI/CoIs and scientific users registered to the NDC. Their main tasks are:

— the DC-to-DC transfer of data files from other remote NDCs
— the 'ingestion' into PP/SP databases of locally and remotely validated CDF files
— the catalogue management
— the user and access rights management
— the monitoring of the NDC's activity.

Scientific users are provided with a set of client-server applications to:

— browse through the CSDS-UI and JSOC catalogues
— fetch CDF and summary plot data files to their home computer and
— visualise and manipulate interactively Primary and Summary Parameters.

The CSDS-UI application is based on a client-server architecture, available for both Sun Solaris and DEC Alpha OpenVMS operating systems. CSDS-UI communications rely on the TCP/IP protocol. The following types of carriers are supported:

— NDC LAN infrastructure, for NDC personnel, local PI/CoIs and local science users

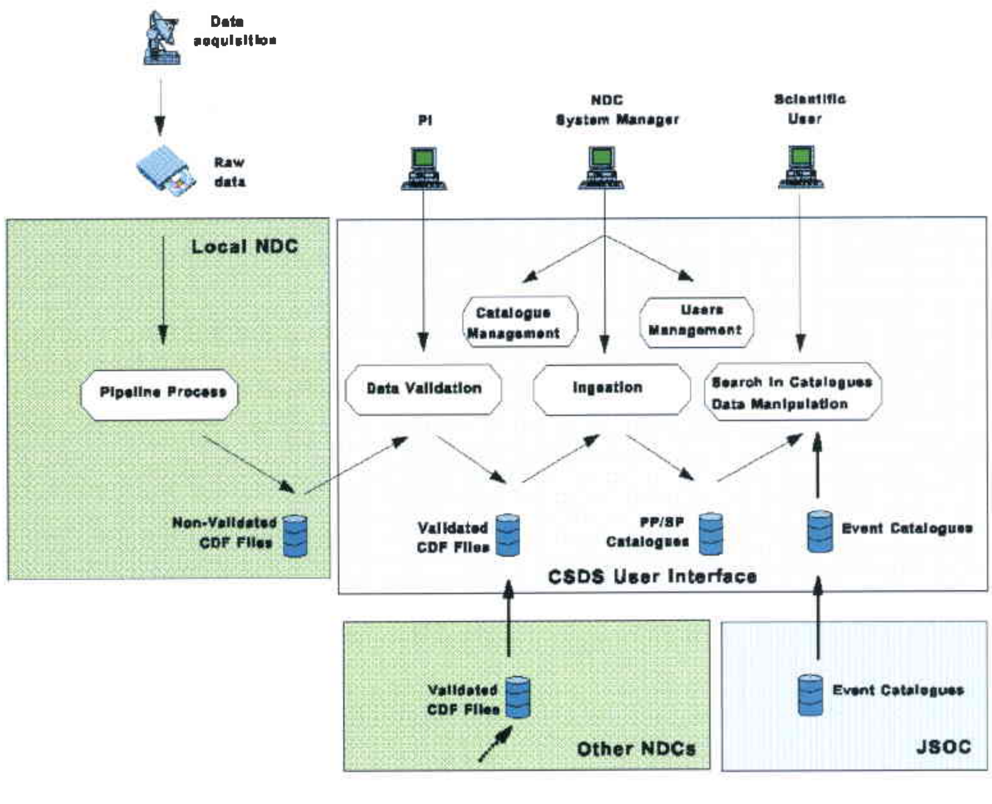


Figure 1. The CSDS User Interface's main components and its interfaces

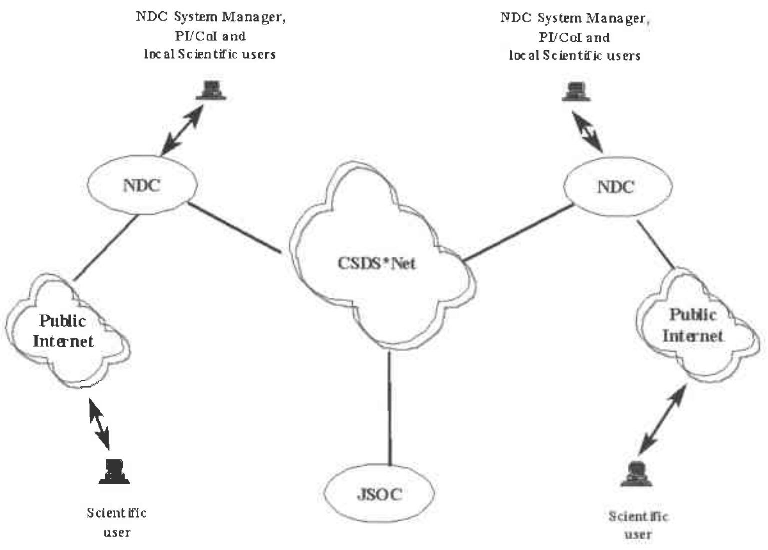


Figure 2. Interconnection of NDCs and users

— National Internet infrastructure for the remote PI/CoIs and remote science users
— CSDS*Net for data transfer between NDCs and with JSOC.

This configuration is depicted in Figure 2.

CSDS user interfaces are based on Motif (Graphic User Interface or GUI) or, for batch processing or low network bandwidth, on a character-based interface (Command Line Interface or CLI). Catalogues and related query functions, and user registration were developed using Oracle products. Oracle is also the basis for the PP/SP catalogues and the events catalogues.

Data validation

The 'Data Validation' application allows the PI/CoI to validate PP and SP CDF data files produced by the pipeline process. Through a GUI (Fig. 3), it allows CDF file validation attributes to be entered and modified, and the incremental CDF file version numbering scheme to be managed. Data validation is run locally, at each NDC.

NDC system manager applications

The NDC system manager is responsible for the management of the data products, catalogues and users' access rights, and for the NDC's activity monitoring.

Data files and catalogue management

On a routine basis, the NDC system manager fetches, from others NDCs, data files and in particular the validated CDF files for the instruments not related to the manager's own NDC. This function is provided by the DC-to-DC file transfer application.

Once available, remotely or locally produced data files are ingested in the PP and SP database and are catalogued by extracting the relevant information from the data files. This process is shown in Figure 4.

In addition to populating the files database and updating the related catalogues, the NDC system manager is required to manage them. The 'Catalogue Management' application allows the NDC system manager to up-date the catalogues in order to reflect any manual modification performed to the data-bases such as a deletion or relocation of a data file. The Catalogue Management func-tion is provided through a GUI built on the Oracle Form product. The GUI is shown in Figure 5.

Users and access rights management

Whereas PI/CoIs have full access rights for all instrument data files and catalogues, other users, by default, may access only SP data files and catalogues. Whenever needed, for example during a scientific campaign, the access rights of a non-PI user can be extended to the PP data by granting the user one or more 'campaigns'. A campaign is defined as a period of obser-vation time and a list of instruments for which access to the PP data files and related catalogues is allowed.

In agreement with the PIs, the NDC system manager takes care of the data access security aspects by managing the campaigns, the users and access rights data-bases. These functions are provided by the 'User and Access Rights' application based on Oracle Forms.

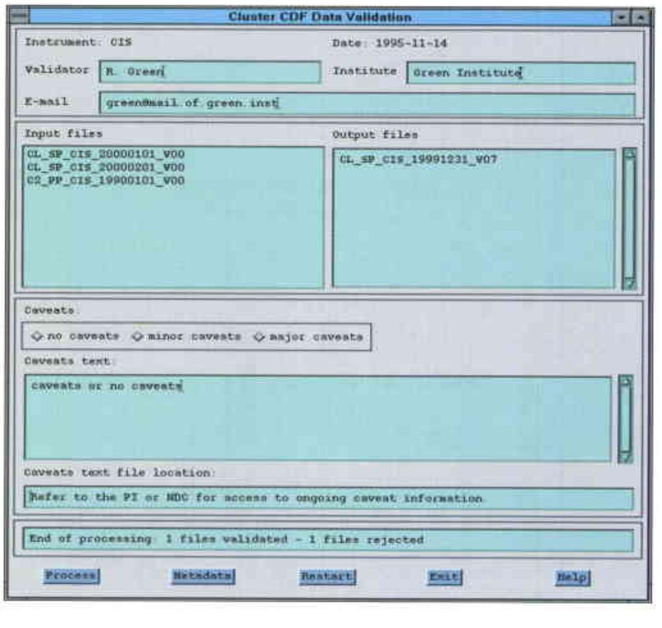


Figure 3. The GUI for the 'Data Validation' application

NDC's monitoring of activities
All applications produce log information either as flat files or into the Oracle database. The NDC system manager analyses these logs to obtain valuable information about the NDC server behaviour. In particular, the system manager can appreciate how the users' activities affect the NDC server and tune the configuration accordingly. Log information is also useful for identifying and fixing users' problems.

User applications

The CSDS-UI registered user is provided with a set of applications to access and manipulate the data that is located at the local NDC or has already been retrieved on his computer. All these applications have a GUI and most of them rely on a client-server architecture.

The user applications are:

— the catalogue browser
— the Interactive Science Data Analysis Tool (ISDAT)
— the simple display
— the summary plot browser.

They are reached via the 'Session Manager' window, which provides a menu of the applications available.

The catalogue browser application
The catalogue browser allows the user to interactively search through the catalogues. Three different catalogue types are available (Table 1). The catalogue browser is based on the Oracle Forms product.

From the catalogue browser, the user can save and re-load a search definition and save, as an ASCII file, a search result. From the PP and SP catalogues only, it is possible to fetch, merge or subset CDF files (Fig. 6) and retrieve the result file to the user's computer (Fig. 7). Lastly, a query on PP or SP catalogues can be saved for re-use by the data manipulation application, ISDAT (see below); this constitutes the ISDAT interface to the CDF data files catalogues.

The data manipulation application ISDAT
The Interactive Science Data Analysis Tool, ISDAT, is the CSDS-UI scientific data manipulation package. The system allows the scientists to use different applications running on their own machines (the clients) to select and plot data that reside on the NDC machine (the server). An overview of the ISDAT architecture is shown in Figure 8.

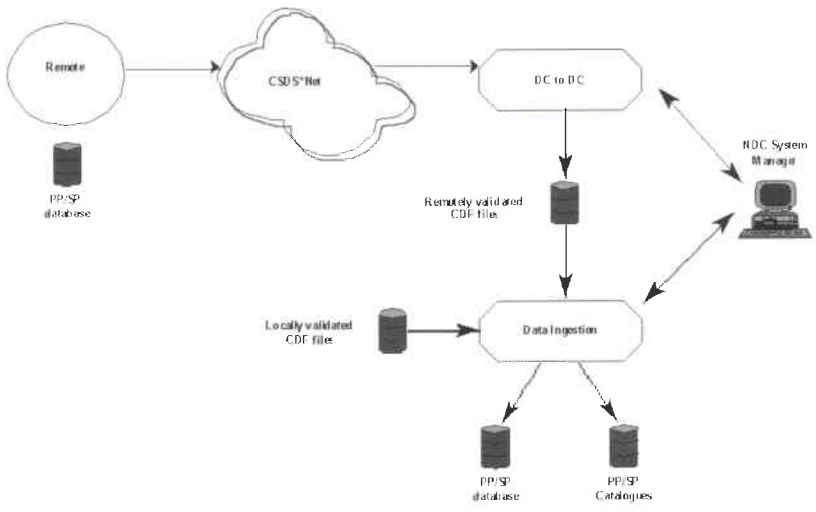


Figure 4. The NDC system manager is responsible for the management of the data products: DC-to-DC file transfer, data ingestion and catalogue loading

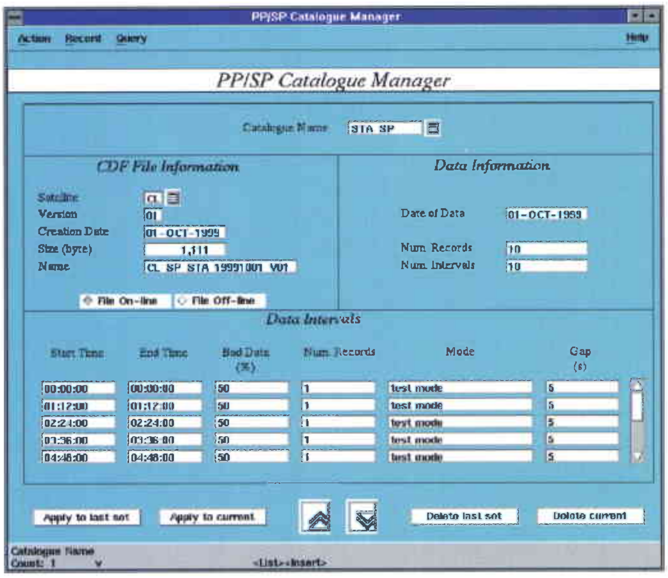
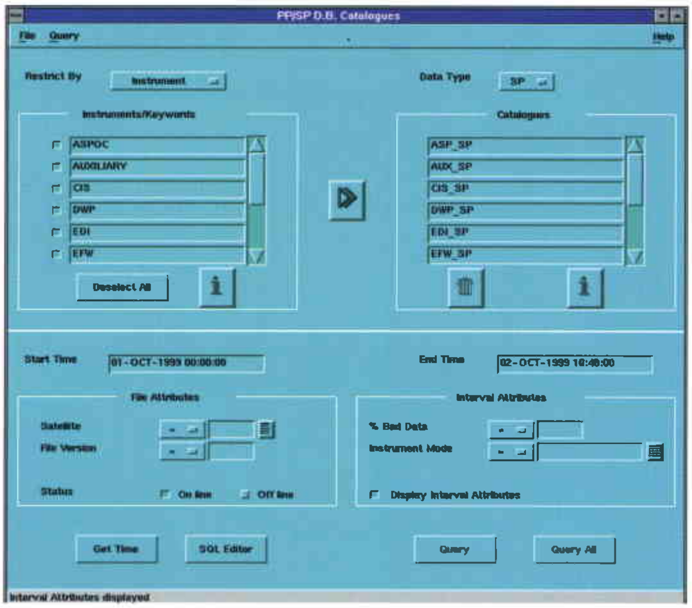


Figure 5. The GUI for 'Catalogue Management', used by an NDC system manager

Table 1. The three different catalogue types available via the catalogue browser application

Catalogue type	Contents
PP/SP CDF data files	CDF file information: name, date of the data measurement, file version, size, creation date, etc.
	Data interval information: start time and end time, instrument mode, percentage of bad data, duration of gaps, etc.
	(There is one catalogue per instrument and data type, i.e. 21 catalogues.)
Orbit geometry	Sampled data from the auxiliary CDF data files, which contain data related to the quality and shape of the tetrahedron formed by the four Cluster spacecraft
Event catalogues	Predicted solar cycle trends Predicted geometric positions Predicted scientific events Predicted scientific positions Scientific events



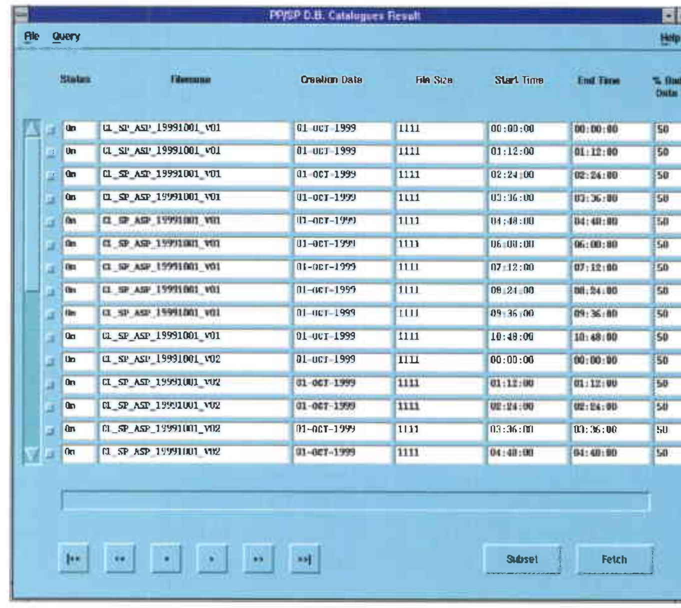


Figure 6. The GUI for the PP/SP query made via the catalogue browser

Figure 7. The GUI for the PP/SP result obtained via the catalogue browser

ISDAT allows the scientific user to select data from the PP and SP CDF files on the basis of the instrument, time interval or another parameter of interest. The selected data can then be displayed, by means of a specialised client. The clients display data in different ways, for example, one produces graphical plots (the cuigr client) while another shows the metadata of the CDF files (the cuimeta client).

All of the CDF files are indexed as part of the 'Data Ingestion' application, so the system provides quick access to the data. In addition, the ISDAT server verifies the user data access rights by interfacing with the Oracle user database in the NDC.

Several ISDAT clients are available. They are initially invoked via the ISDAT Time Manager client. The user specifies the time interval to be viewed. All of the clients 'owned' by that Time Manager will then display data for that time interval (although the type of data displayed will be different), allowing for example one client (the cuigr) to plot an instrument parameter while another client (the cuimeta) shows the metadata for the same instrument over the same period.

A few examples of the most important ISDAT clients are:

— The ISDAT 'Time Manager' client
After the set-up of the session with the ISDAT server, the Time Manager offers the user the possibility to select the data set on which to work: PP or SP CDF files, Satellite, Instrument, as well as the time period of interest. Once a suitable selection has been made, the user can select which client to use from the 'Clients' menu.

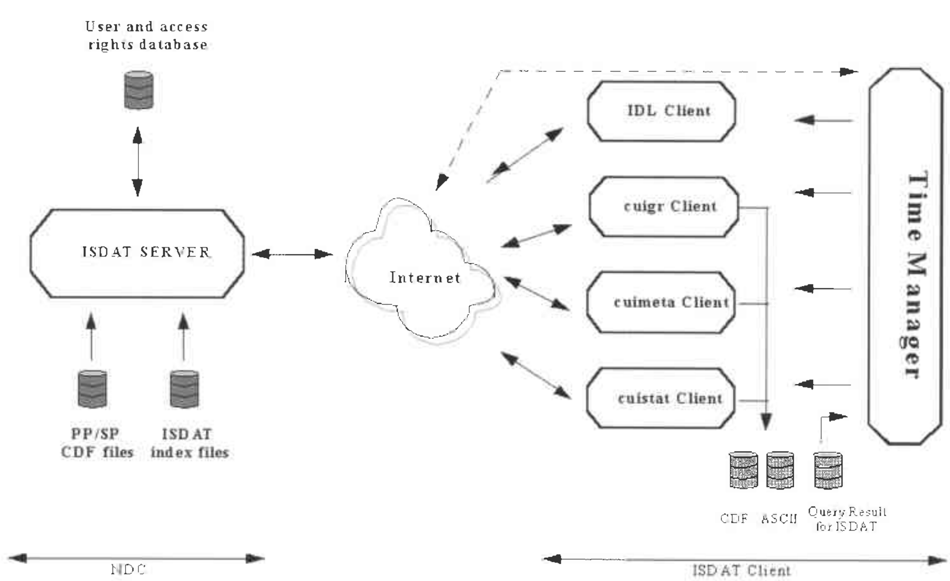


Figure 8. ISDAT client-server architecture

— The ISDAT graphic client
The ISDAT graphic client is a general purpose display and data manipulation tool. It allows the computation of derived parameters, plotting of parameters versus time or versus another parameter in a multi-panel plots window. In addition, functions are provide to save the retrieved or computed values in both CDF and ASCII files. The GUI for the graphic client is shown in Figure 9.

The simple display
The 'Simple Display' application provides a quick way for the users to view the CDF files that they have retrieved from their NDC, but it does not provide any data manipulation facilities like ISDAT. The GUI for this application is shown in Figure 10.

The Summary Plot Browser
The 'Summary Plot Browser' provides the user with a GUI to browse and retrieve, from the local NDC, SP files.

The CSDS UI project

History
Since the CSDS Announcement of Opportunity in 1990, the Agency was tasked with providing a software environment that the Cluster scientific users could use to access the data. At that time, the ESA-funded European Space Information System (ESIS) was the preferred environment. It was under development, with the Pilot Phase to be approved at the end of 1993. It became clear at the beginning of 1994, however, that the future of ESIS looked very uncertain*, and the Cluster Project decided to take urgent action to recover the situation.

A 'tiger team', composed of staff from ESA and the Data Centres, was set up to address the situation. A User Requirements document, containing the specifications for the Cluster community's requirements, was prepared with the joint contribution of all the affected parties: the end-users, ESA and the Data Centres. On the basis of that document, the tiger team reviewed the existing and planned software systems available within the Cluster community, and identified those most suitable for the provision of the required services.

The ESIS software, provided by ESRIN, and the ISDAT package, provided by the Swedish Institute of Space Physics (IRF-U), were identified as the best candidates to be the building blocks for a new CSDS User Interface**. These recommendations were presented to, and accepted by, the CSDS Steering Committee and the Implementation Working Group. The project team was then finally set-up and the cost at completion agreed.

Thanks to a goal-oriented management approach, good collaboration, and the joint effort of all the entities involved, the CSDS-UI project team was already in place before the end of May 1994 and was working towards Release 1 of the system.

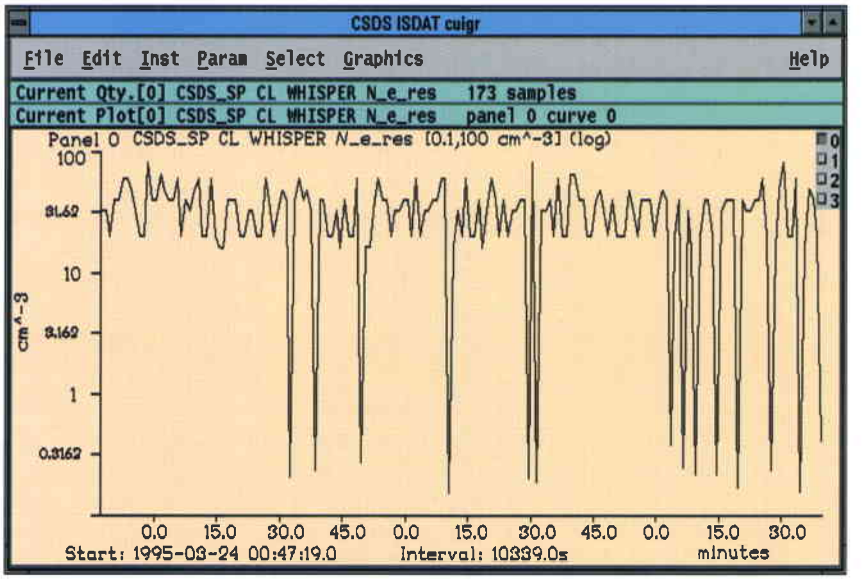


Figure 9. The GUI for the ISDAT graphic client

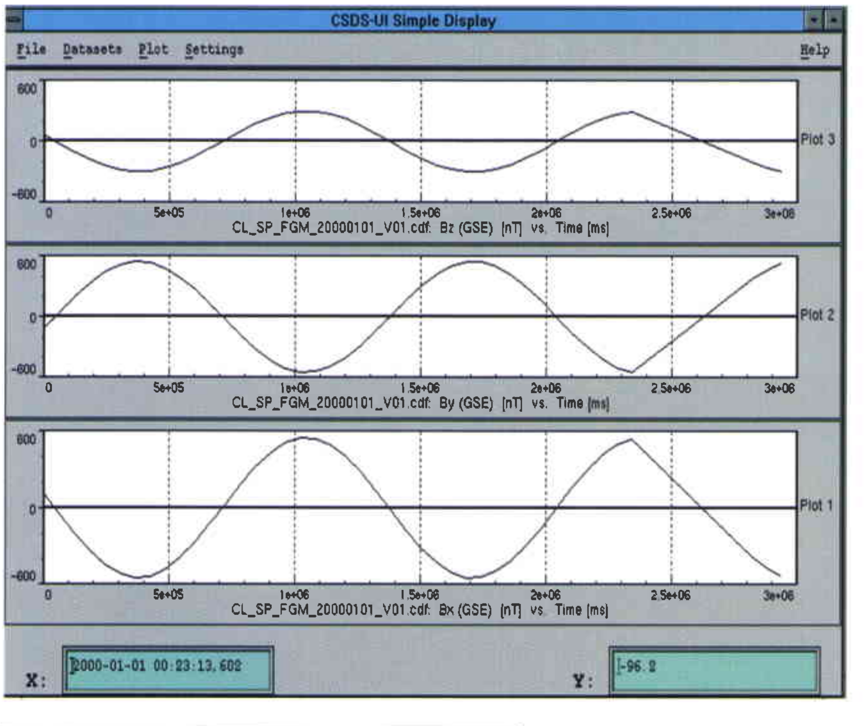


Figure 10. The GUI for the simple display

* A few months later, in June 1994, ESA's Science Programme Committee (SPC) decided to transfer ESIS to the scientific institutions. ESA no longer supports the development of ESIS.

** As the reader may have realised from the technical description, the term 'User Interface' was probably too limited to define the overall software that provides much more functionality to end-users and Data Centres, than just the interface to data.

Major project activities

The major project activities were:

- The extension and modification of the original ESIS client/server software to cope with specific CSDS-UI requirements for catalogue browsing, user access control and logging
- The extension and modification of the ISDAT software to cope with specific CSDS-UI requirements for scientific data manipulation
- The development of a dedicated Data Validation and Ingestion software to interface with the NDC pipeline systems
- The integration of the above packages into a consistent software system to be made available for two different computer platforms (Sun/Solaris and DEC Alpha/ OpenVMS).

The project team and the division of work

The CSDS-UI project was carried out by ESA, with the support of contractors Rutherford Appleton Laboratory (RAL, UK), Queen Mary and Westfield College (UK), and IRF-U. With respect to ESA's role, ESTEC performed the project management, while ESRIN was responsible for the development of the following modules:

- Catalogue browser
- User data logging
- Access control
- CDF file manipulation.

ESRIN was also responsible for the overall CSDS-UI integration, testing and deployment to the Data Centres, and will also provide user support and maintenance during the operation of the Cluster satellites.

RAL was responsible for the development, integration and testing of the following modules:

- Data ingestion
- Data validation
- File transfer.

IRF-U was responsible for the adaptation, improvement and extension of the ISDAT package to meet the CSDS-UI requirements for the scientific analysis of SPs and PPs.

Queen Mary and Westfield College acted as the consultant for all the aspects pertaining to the CDF.

Budget

The overall project development has remained within the original cost at completion of 1730 KAU. (This figure includes only direct costs. It does not include about 200 KAU of ESA staff costs.) The 270 KAU originally kept to cover contingencies has been used to include new functionalities as requested by the users.

Schedule

The project adopted an Incremental Delivery Approach (Fig. 11). Three software deliveries were envisaged. The formal acceptance of the software has been applied however to the final version only.

The first delivery (Release 1) took place in July 1994, just three months after the official start of the project. This release mainly addressed the system management functionalities made available to the Data Centres.

The second delivery (Release 2) was distributed to Data Centres in February 1995. It contained all the Data Centre functionalities and most of the functionalities for the end-user. The Data Centres evaluated this version, and the feedback was reported to the development team. Moreover, this version gave the the Data Centres the opportunity to become acquainted with the various installation procedures.

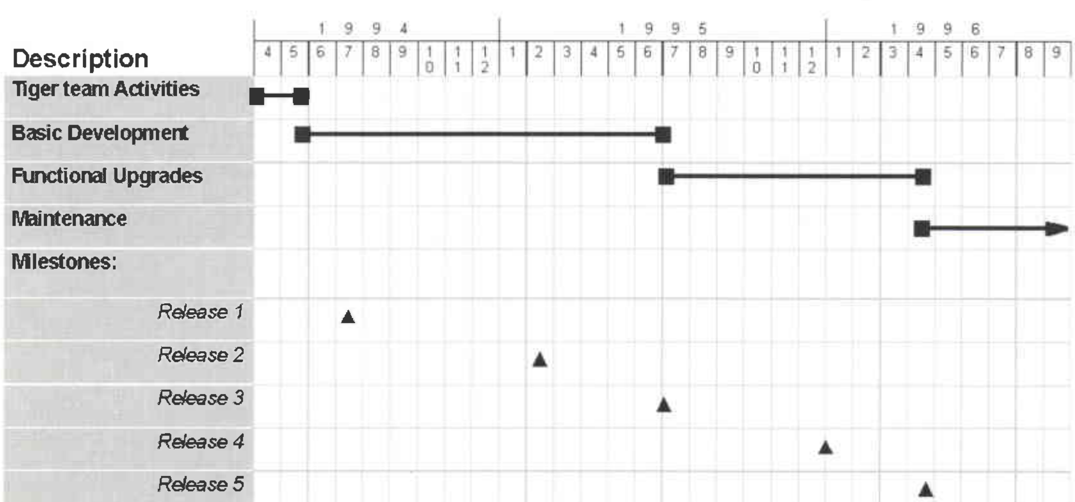


Figure 11. Schedule for the CSDS User Interface project

Finally, in July 1995, after having passed a formal acceptance test procedure with the Cluster project office, the final version (Release 3) was made available to the Data Centres and to the end-users.

The Data Centres, in turn, were in charge of re-executing the acceptance procedures before formally accepting the software. This activity, carried out during the past summer, led to the proposal of several new features to be implemented, and identified some critical limitations in the performances.

Based on these results, a new version (Release 4) was prepared and distributed in December 1995. The user community has introduced some more new requirements and ESA is now planning a fifth version for release in April 1996, in conjunction with the new launch date for the mission.

Maintenance of the UI

Throughout the life of the Cluster mission, i.e. until mid-1998, ESA will provide regular maintenance to the User Interface. Procedures to collect the Software Problem Reports from end-users and Data Centres have been put in place and will be implemented on a fixed-effort base (requiring about two person-years per year).

Conclusions

The CSDS-UI project is the practical demonstration of an efficient way to develop the infrastructure to distribute the data from ESA scientific missions at a relatively low cost and within a strict schedule. A few basic principles that may be easily adopted in other, similar projects, have been followed:

— Involve the customer in the definition of the user requirements from an early stage.
— Agree on a minimum set of requirements. Development started only when this was achieved.
— Do not re-invent the wheel. Existing and proven applications were selected.
— Each to his own trade. Scientific institutes were responsible for the development of the scientific applications and ESA, as the funding agency, exercised overall management and control.
— Do one thing at a time. New requirements were screened and introduced as extra deliveries at the appropriate time.
— Think ahead. Plans with a defined budget and spare resources for contingencies were developed.
— The user's advice is the best advice. Frequent incremental deliveries were introduced to obtain feedback from the users.

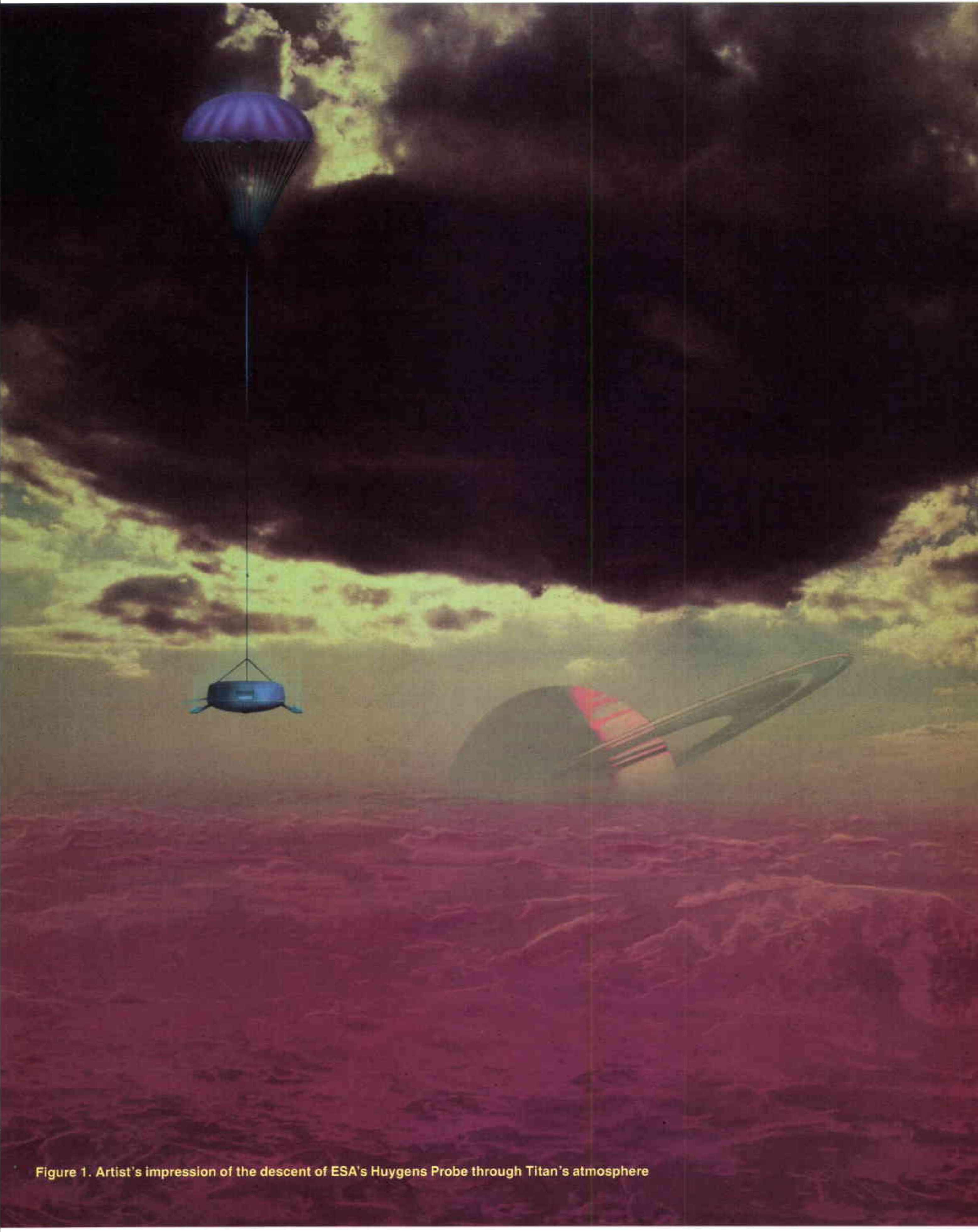


Figure 1. Artist's impression of the descent of ESA's Huygens Probe through Titan's atmosphere

Drop Testing the Huygens Probe

E. Jäkel
Huygens Project, Scientific Projects Department,
ESA Directorate for Scientific Programmes, ESTEC, Noordwijk, The Netherlands

P. Rideau
Huygens Project, Aerospatiale, Cannes, France

P.R. Nugteren
Fokker Space Systems, Leiden, The Netherlands

J. Underwood
Martin Baker Ltd., Higher Denham, United Kingdom

The Huygens Probe was drop-tested at the ESRANGE Balloon Launch Site in Kiruna, Sweden, on 14 May 1995, to simulate its spectacular journey through Titan's atmosphere. The Probe's descent to the surface of Saturn's largest moon is scheduled for 27 November 2004 (Fig. 1). The development and verification programme included this demonstration, with a full-scale model, of the Probe's essential characteristics during its free fall and the Titan parachute descent.

Figure 2. The Huygens Probe and gondola assembly prior to suspension from the auxiliary balloon

Introduction

A special full-sized model of the Huygens Probe, designated SM2, was assembled for this test. It was attached to a gondola and lifted to an altitude of approximately 38 km by a stratospheric balloon. The probe was then separated by ground command from the gondola for the parachute descent test.

The specific objectives of the drop test were to demonstrate:

- the descent sequence under dynamic conditions
- the functioning of the descent subsystem, including the deployment, inflation, drag coefficient, structural strength and stability of the parachutes
- the operation of the parachute deployment device, separation of the back cover, separation of the front shield and operation of the parachute jettisoning mechanism
- the functioning of the spin vanes under the stabilising drogue chute

and to provide the data needed to correlate predictions with flight results.

The SM2 Probe

Mechanical design

The external shape of the SM2 Probe (Fig. 2) is almost identical to that of the flight model that will descend into Titan's atmosphere. The inner structure is built to flight-standard, as are the back-cover and front-shield release mechanisms and the descent control subsystem. A special bracket was added to interface the Probe and the gondola to allow a pyrotechnic separation, with umbilical separation provided by a lanyard.

Electrical design

The electrical system was specially designed to meet the objectives of the drop test and was powered by NiCd rechargeable batteries. The data acquisition and telemetry system managed the interfaces with the various sensors, providing signal conversion and conditioning of the sensor outputs, formatting of the data into PCM frames, and transmitting the data (at 38 400 bit/s) to ground via the gondola. It simultaneously stored the data in a solid-state recorder (16 Mbyte) onboard the Probe.

The S-band transmitter (2 W), utilising the telemetry link between the Probe and the gondola, operated at a frequency of 2.2515 GHz and had a link range of up to 18 km at a 55° angle. The Probe could be commanded from the ground via the gondola up to the moment of separation; thereafter, it operated autonomously under time-tagged commands from the Pyro Timing and Firing Unit.

The Probe's instrumentation determined altitude and horizontal position, vertical and horizontal velocity and accelerations, roll, yaw and pitch axis rate, and also handled onboard event timing, visual imaging and housekeeping data.

Figure 3. Auxiliary and main-balloon filling on the 'launch pad'

The following instruments were used for data registration during the descent:
- accelerometers
- film cameras (upward- and downward-looking)
- angular rate sensors
- temperature sensors
- a GPS receiver

together with the following equipment
- Power Distribution Unit (PDU)
- Pyro Timing Firing Unit (PTFU)
- Camera Power Supply (CPS)
- PCM encoder
- solid-state data recorder
- transmitter and telemetry antenna
- battery packs
- heater mats and thermostats.

All sensors and data acquisition and telemetry equipment were off-the-shelf items. The PDU, PTFU and CPS were custom-made.

Redundancy

As a compromise between programme risk and available budget, a limited redundancy scheme was applied. In particular:
- all safety and mission-critical elements were fully redundant
- the pyros were hot redundant and powered by fully redundant battery clusters
- the separation detection was based on majority voting
- the data acquisition was redundant, through: (a) relay via the gondola to ground, (b) storage in parallel in the Probe's solid-state data recorder, and (c) a direct link to ground at S-band (additional backup).

The Probe's integration, testing and launch

The electrical testing of the various units was performed by the unit suppliers and later by Fokker Space & Systems (FSS) as work-bench tests prior to integration. The Probe and balloon gondola were integrated by FSS's engineers in the company's clean room at Schiphol (NL). The radio-frequency and mass-property tests were performed at ESTEC in Noordwijk (NL). Finally, just prior to its shipment to ESRANGE (S), a system functional test was conducted on the combined gondola/Probe assembly by FSS at Schiphol, which included a pyro separation test.

The Flight Acceptance Review was successfully completed at FSS on 4/5 April 1995, and the test campaign started on 17 April at the Swedish Space Corporation's sounding-rocket and balloon launch facility at ESRANGE. All tests performed at Schiphol were repeated in Kiruna after the intervening shipment and reassembly. An end-to-end test with the CNES ground station was also performed at the launch site.

A complete dress rehearsal for the drop test was successfully conducted on 12 May during which operation of the gondola, Probe and ground station was checked whilst commanding the Probe just as during the real flight. A Launch Acceptance Review held at ESRANGE on 13 May showed that all systems were ready for launch.

Flight and recovery

The Huygens Probe System Drop Test took place on 14 May 1995, with the following flight scenario:

4

5

Figure 4. Probe/gondola ascent at the moment of auxiliary balloon release

Figure 5. Main balloon and Probe/gondola ascent after auxiliary balloon release

- Probe/gondola suspension under auxiliary balloons and balloon inflation (Fig. 3)
- launch and ascent (Figs. 4 & 5)
- release of the Probe and subsequent release of the balloon at an altitude of 37.4 km
- free fall of Probe
- descent of Probe and gondola under parachutes
- landing of the various Probe items and the gondola
- recovery of the different Probe items and the gondola (Figs. 6 – 8).

The weather forecast was acceptable and the wind directions in the troposphere and stratosphere, determined with a sounding balloon on the evening of 13 May, confirmed that the wind pattern would guarantee a safe landing for all items descending without a parachute, within the ESRANGE safety zone.

The batteries were fully charged and the Probe was warmed-up overnight to approximately 30°C in order to keep it within temperature limits during the very cold checkout environment on the launch pad and the almost 3 h ascent phase, during which it would be largely inactive. The gondola lifted-off at 8.15 a.m. local time (Figs. 3 & 4) and two in-flight checkouts were performed during the ascent phase, one 1 hour prior to Probe release and one to confirm healthy status at release.

The Probe was released from the gondola at 11.09 a.m. local time at an altitude of 37.4 km. All of the Probe's systems functioned perfectly during the descent, the descent module landing at 11.27 a.m. (Fig. 6). The Probe was operational after landing and good data were transmitted to ground via the gondola, which had a much longer descent time.

All housekeeping data were recorded and distributed to the analysis teams. The film cameras operated flawlessly and the quick-look analysis revealed that the parachutes and mechanisms had operated according to plan. The Probe and the gondola (Fig. 7) were both recovered and flown back by helicopter to the launch site (Fig. 8) the same day; the front shield and back cover were located the same day, but were recovered the following day.

Figure 6. The descent module after landing

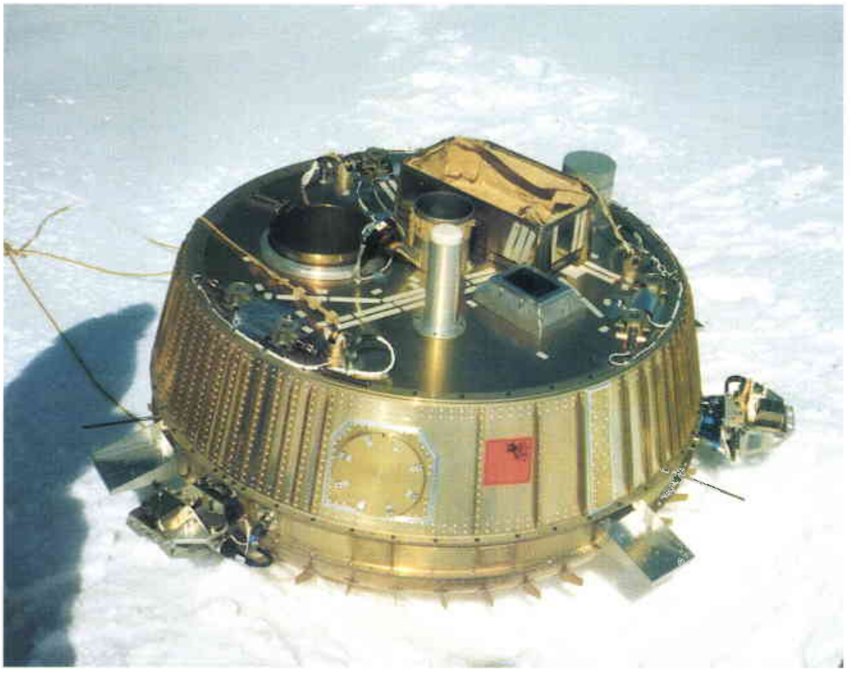


Figure 7. The gondola after landing

Figure 8. Recovery of the gondola by helicopter

Post-flight analysis

The post-flight parachute analyses were conducted by Martin Baker Ltd. and the Probe and system analyses by Aerospatiale. Analyses of the whole sequence of events (parachute deployments/inflations, back-cover and front-shield separations) were based on the film material shot, which was of excellent quality. The other sensors (GPS, gyroscopes, accelerometers) were used for the drag-coefficient and Probe stability analyses.

All three flight parachutes – pilot, main and stabiliser – deployed cleanly and inflated very positively. Pilot- and main-chute inflation occurred at Mach 0.8, at a dynamic pressure representative of conditions on Titan. The parachute deployment and inflation times were as predicted, and the drag coefficients were also within specification.

Detailed analysis of the film taken confirmed that there was no post-separation contact between the Probe and its back cover or front shield. The back-cover separation was slightly faster than predicted, due to a lower Probe wake recirculation (subsonic) compared with the predicted Titan-entry case (supersonic). The front shield's separation showed good correlation between predictions and flight results.

The stability analysis confirmed that the main parachute, operating in the Earth's upper stratosphere, provided very positive damping of Probe oscillations, which is consistent with predictions for Titan's atmosphere.

During the descent phase under the stabiliser chute in the lower stratosphere and troposphere, there was no obvious damping, which is in contradiction with predictions for the Titan atmosphere. Additional helicopter drop tests were therefore conducted and their results demonstrated that this undamped motion was not due to an interaction between the descent module's wake and the stabiliser chute. Further analysis of the wind conditions during the original drop test revealed that during the descent through the lower stratosphere and troposphere the wind had reached speeds of 50 m/s and there was a high wind gradient. It was the resulting turbulence continuously exciting the Probe and stabiliser chute that was causing the undamped motion. Conditions on Titan are such that there will be sufficient damping to stabilise the Probe within specified limits.

The spin analysis showed good agreement between predictions and test results for the descent under the main parachute. Lower than expected spin rates during the descent under the stabiliser chute were recorded. The Probe will nevertheless meet all of the scientific objectives, even under worst-case assumptions.

Conclusions

This highly successful Huygens Probe System Drop Test allowed a complete flight sequence test to be conducted with a full-scale Probe model. Most importantly, it demonstrated: (i) correct parachute deployment/inflation in the Probe's wake, with correct dynamic pressures for the pilot and main chutes: (ii) clean back-cover and front-shield release/separation.

Although the individual parachutes and mechanisms had already been tested extensively at subsystem and system level, the SM2 Probe Drop Test demonstrated the descent sequence under realistic dynamic conditions for the first time and has thereby provided the necessary total confidence regarding the flight-model Probe's successful descent into Titan's atmosphere in November 2004.

Acknowledgement

The considerable experience of the French national space agency, CNES, was of major help in procuring and operating the balloon and the ground station, and in selecting the launch site. The CNES/Air sur l'Adour balloon team was led by P. Faucon.

The Drop Test was conducted by a combined team drawn from the ESA Huygens Project, Aerospatiale, Fokker and Martin Baker, CNES/Air sur l'Adour and ESRANGE.

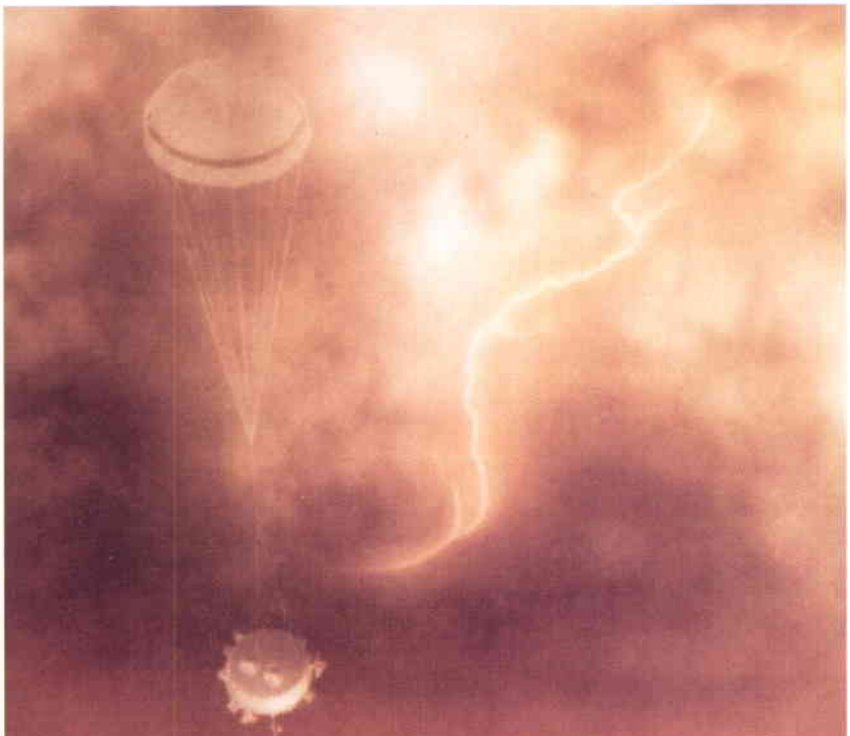
The authors would like to take this opportunity to express their appreciation for the excellent spirit of cooperation between the participants and the efforts of the ESRANGE Launch Site Team, led by S. Kemi and B. Sjöholm.

Lightning Susceptibility of the Huygens Probe

C. McCarthy & H. Hassan
Huygens Project Division, ESA Directorate for Scientific Programmes, ESTEC, Noordwijk, The Netherlands

After an interplanetary cruise phase of some seven years, ESA's Huygens probe will be targeted on Titan and released from its NASA mothercraft, Cassini. Thereafter Huygens will begin its 22-day coast phase prior to entering the Titan atmosphere on an ambitious mission to collect scientific data from the largest moon in the Saturnian system.

To fulfil its mission to collect scientific data from Titan, ESA's Huygens probe must descend through the Titan atmosphere. In doing so, it faces the possibility of being struck by lightning, particularly in the lower regions of the atmosphere where clouds are known to exist. Protection against such a threat had to be built into the design, and the design later had to be tested. It proved to be the first time that a European spacecraft had to be tested for lightning susceptibility. The probe performed well in the testing: it was able to survive all strength of strikes aimed at it. This gives the project team the confidence to forge forward with the assembly of the flight model in preparation for the launch in October 1997.


Artist's impression of the Huygens probe as it descends through Titan's atmosphere

The threat of lightning

During the probe's design phase, concern was raised about the possibility of the probe being struck by lightning during its descent through the Titan atmosphere, particularly in the lower regions where clouds are known to exist (cloud movement causes triboelectric charging). Although there is little hard evidence of spacecraft suffering from lightning strikes during flight, a few facts and incidents deserve to be mentioned:

- During its launch in 1969, Apollo 12 was 'struck' twice as it rose through the cloud layer above Cape Canaveral. No lightning was observed either before or after the launch. The cause of the strikes to the spacecraft in this case is believed to be the intensification of a pre-existing electric field by the presence of the vehicle itself.
- The instrumentation on all four Pioneer Venus probes failed at an altitude of about twelve kilometres. It is possible that the failures were due to electric discharges.
- Research performed by NASA's Ames Centre in California shows that commercial aircraft flying in the United States are struck by lightning once per 3000 hours of flight time, despite the fact that most aircraft operating time is spent above the clouds.

Lightning is known to exist in the atmospheres of Earth and Jupiter, but what about Titan? No terrestrial-like electrical discharges were observed by Voyager 1 during its fly-by in 1980. This, however, does not rule out discharges with a magnitude, repetition rate and characteristics different to those known on Earth. In fact, the objective of one of the Huygens probe experiments will be to search for and characterise lightning in the Titan atmosphere.

Given the threat, it was deemed necessary to protect the probe from damage by a possible Titan lightning strike. The primary method used was to shield all of the probe instruments in a metal 'cocoon'. This decision imposed certain constraints on the design at both system and subsystem level. The effectiveness of the chosen design solutions consequently had to be tested and verified on the Engineering Model (EM) probe.

Testing for lightning susceptibility

Testing of a spacecraft for susceptibility to lightning is unusual for ESA as none of its vehicles have yet been required to perform an entry/re-entry through an atmosphere. In fact, it is believed that the Huygens probe is the first fully functional European spacecraft that may be subjected to direct lightning strikes.

The venue chosen for the test was the Universität der Bundeswehr in Munich, Germany, which is not far from the facilities of Daimler-Benz Aerospace, the company responsible for the assembly, integration and testing of Huygens. The university's high-voltage test facilities are mainly dedicated to research work, but about 20% of their time is allotted to commercial testing in order to stay in touch with the 'outside world'. Where possible, unusual tests are selected for the commercial apportionment. The testing of the probe fell squarely into this category.

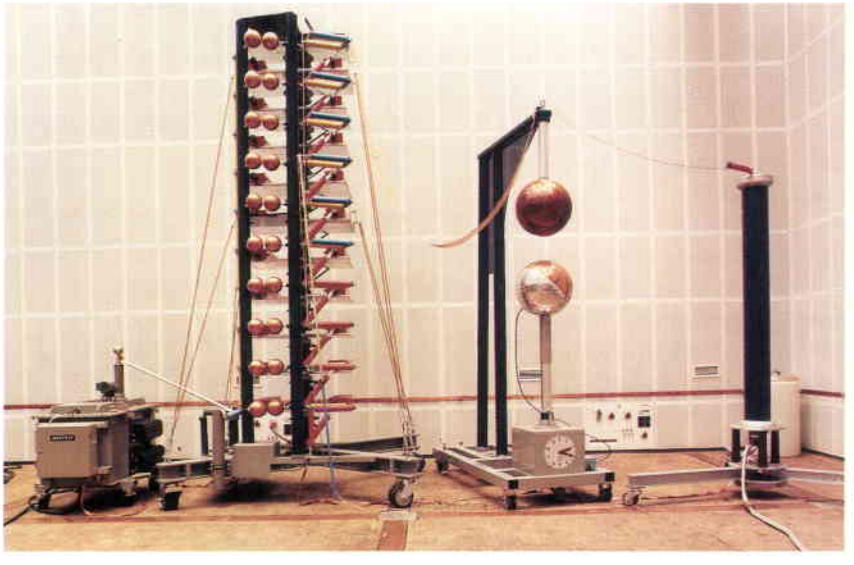


Figure 1. The impulse voltage generator (with only 10 stages). The gold balls (on right) are used to transmit the current to the object being tested.

Figure 2. The lightning current simulator with its two impulse current generators

The facility has:

- An impulse voltage generator (Fig. 1) which has as its source a 12-stage Max generator, with each stage capable of producing up to 100 kV, giving an overall capability of 1.2 MV and 36 kJ. Various output waveforms can be selected as required.
- A lightning current simulator (Fig. 2) comprising two impulse current generators, each with a capability of 100 kV and 100 kJ, capable of producing current peak values up to 200 kA. Various output waveforms can also be selected.

A short example helps to put the above numbers into perspective: the facility performed one test that involved generating an electrical arc over a distance of four metres.

The impulse voltage generator was used to test the probe. The test that was chosen consisted of a number of direct strikes of 5 kA maximum amplitude with a pulse rise time of 50 kA/μs. The amplitude selected is considerably less than the 200 kA used as the terrestrial model when testing an Earth-bound design. Because Titan is much farther from the Sun than the Earth is, there is less energy available on Titan, less convective motion, and Titan has a more conductive atmosphere.

The test configuration used (Fig. 3) was with the probe mounted fore dome upwards and isolated from the ground plane by standing it on wooden blocks. The current was injected by positioning the electrode with an appropriate spark gap at selected points on the fore dome and on the central ring, with the ground strap positioned on the probe top platform and on the central ring.

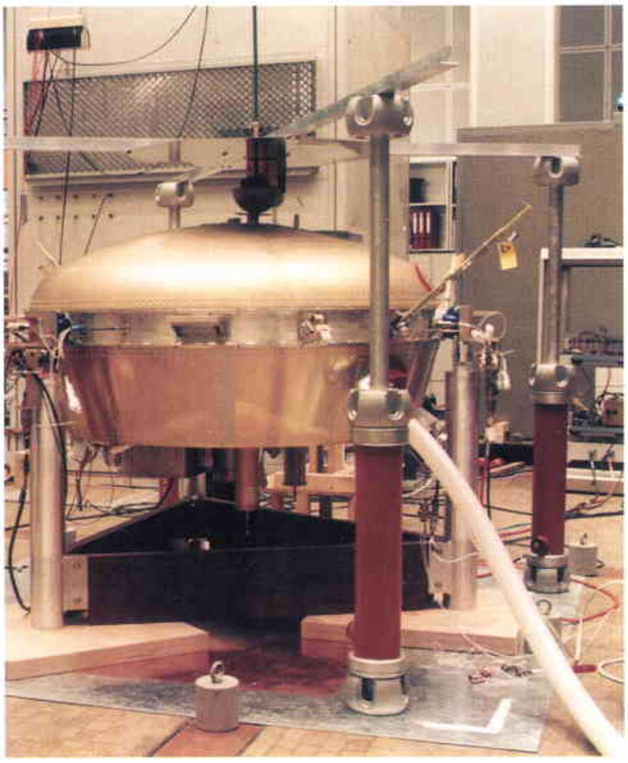
The current injection and exit points were chosen to ensure that main current paths through the probe structure would be through or adjacent to areas of known susceptibility. For example, most cables were routed in a bundle around the periphery of the equipment platform, which is directly on the inside of the central ring, so magnetic fields set up by large current pulses travelling around this ring could conceivably give voltages induced into some of the signal lines contained in these bundles.

The test was performed with the probe activated and running in descent simulation mode, with power being provided by its internal batteries. Data communications were via specially-constructed fibre optic links thereby preserving the electrical isolation of the item under test. Prior to the start of the susceptibility testing, the probe had to be initialised via its Electrical Ground Support Equipment (EGSE); this essentially runs through the procedures performed by the orbiter prior to separation with the probe. Following initialisation, the umbilical connections were disconnected and the EGSE was removed from the test chamber since it is built only to commercial standards and is not 'lightning proof'.

Figure 3a. The probe being prepared for testing, with the impulse voltage generator in the background. The central ring (silver band) separates the fore dome (on top) from the probe top platform (copper-coloured, on bottom)

Probe passes test

The plan was to start the testing with a low-amplitude current level of about 1 kA and build up progressively to the maximum value, noting susceptibility levels if any should occur. Strikes were made first on the fore dome and then on the central ring. Both the audible and visual effects were impressive, even when viewed from a distance of several metres through a protective metallic grid. The probe proved to be virtually impervious to any strength of strike that was directed at it and continued to operate normally throughout the test. There were a few very minor 'hiccups' on the telemetry data stream which resulted in a loss of data for a maximum period of six seconds with autonomous recovery afterwards. This can be tolerated from a systems viewpoint.



3b. The probe undergoing testing for susceptibility to lightning. An electrode (dish shape above fore dome) with a suitable spark gap is placed at selected points on the fore dome and the central ring, and current of different amplitudes is injected.

The EGSE did not fare quite as well. During one lightning strike, the front end rack stopped completely and needed to be reset. When one considers that this rack was not 'wired' to the probe (communication was via an optical link) and had been moved five or six metres away at the time of the strike, it gives an indication of how effective the probe's lightning protection really is. A full post-test checkout was subsequently performed; it showed that all the probe systems had survived the test.

Conclusion

This test marks the end of a successful Huygens Probe EM system test campaign. The results achieved give the team the confidence to go full speed ahead with flight model assembly, leading to launch in October 1997. In turn, it also brings us one step closer to the longer-term objective of receiving pictures and data from Titan's cloud-covered surface in 2004.

Acknowledgement

The authors would like to thank the staff of the Bunderswehr University without whom this particular test would not have been possible, and also the Daimler-Benz Aerospace and Aérospatiale teams for their hard work dedication and cooperative spirit shown throughout the entire EM test campaign.

The Ariane-5 Booster Recovery System

J. Gigou
Directorate of Launchers, ESA, Paris

J.M. Astorg
Directorate of Launchers, CNES, Evry, France

F. Barreau
Directorate of Launchers, Aérospatiale, Les Mureaux, France

Ariane-5's solid-rocket boosters are designed for high reliability and minimum cost. Already during the preliminary design stage, the possibility of recovering the boosters after flight was therefore considered to be of great interest for meeting both of these goals. To ensure enhanced reliability during the entire production phase, there will be stringent post-flight inspection of the spent boosters. The possibility of refurbishing and reusing the recovered boosters has, however, been rejected. It is currently considered a non-cost-effective option because of the specific design and reliability complications that this would incur. It is currently planned to recover four boosters per year.

Introduction

The Ariane-5 heavy-lift vehicle currently under development is the successor to the Ariane-4 generation of launchers. Specific Ariane-5 design goals are:
- optimum performance
- low launch costs
- very high reliability and safety, and
- operational flexibility.

Ariane-5 is being developed under the auspices of ESA, which has entrusted the prime contractorship for the programme to the French National Space Agency (CNES).

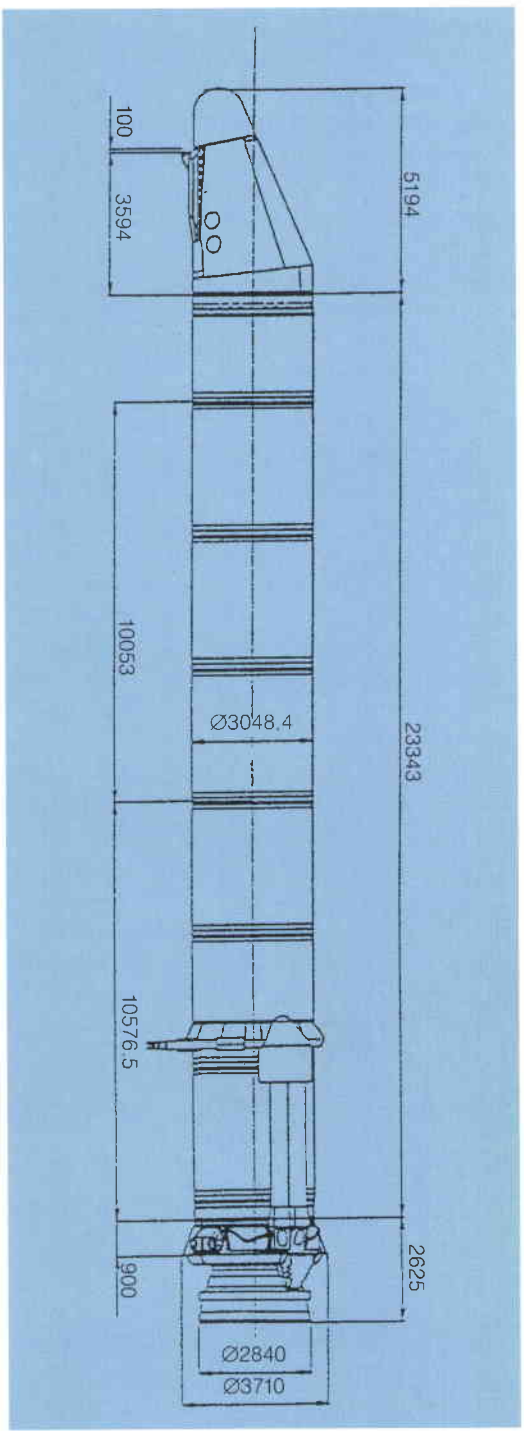
For the first two minutes of Ariane-5 flight, propulsion will be provided mainly by two large solid boosters (EAPs), assisted by the cryogenic main stage, which forms the lower composite of the launcher. The upper composite includes the Vehicle Equipment Bay (VEB), a storable-liquid-propellant stage, a fairing, and a dual-launch Ariane support structure (SPELTRA) and adapters (Fig. 1). Payloads are housed under the fairing and in the case of a dual launch within the SPELTRA.

The twin solid boosters have been designed and developed by:
- Aérospatiale (F) which is responsible for the booster stage, and whose main subcontractors are SABCA (B), Fokker (NL),

Figure 1. Ariane-5 on the launch pad

Dassault (F) and Raufoss (N)
- Europropulsion, a joint venture between SEP (F) and BPD (I), which is responsible for the solid-propellant engine.

The EAP stage (Fig. 2) consists of:
- a solid-propellant engine, whose function is to provide thrust
- a conical aluminium aft skirt, which acts as a support for the launcher on the launch table until lift-off
- a conical aluminium front skirt, a structure which is at a 12° angle, terminated by a hemispherical nose cone structure which transmits thrust to the cryogenic main stage through a damper device and includes the electrical flight and recovery systems
- a forward attachment device, which transmits the longitudinal and transverse loads between the solid-booster stage and the cryogenic main stage
- an aft attachment device, whose main task is to transmit transverse loads between the solid-booster stage and the cryogenic main stage
- a nozzle actuator unit, which directs thrust
- a telemetry subsystem
- pyrotechnic subsystems for stage separation and range safety.



The total mass of the EAP stage is 277 tons at lift-off, decreasing to 40 tons at the end of a two-minute burn. The boosters are then separated from the main stage and are ready to enter their recovery phase.

Moscow's Scientific Research Institute for Parachute Construction (SRIPC), which has much experience in recovery systems, has been helping with the development of the Ariane-5 booster recovery system. SRIPC has been involved in all Soviet manned space recovery systems, including that for the Soyuz capsules.

One of the challenges in developing the Ariane-5 Booster Recovery System (BRS) has been that of working with a variety of such

Figure 2. One of the Ariane-5 boosters

organisations with different technical and managerial methods. The excellent cooperation that has been established between the different organisations involved, coupled with the extensive ground testing and simulation that have been conducted have contributed to the present high degree of confidence in the system that has been developed.

Fokker Space and Systems has been responsible for the BRS system studies and hardware development management. SRIPC and Spain's Confecciones Industriales Madrilenas (CIMSA), in the form of Union Temporal de Empresas (UTE), develops, qualifies and produces the BRS parachutes, canister and the control box, including the altitude-determination system.

For the nose-cone release system, the pyrotechnic pistons are developed by Aérospatiale (F) and the pyrotechnic chain by Dassault (F) as an Aérospatiale sub-contractor.

The maritime segment is designed by the German company Harms-Bergung and the maritime operations in French Guiana will be managed by CNES.

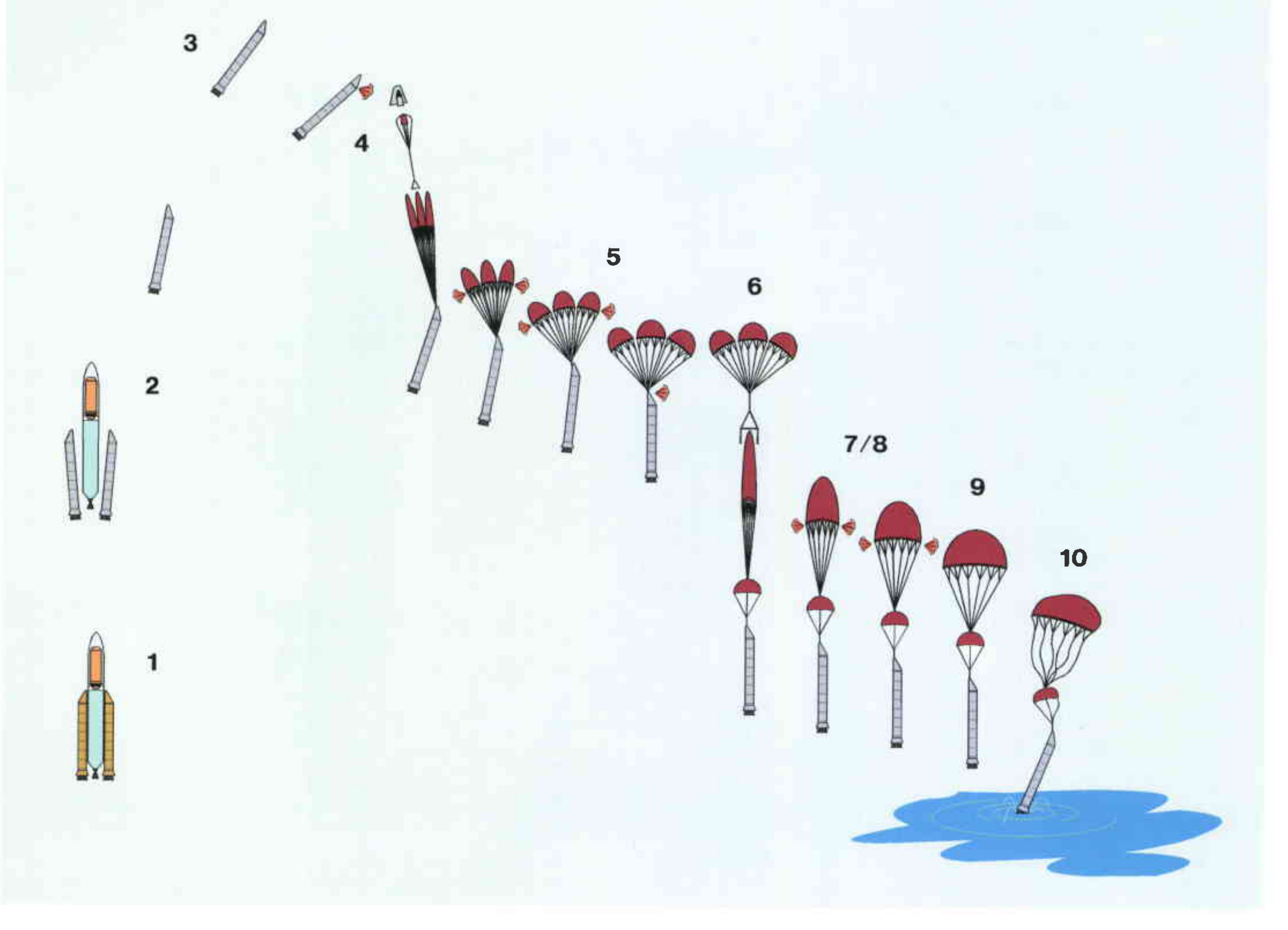
The on-board system

The reduction in launcher payload capacity due to the inclusion of the Booster Recovery System (BRS) is small, and the system can be omitted when necessary for launch performance reasons.

All BRS elements are housed in the booster's front skirt. The BRS is equipped with its own power supply and control system and has limited electrical connections to the stage. The control system maintains the BRS in a 'dormant state' during Ariane's ascent phase and for up to 10 seconds after EAP separation. This ensures that there is no possibility of accidental operation of the parachute chain and no electrical interference with the launcher systems.

Before splashdown, the EAP stage is decelerated to a speed of 27 m/s and reoriented into a vertical nozzle-down position with a 10° maximum impact angle. A four-stage parachute system is used, which includes an auxiliary parachute, a cluster of three drogue parachutes, a main parachute, and an additional chute to limit the speed increase during the main parachute's deployment (Fig. 3 and Table 1).

Figure 3. Schematic of the Booster Recovery System's operation. The main events (1–10) are listed in Table 1 (next page)



These six parachutes are packed in separate bags , compressed to reduce volume, and housed in the parachute canister. The auxiliary parachute is linked to the nose cone by a 15-metre strap. The drogue parachute is connected to the booster via a removable anchor bracket. The main and additional parachutes are connected to the booster skirt via a fixed anchor bracket. All of these elements, including the moving parts of the anchor brackets, are delivered in kit form ready for use.

The canister (Fig. 4) is made up of welded aluminium skin panels with a beam-reinforced bottom and four connection brackets to the first ring frame at the top section. Four struts located in the middle of the shell and connected to the third ring frame prevent any lateral motion under the 18 g maximum ascent and re-entry flight loadings.

Both anchor brackets for the drogue and main parachutes are made of titanium alloy to save weight, but must be strong enough to transfer

Figure 4. The parachute canister

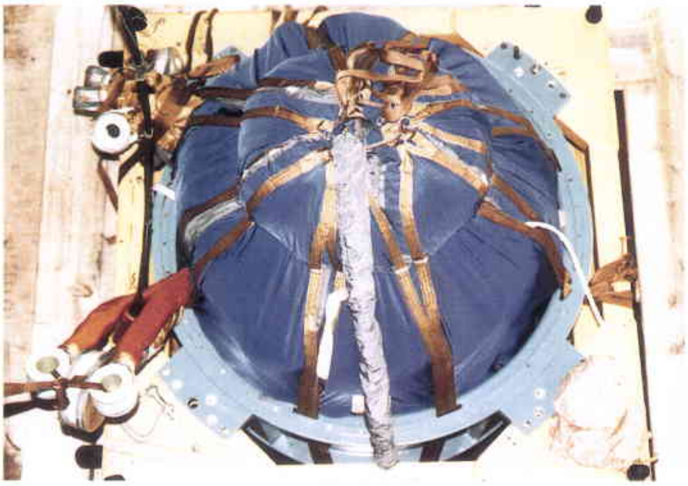


Table 1. Main events in the booster recovery sequence

Altitude	Events (referenced to Fig. 3)	Initiated by
0	Launch phase (1)	
±10 km	Removal of first safety barrier in control system (switching of baro relay) (1)	Pressure
59 km	Booster separation from central stage (2) Removal of second safety barrier in control system. Arming of safety device (BSA).	Electrical signal supplied by booster
150 km	Culmination of ballistic phase (3)	
8.5 – 27 km	Removal of third safety barrier in control system (switching of baro relay), initiation of Altitude Determination System (ADS) (3)	Pressure
4.8 – 5.2 km	Ignition of nose-cone release expandable tube (4) Ignition of nose-cone separation pistons Separation of nose cone Release and deployment of auxiliary parachute Release and deployment of drogue parachutes De-reefing of three drogue parachutes, in four steps (5)	Altitude from ADS Time delay from ADS Separation piston force + aerodynamic force Nose cone movement Auxiliary parachute force Built-in cable cutters with pyrotechnic delay
1320 – 2770 m	Activation of drogue strap release pyros and release of drogue parachutes (6) Release and deployment of additional parachute (7 & 8)	Time delay from ADS Drogue parachute force
1200 – 2640 m	Release and deployment of main parachute (7 & 8) De-reefing of main parachute, in four steps (9)	Drogue parachute force Built-in cable cutters with pyrotechnic delay
0	Splashdown at v < 27 m/s (10)	

shock loadings of up to 132 tons at parachute opening.

The nose-cone release system (Fig. 5) uses an expandable tube to break the connection ring to the cone and prevent any fragment generation towards the parachute pack. The cone is jettisoned at 27 m/s with the help of four pyrotechnic pistons installed on the first ring frame of the booster. These pistons and the tube are activated simultaneously by a pyrotechnic chain. The pyro command is generated by the control system and secured by a safe-and-arm device (BSA). The safe position is maintained until the end of the ascent flight to avoid any risk of premature separation.

The control system consists of a control box (Fig. 6), an altitude determination system (ADS), and a power supply. The three subsystems are fully redundant to ensure a high degree of reliability. Power is supplied by two nickel-cadmium batteries. The control box is activated just before booster separation by a command from the on-board computer.

Integration of the BRS into the booster skirt

The parachute system is integrated into the skirt during the booster's final assembly in Kourou, French Guiana. This operation is carried out using a special jig to give the parachute system the necessary 12° inclination in the skirt (Fig. 7). Two removable guide rails prevent any contact between the parachute system and the booster during installation, and align the positions of the threaded holes for connection. The two brackets of the drogue and main parachutes are connected with their counterparts on the top ring. Once the pyrotechnic chains have been connected, the nose cone closes the front skirt of the booster.

Figure 5. The booster's nose cone

Development status

Qualification testing of the parachute chain has included three release tests from a helicopter with a mass of 5 tons for the qualification of the drogue parachute, and five release tests from aircraft with a mass representative of the booster for the qualification of the overall parachute chain (Fig. 8). A failure during one of the drop tests led to a redesigning of the main parachutes, which were subsequently successfully requalified.

The canister and control box have also been flight-qualified and all tests have been successfully completed.

The nose-cone separation static test has already been completed and the dynamic test respecting the real dynamic pressure conditions is presently being prepared in Russia.

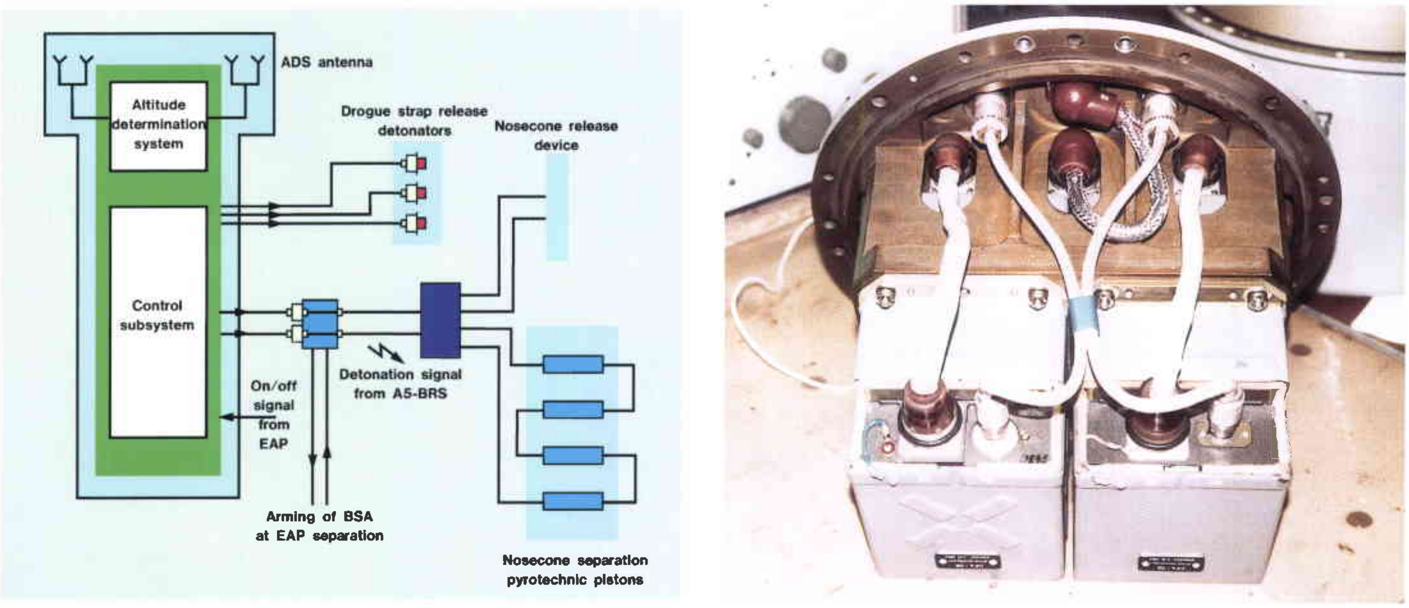


Figure 6. The control system and its layout

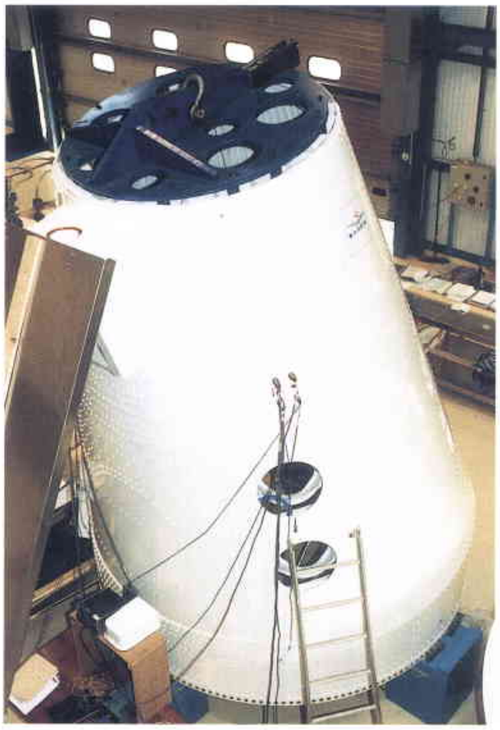
Qualification of all pyrotechnic devices, including safety testing (e.g. ignition of reefing cutter in folded parachute pack) has also already been completed.

The maritime segment

The two boosters will fall back into the Atlantic Ocean approximately 500 km down range of the Kourou launch site. Impact will occur nozzle-first, with the main and supporting parachutes remaining attached to the booster's front skirt. After impact, the booster will stabilise in a vertical position with about 10 m of it above the water.

A specially equipped vessel will be waiting, approximately 8 km from the expected splash-down point, to tow the two boosters to Kourou harbour, to be dismantled ready for post-flight examination, first in Guiana and later in Europe. To facilitate the search process, both boosters will be equipped with Sarsat localisation and homing beacons.

Prior to towing, each booster will be rotated into a horizontal position using a special inflatable buoy installed in the booster's nozzle by divers. Air will then be injected to expel the water from the motor. The total recovery operation, including towing back to Kourou harbour, is expected to take about 80 hours.



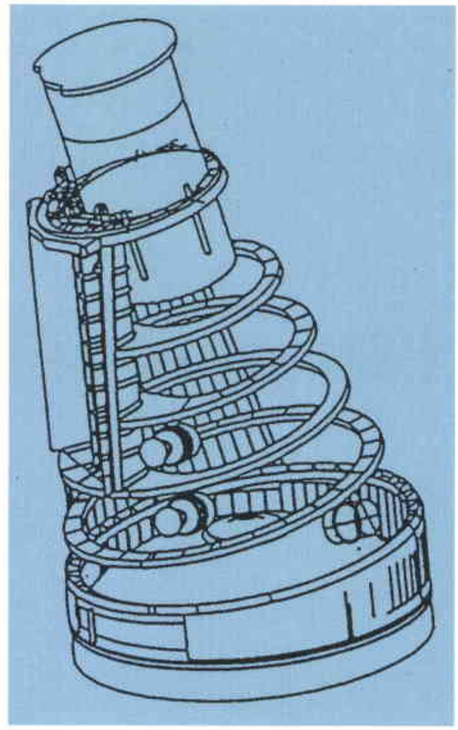


Figure 7. Integration of the parachute system into the skirt

Conclusion

All booster recovery qualification tests have been completed apart from two nose-cone separation tests. The flight-model boosters for the first launch of Ariane-5 (V501), presently expected to take place in April 1996, have already been delivered to the Kourou launch site.

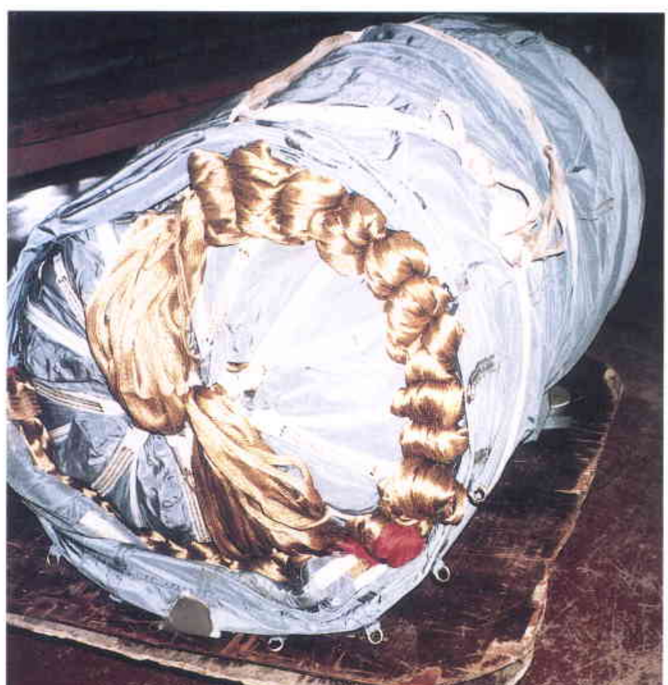
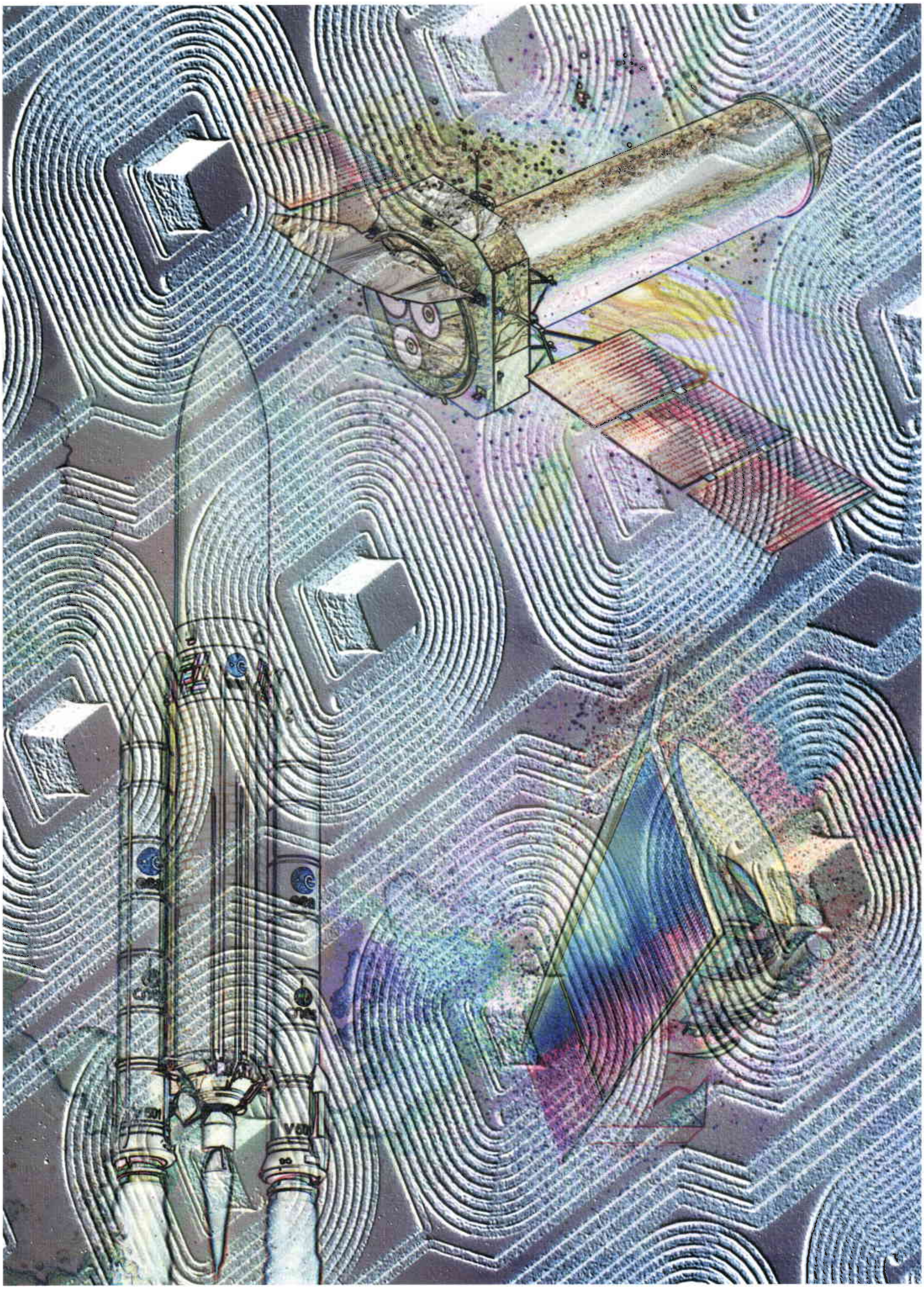


Figure 8. One of the parachute release tests



Future Applications of Micro/Nano-Technologies in Space Systems

A. Martínez de Aragón
Technical Directorate, Systems and Programmatics Department,
System Studies Division, ESTEC, Noordwijk, The Netherlands

The reduction of costs for a given performance is a major goal of space systems technologists. Extreme miniaturisation, by reducing the levels of resources required, is a possible solution. Micro/nano-technologies allow the production of multiple types of microdevices and their integration into microsystems, resulting in application-specific integrated microinstruments. In recognition of their importance, ESTEC and Industry held a Round Table on Micro/Nano-technologies for Space. Based on the conclusions and recommendations made at the meeting, activities are proposed to gradually introduce these technologies in space-based systems.

The challenge to reduce costs and delays in space activities

The main objective of most space agencies in the mid to long term is to reduce the costs and delays associated with space-based services. This means strongly reducing spacecraft lifecycle costs and lead time, without reducing (and most likely increasing) performance. In turn, this would allow the full potential of space to be exploited and space-based systems to be competitive with ground-based systems that provide similar services. For scientific and experimental missions, more data and data of a higher quality and interest would be produced within a shorter time from the mission approval, and that within the budgetary limitations, to satisfy the respective communities. In commercial sectors, space-based services should be considerably cheaper for the operator than the equivalent ground services in order to offset some perceived disadvantages of space, such as difficult (if not impossible) upgrades and maintenance or less direct control, and to become competitive.

Spacecraft manufacturing is currently a labour-intensive, one-off, artisanal task: few similar units are ever produced. Due to this fact, traditional cost reduction approaches such as new design and production paradigms, modularity, and pre-fabrication, will help reduce the costs, but not to the required levels. A sensible way to significantly decrease costs and enable commercialisation could be via a technology or engineering break-through, oriented towards mass production of space subsystems, and based on distributed (instead of the current centralised) systems and services. The economies of scale achieved by centralising functions would be exceeded by mass-production savings, and a new lifecycle could be initiated, resulting in more affordable space-based systems and services.

Figure 1. Magnetic printing heads (in background) with magnetic poles and metallic coils integrated on silicon, produced by CESM (CH).

Why micro/nano-technologies?

One area where innovation is proceeding at a very fast pace is miniaturisation, as may be observed in everyday life. High levels of miniaturisation may be achieved by applying micro/nano-technologies. The term micro/nano-technology is broadly defined to encompass the synthesis and integration of materials, processes and devices of sub-millimetre to submicron size. It is used to mark a distinction between micro (current state of the art in disciplines such as electronics) and nano (mostly understood as referring to molecular devices). These technologies allow the production of microsystems (the European term) and microelectromechanical systems (MEMS, the American term), understood to be the integration of microelectronics with peripherals and micromechanics, and resulting in devices such as application-specific integrated microinstruments (ASIM) and eventually nano-satellites (satellites weighing only a few kilograms).

Microengineering is a discipline dealing with the design, materials synthesis, micro-machining, assembly, integration and packaging of miniature 2-D and 3-D sensors, actuators, microelectronics and microelectro-mechanical systems. The goal of the discipline is to develop and produce intelligent micro-instruments, and some results are currently being applied, in among other areas, medicine or the automotive industry: smart (chemical, pressure, temperature) sensors to reduce emissions, smart microaccelerometers for crash detection and airbag deployment, and smart micro-gyroscopes in active suspension systems.

Microsystems manufacturing relies mostly on the equipment and fabrication techniques used for very large scale integration in the electronics industry, as for example to produce microprocessors. It is expected that the advantages shown by these techniques in terms of cost and reliability, e.g. in current computers, will also apply to microinstruments and microsystems. Other techniques are specific to microsystems, such as bulk and surface micromachining and LIGA (Lithographie mit Synchrotonstrahlung, Galvanoformung und Abformtechnik mit Kunststoffen, or deep-etch X-ray lithography, electroforming and moulding), the latter allowing moulds for mass fabrication of microstructures to be produced.

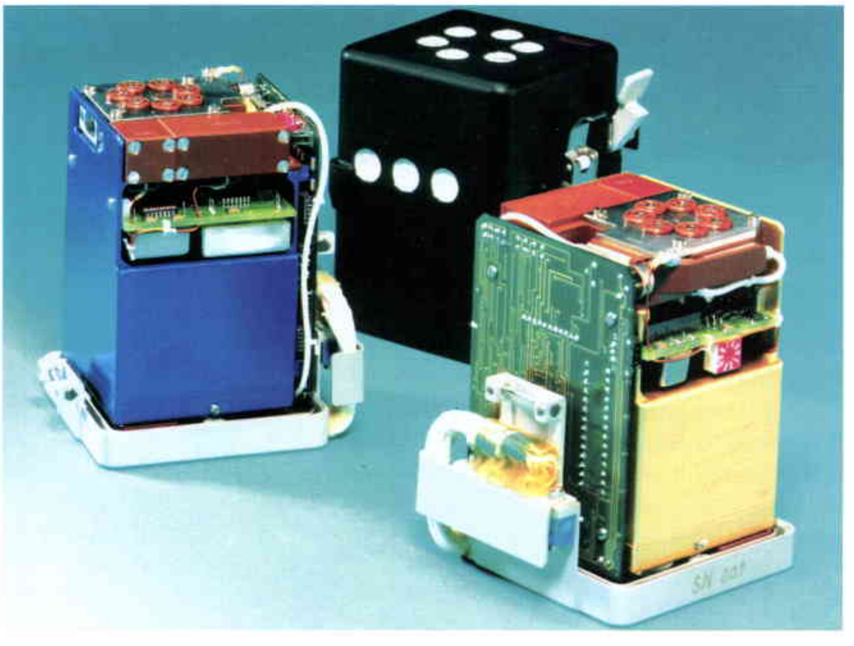


Figure 2. Flight models of the Space Bioreactor, mounted on the base of a Type II experiment container (black box at the back). Dimensions: 84 x 60 x 60 mm³. Produced under ESA contract 10080/92 by Mecanex S.A. (CH) in collaboration with the Institute of Microtechnology (IMT) at Neuchâtel and the Space Biology Group ETH Zurich. The limited space available in the experiment container made essential the use of miniaturised components. Key elements are a micropump for fluid circulation and microsensors to monitor vital parameters in the reactor chamber, manufactured at IMT. Four units flew on STS-65 (1994), and it is scheduled for reflight in March 1996.

Most European countries are heavily involved in microsystems research, with public funding at high levels. As an example, the European Union will invest about 100 million ECU in the Fourth Framework Programme, through the ESPRIT and BRITE-EURAM programmes, in microsystems and related technologies. ESA member states have the capability to produce and, with high proficiency, to design new devices and to conduct research on new concepts and applications. Although the quality of fundamental research, creativity and ingenuity are high in Europe, applications are still scarce and there seems to be a gap between research on the one hand and industry or users on the other.

The main advantages offered by micro/nano-technologies are:

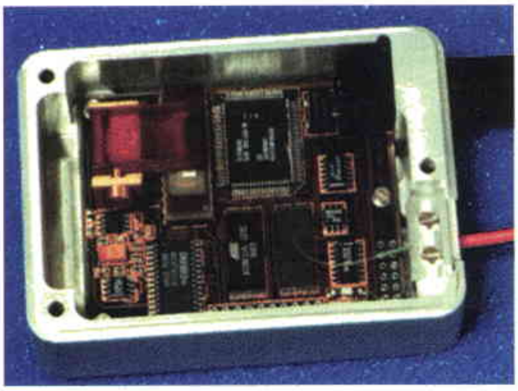
- the total resources required (e.g. mass, volume, power) are reduced
- a simple overall system results from the integrated microsystem replacing several discrete components
- microsystems are produced in a batch process, which adds mass production benefits such as low unit cost and the possibility of incorporating redundancy into the wafer layout by design
- high system reliability is made possible by incorporating several microsystems for redundancy (the low unit cost and low resources required per unit make replication feasible) and via built-in redundancy, resulting in lower risks
- system performance per unit cost and mass is higher, which could be used to reduce the total cost (commercial systems) or to increase the total performance for a given cost
- small test facilities are suitable
- there are synergies between different sectors, which would allow the production of common microsystems and thus help reduce for each sector the high development costs and the investments required to reach maturity, and solve microsystems limitations; joint developments would allow the critical mass needed to fully profit from batch production advantages to be reached.

These advantages are even more significant for the space sector, where each of the points has a strong influence on cost. Microminiaturisation could play an essential role in Europe in designing new generation satellites, thus preparing the European space industry for the challenges of the global competitive market. The impact could be similar to that achieved by the transition from the vacuum tube to the integrated circuit, which has resulted in the huge consumer electronics market.

Microsystems are a growth sector, although one that is still in the early development phase. As such, there are a number of critical issues that would require specific actions for their correction, such as:

- the cultural change required to accept and fully exploit the advantages offered by

microsystems, which demands new ways to present and discuss problems (new or old) and for new paradigms in their solution, and not just the miniaturisation of current solutions
- the generation of embedded software to allow smooth and reliable operation of microsystems which, given the flexibility required to operate smartly, communicate and interface with other microsystems and the external world, will be extremely complex
- lifetime, which is of particular concern, notably for micromechanical parts, since their reduced dimensions change the importance of some effects (e.g. friction) with respect to ordinary-sized components; in addition, some characteristics of the materials used introduce undesired effects that have to be compensated in new ways (for example, valves made of silicon, which



leak under high pressure due to silicon's rigidity, requiring innovative solutions)
- the development of low-volume production and testing techniques for devices having a minimum feature size of less than 0.2 microns
- packaging and interconnecting, which for microsystems are significantly different from semiconductor and hybrid packaging due to the sensors and actuators having to interact with the environment and being frequently exposed to rougher operating conditions; in addition, the packaging and interconnection costs may be a significant part of the total microsystem cost
- the need for improved tools for the computer-aided design of microsystems.

Micro/nano-technologies in space

Launch is one of the highest cost factors for space-based systems and is directly related to mass. Payload and platform are the two other major contributors to cost. The platform mass and cost are related to the payload mass, power requirements and volume. Any reduction in mass, volume and power requirements is thus desirable and will have a significant effect on cost. Microsystems are considered an excellent means of obtaining these reductions. They could become the means to implement decentralisation, whereby a given number of dispersed components could be used in place of a larger centralised unit, thus achieving greater efficiency, redundancy and economies of scale. This leads to cost reduction on space-based systems — not only at the payload and platform levels but also in launchers and ground facilities down to the end-user — through the economies of scale achieved by batch production, and the replacement of some high-performance units with multiple standard-performance parts, each based on a

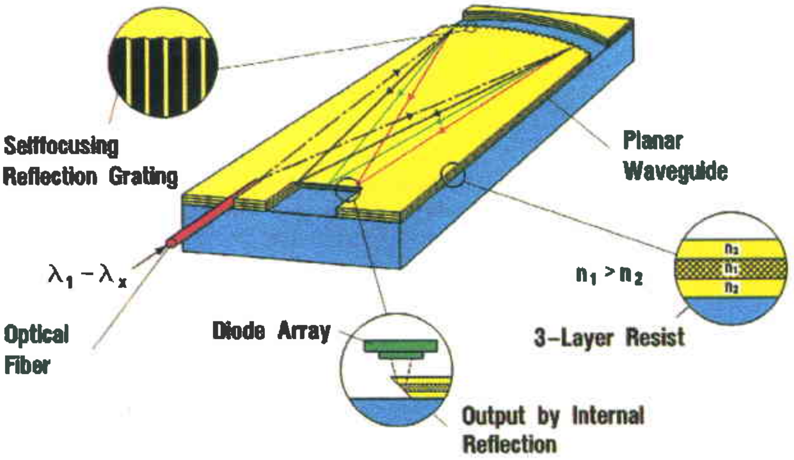


Figure 3. Complete microspectrometer system: A LIGA microspectrometer is placed on a photodiode array, in the upper left corner (orange rectangle). Its dimensions are 18 x 7 x 6 mm³. The critical dimensions are the grating teeth with 3 m length and 0.2 m height which extends over the full LIGA height of 125 m. The system's characteristics are: sensible to energy in wavelenghts from 400 to 1100 nm (other ranges also available: near UV, IR), transmission of 25%, spectral resolution 7 nm, dynamic range up to 20000; ADC, micro-controller and serial port included. The overall dimensions of the system are 70 x 60 x 15 mm³. The signal is received from the collecting optics via fibre-optics. Developed at the Institut für Microstrukturtechnik (FZK/IMT), Forschungszentrum Karlsruhe GmbH (D) with internal funds. Being considered as instrument in preliminary analysis.

microsystem. This is because cost increases exponentially with performance after a certain point. This requires new ways of thinking about the services demanded, and the systems needed to provide those services. In the space sector, other changes would be necessary, such as in the path from data acquisition on-board the spacecraft to delivery of information to the end-user, spacecraft networking, launch, de-orbiting, operations, ground infrastructure, tracking and station-keeping, amongst others.

The Technical Directorate of the European Space Agency started considering micro/nano-technologies and the resulting microsystems to solve specific problems in the early 1980s. Since then, activities have taken place in areas such as micro-sensors, -optics, -lasers, -mechanics, -electronics, life support, bio-reactors, robotics, thus showing the multidisciplinary nature and potential of micro/nano-technologies. European microsystems have flown on several space missions, including Olympus and several Space Shuttle missions.

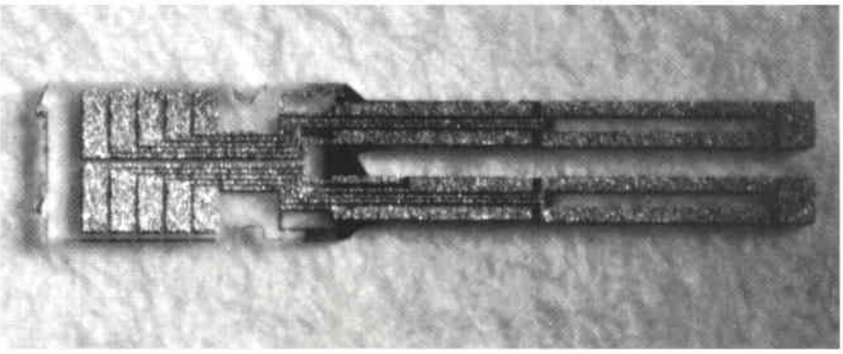


Figure 4. Quartz angular rate sensor (tuning fork) developed by Jan Söderkvist, Colibri Pro Development AB (S), for automotive and other applications. The sensor is well suited to space applications due to its small size and ability to withstand harsh conditions. The tines of the tuning fork sensor element shown are 2.5 mm long.

Based on the developing interest, the increasing internal activity, the perceived potential of micro/nano-technologies and a growing system awareness, an informal working group was formed in ESA's Technical Directorate. Contacts were made with European industry, research centres and organisations, as well as the European Union. A preliminary assessment showed that micro/nano-technologies constitute a good target for cooperative applied research under the coordination of an organisation such as ESA, since space may provide good opportunities to demonstrate the potential of microsystems, which then may help the space sector in opening ways to reduce costs and broaden applications. In addition, the innovative concepts required to create microsystems may permeate into the space sector and stimulate new mission ideas. Activities could be coordinated amongst the different interested parties, including funding institutions, to avoid duplication of efforts and increase the overall effectiveness.

Round Table on Micro/Nano-Technologies for Space held

The ESA Working Group on Micro/Nano-Technologies recommended holding a Round Table on Micro/Nano-Technologies for Space together with Industry. This Round Table, which was organised by the System Studies Division of the Technical Directorate, took place on 27 – 28 March 1995 at ESTEC in The Netherlands. The support of the national delegations was essential to the success of the Round Table. The main objectives, framed by the generic goal of reducing the costs of access to space and of space-based services, were to better understand micro/nano-technologies and how these technologies may benefit the space sector, to establish working contacts with the micro/nano-technologies community, and to generate ideas on the potential uses and new missions which micro/nano-technologies may enable*.

The Round Table was organised around the following points:

a) presenting microsystems technologies to the space community: ESA, national delegations and space agencies, industry, and research institutions
b) presenting the peculiarities of space systems, together with areas where microsystems could be applied in the future, to an interested selection of microsystems researchers
c) presenting what other non-European space agencies are planning for the future
d) proposing recommendations for the future and making suggestions for an action plan.

The general conclusion was that micro/nano-technologies could, in due time:

— contribute to a significant reduction in the cost of access to space, profiting from microsystems' recognised advantages and ultimately based on distributed systems and services
— make possible certain types of missions and applications, by virtue of their volume/mass/power reduction potential.

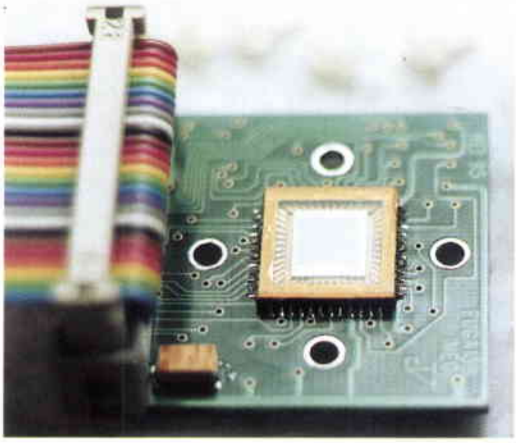


Figure 5. The Fuga 15 video camera chip is the basis of the visual telemetry system on-board Envisat. It is being developed by MMS (F), IMEC (B) and OIP (B). The microcamera features include random addressable pixels, logarithmic response and a digital interface.

* The Round Table presentations have been published as ESA WPP-91. To order a copy, contact the author by fax (31.71.565.5184) or by e-mail (amartine @vmprofs.estec.esa.nl).

One basic view that emerged from the Round Table was that the competence to manage the technologies required to produce micro-devices (in the fields of sensors, optics, lasers, mechanisms, electronics, etc) and to combine them into one fully working microsystem had to be fully developed in Europe. The space sector may offer possibilities for demonstrating the usefulness of these technologies and ESA should help develop the competence to design and produce micro-systems adapted to the space environment and capable of satisfying the space sector requirements.

It was agreed that micro/nano-technologies should be seen as a key factor within the cost reduction and miniaturisation efforts. These technologies could be a means to produce very small payloads and spacecraft with all the related benefits. Micro/nano-technologies are suitable for building distributed systems consisting of several similar or identical small units, whose combined effect would be equivalent to that of one large system unit. This type of concept is the basis, among others, of very long baseline interferometry, synthetic aperture radar and phased arrays.

It was also recommended that a detailed analysis should be initiated to derive specific requirements based on common space missions requirements which could be presented to the micro/nano-technologies community for evaluation. Instruments for Earth observation, planetary exploration, space science and communications missions should be specified. Increases in the platform efficiency per unit mass could be based on advances in areas such as management of highly distributed systems and the data they generate, decentralised control and support (e.g. power regulation at the user level), autonomy (of each subsystem and of the total spacecraft), on-board intelligence, spacecraft networks, inter-spacecraft communications. These are some of the subjects to consider at the space segment level, together with product assurance and qualification, in addition to how the subsystems and payload mass, volume and power consumption should be reduced. Similar analysis should be applied to the ground equipment and the launchers.

Other general recommendations, amongst the major suggestions of the Round Table, included those to reconsider product assurance and the space qualification process, and to follow standardisation efforts in industry and specialised organisations, within the objective of defining reusable modules.

The Round Table considered that ESA should endeavour to:

- adopt innovative systems approaches specifically for microsystems
- evaluate at pre-phase-A level distributed missions profiting from microtechnology's potential (a distributed payload could be MIRAS in the microwaves region of the spectrum; an optical imager could be distributed on several spacecraft)
- analyse at a basic level payload/missions using commercial off-the-shelf components, and then assess and study what should be done to space-qualify the result.

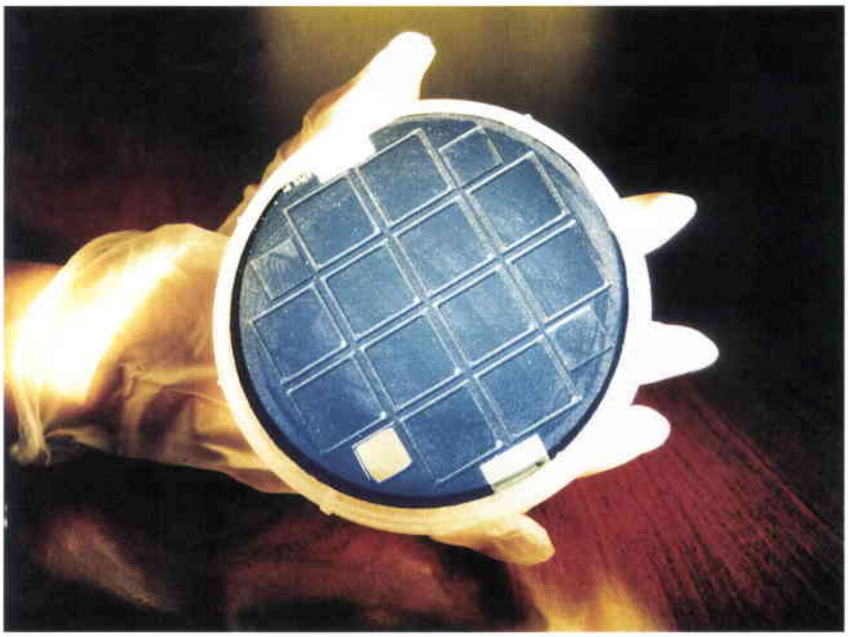


Figure 6. Thermal switch for temperature control. The emissivity may be changed to any value, which allows dynamic temperature control. Internally funded development conducted by Verhaert D&D (Kruibeke, B), IMEC (Leuven, B) and Wildcat Micromachining (USA). Its adaptation to space is under study.

Actions proposed for future activities on micro/nano-technologies for space include:

- specify space-related requirements to device developers, and assess with them the feasibility of those requirements
- establish good communication channels between potential space users and micro-systems developers (research centres, laboratories, universities, industry)
- initiate small programmes for developing and qualifying integrated devices for adverse environments (with utilisation in space)
- harmonise ESA initiatives with national and European Union programmes, including demonstrators for the technologies
- introduce microsystems as a specific subject within ESA's technology programmes

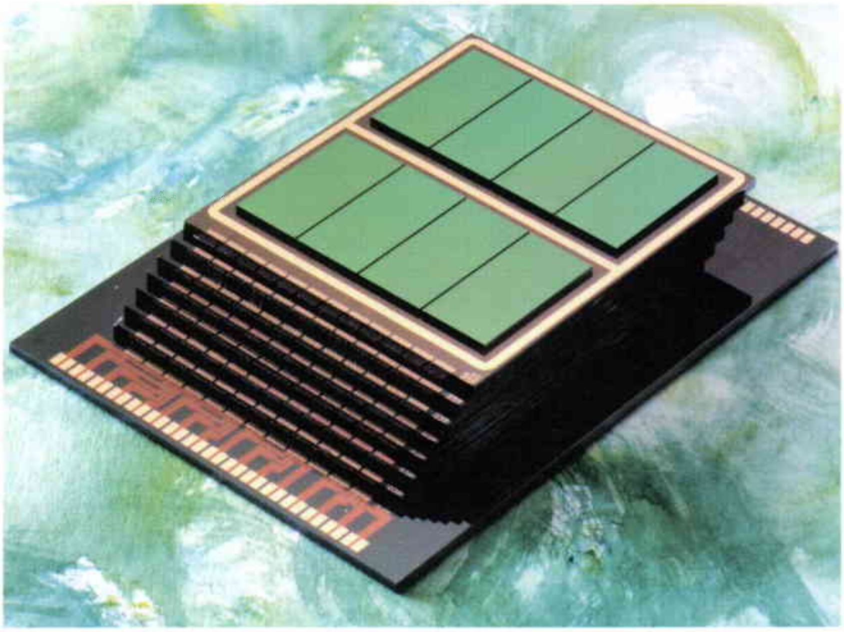


Figure 7. 3-D multi-chip-module (MCM) associating 8 x 8 silicon chips in 8 levels connected by fusible microbumps and wire bonding. Developed by LETI (Laboratoire d'électronique, de technologie et d'instrumentation, F), this MCM has 1 Gigabit memory capacity.

— study, at the system level, mission opportunities and the implications of the cultural change associated with micro/nano-technologies.

How to proceed

The motivation behind the application of microsystems to space is manifold: significant cost reductions, the possibility of enabling new functions and improving the performance of existing ones, better ways of doing a job, the ability to accommodate data proliferation and increases in data quality, shorter development times, controlled risk, with all of these reasons resulting in better performances per unit cost and mass.

Microsystems are being developed at a fast pace for applications in areas such as automobiles, medicine, aeronautics, defence, and consumer electronics. The space sector should follow closely these developments in search of synergies, and be ready to adapt and integrate available elements, and profit from the industrial push. Joint actions could be contemplated with other European and national organisations. In this respect, most welcome is the EuroPractice action, funded by the European Union's ESPRIT programme, where four clusters of manufacturing and testing companies have been selected in Europe to facilitate the access to design and production facilities for microsystems as well as multichip modules and application-specific integrated circuits to users interested in accessing advanced technologies.

The photos shown here present some current and foreseen space applications. Some, as is the case for life sciences studies confined to small volumes, have been made possible by the high miniaturisation levels microsystems permit. Other available microsystems having a potential use in space are, for instance, spectroradiometers, mass spectrometers, microcameras, multiparameter logistic sensors, distributed unattended sensors, embedded sensors and actuators, inertial navigation units, GPS receivers, propellant leak detectors and wear monitors for ball bearings.

Essential for fully exploiting microsystems potential are new ways of addressing the problems to be solved, and the search for different solutions. Applications and devices based on principles different to those on which conventional units are based have to appear for the full potential of micro/nano-technologies to be exploited. An example from the past is the replacement of electro-mechanical scan imagers with CCDs. Currently, rotating masses are being replaced by vibrating combs and tuning forks in microgyroscopes and angular rate sensors, microaccelerometers could be used instead of Earth sensors, microresonators could be used in place of much bigger SAW filters, and microelectromechanical RF switches could provide better isolation than PIN diodes.

There are, however, some space-specific limitations of microsystems, and the space sector will have to devote resources to overcome them if it wishes to make widespread use of microsystems in all possible types of mission. The two most critical limitations are the high costs of development or adaptation to space and the high susceptibility to radiation. As for any other devices having a high degree

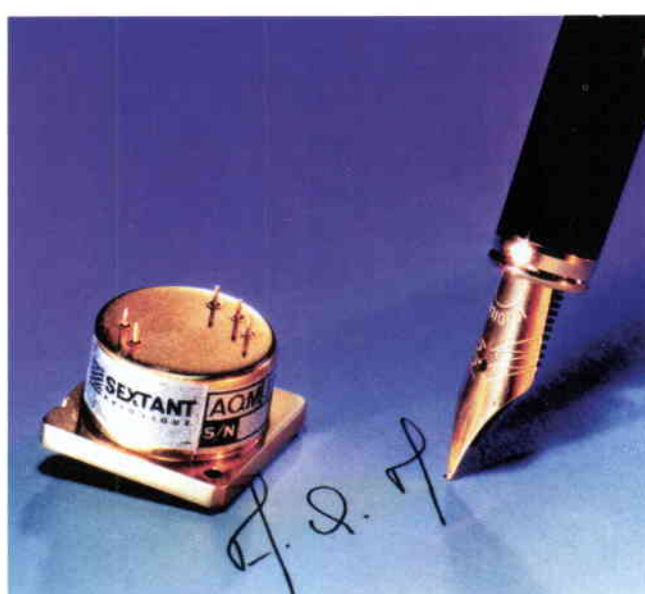


Figure 8. Micromachined accelerometer developed at LETI and commercialised by Sextant Avionique for aeronautic applications

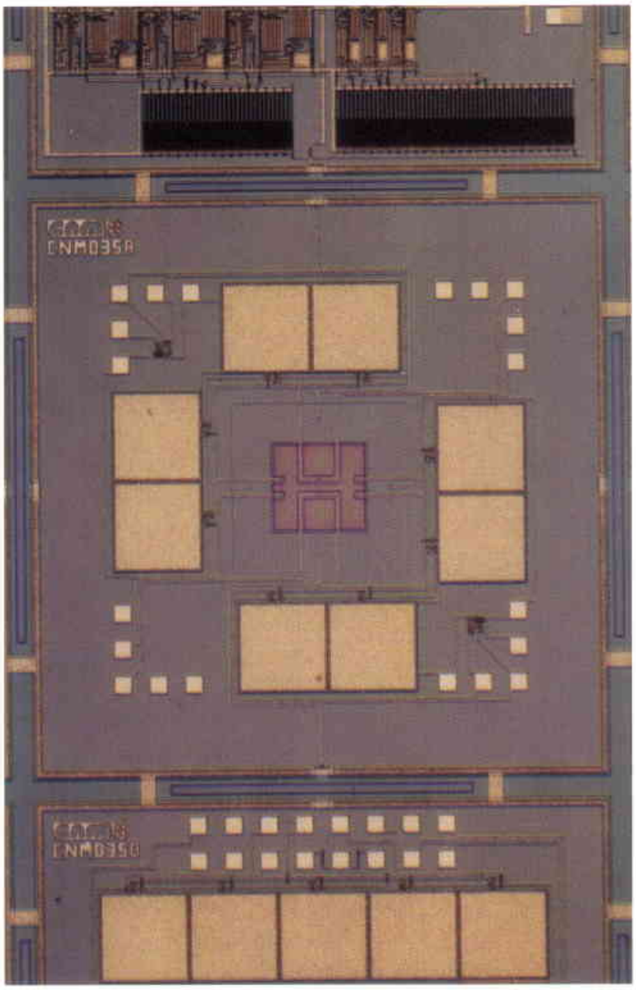


Figure 9. Pressure sensor integrated with CMOS circuitry, developed by CNM (Centro Nacional de Microelectrónica, E)

of integration (e.g. microprocessors), the costs will increase by the need to qualify for space use. The risk of single event upsets (which are non-destructive but disrupt operations) and also of destructive effects such as latch-up currents or low-rate dose degradation and, in the case of micro-mechanisms, radiation-induced deposition are factors to be considered. These problems are not unique to microsystems but affect most high-density and low-voltage microelectronic devices, a proton being a big particle at these scales. The above issues are aggravated by space not being perceived as a market by industrial device producers.

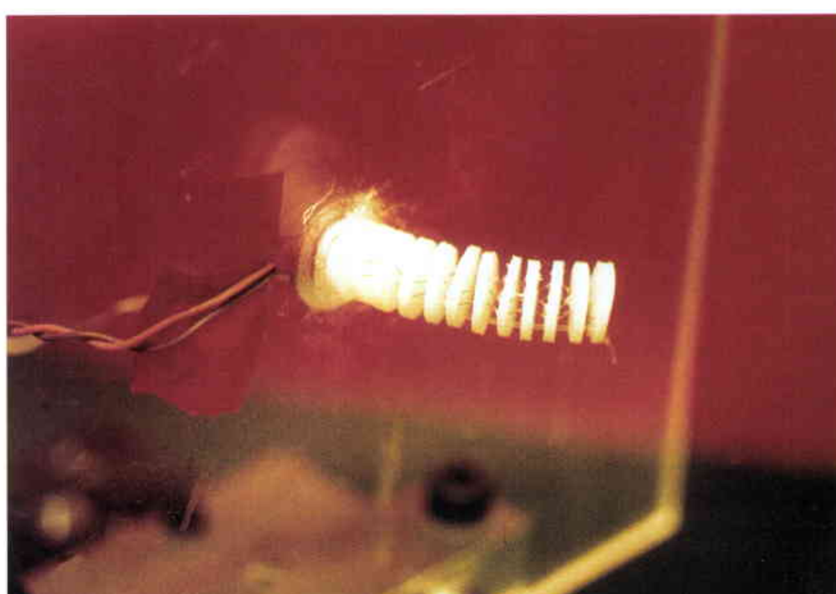
The integration of microsystems into conventional systems is an issue demanding an urgent solution for the first applications of microsystems in space to be able to demonstrate the maximum advantages. Of particular importance are the respective interfaces: microsystems require very low voltages (around 3 V) whilst standard bus voltages are much higher (28 V), the dimensions of standard mechanical connectors are similar to those of microsystems, and other disfunctionalities might be mentioned. Adding to the microsystem all the devices required for an acceptable interface may result, in some cases, in a box not much smaller than the conventional unit to be replaced by the microsystem. To flight-qualify microsystems, and given their low impact on the spacecraft budgets (mass, volume, power), microsystems could be piggy-backed on the modules they would eventually replace, operating in parallel for observation and comparison purposes, and offering an additional redundancy.

The gradual introduction of microsystems in space-based systems may be phased-in in several different ways, and the following is proposed:

a) Use microsystems when the need arises, as has been done until now with examples such as microaccelerometers (Olympus, Space Shuttle flights G21 and D-2), bioreactors based on micropumps and microvalves (Shuttle flight STS-65), micropositioners (Silex experiment on Artemis) and is being proposed for Envisat (visual telemetry systems using microcameras to monitor the deployment of appendages) and MIRAS. In

these applications, microsystems either allow new activities or complement or enhance existing systems. As for new applications, the use of microgyroscopes would allow fast recovery of a tumbling spacecraft, propellant leaks could be detected, the wear of ball bearings monitored, and smart sensors would only report in case of change. Actions will consist in adapting to space available micro-

Figure 10. Active endoscope actuated by modular shape memory alloy microactuators, produced at MitechLab, Scuola Superiore Sant'Anna (I)



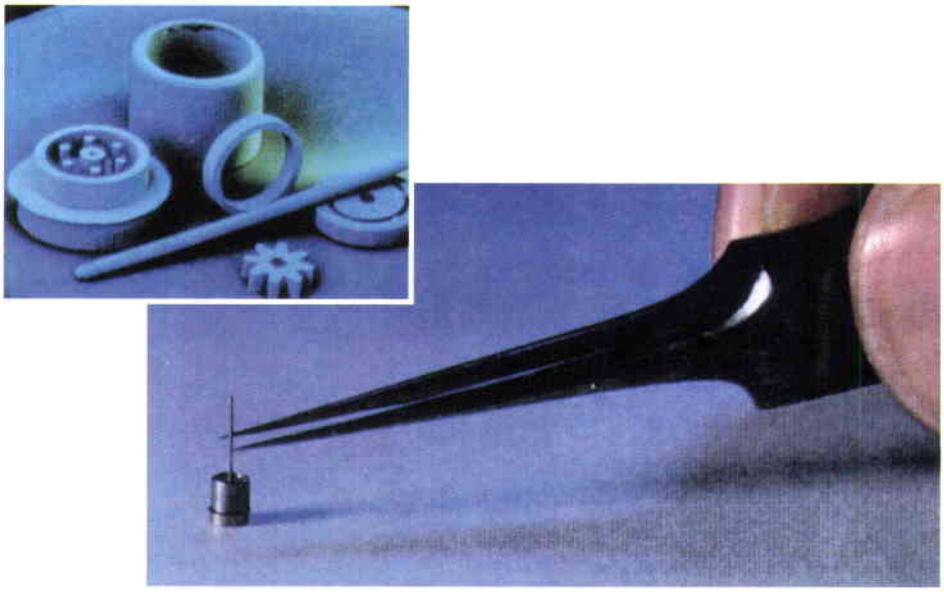


Figure 11. Electromagnetic micromotor developed at IMM (Institut für Mikrotechnik Mainz, D). Such micromotors use various electromagnetic principles and are composed of precision mechanical parts and elements, fabricated by the LIGA method. Ball bearings guarantee long lifetime, and planetary gearboxes allow higher torques. The micromotor's diameter is about 2 mm, and it generates a torque of 0.1 µN.

systems, and producing new microsystems requiring limited levels of development.

b) Develop microsystems that could replace current modules or subsystems; ideal candidates would be instruments, full payloads, subsystems such as attitude and orbit control (since it is the most expensive subsystem on most spacecraft, and it is formed by sensors, actuators and processors, this subsystem, reaction control aside, could profit the most from the advantages introduced by micro/nano-technologies) and on-board data handling. The main advantages would be a release of resources, allowing additional functionalities to be accommodated, more units of a similar type to be flown, or make possible missions where mass is critical (e.g. probes). The above miniaturisation activity would result in smaller and lighter satellites (mini and microsats). It is worth mentioning that nanosatellites have been shown to be as feasible for some limited types of missions such as imaging another satellite during commissioning.

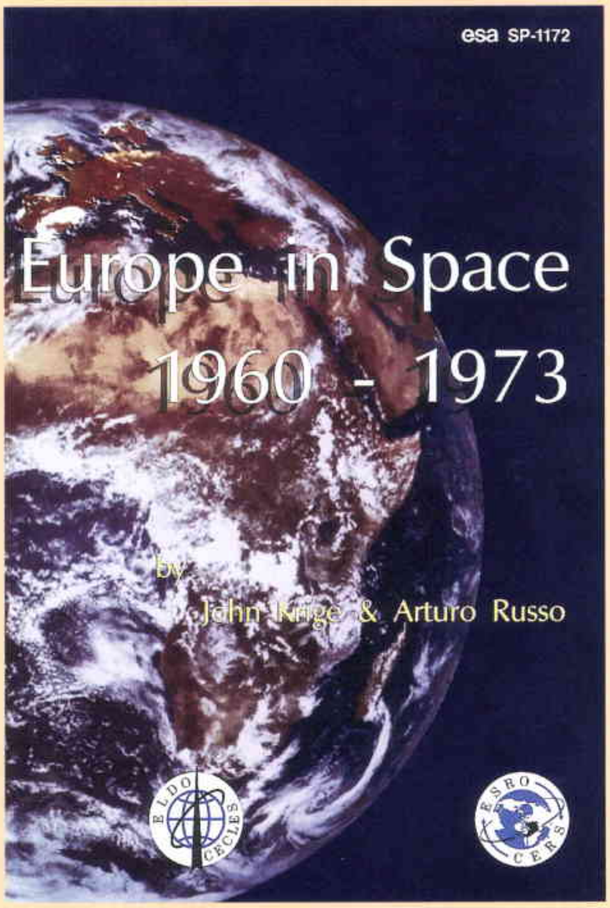
c) Exploit the advantages of decentralisation, either via distributed microsystems on the same spacecraft (the flying carpet concept) or through networks (intelligent constellations) of micro(nano)satellites (the swarm concept). Spacecraft networks are perceived as the next step after constellations.

ESA's technology programmes are well adapted to the peculiarities of research on emerging technologies such as micro-systems. They allow prospective research and development to be performed and research to be conducted both in support of new projects and on existing technologies to reinforce industrial competitiveness (applied research). Both the second phases of the Basic Technology Research Programme (TRP) and the General Support Technology Programme (GSTP) will explicitly include micro/nano-technologies related activities. ESA's In-Orbit Technology Demonstration Programme (TDP), offering flight opportunities in low Earth orbit with short duration missions and thus resulting in a limited accumulated radiation dose, is well suited to show in orbit the achievable performances of the devices produced using micro/nano-technologies.

The European space sector should note developments from other industries that are currently more competitive, and adapt its culture accordingly. An imaginative and flexible effort is required to produce new paradigms which, although different to those traditionally in use, include the new concepts and result in similar or improved functionalities at lower costs. ESA's role would be to foster these changes.

Acknowledgments
The contributions and support of the members of the Working Group on Micro/Nano-Technologies and of the chairmen and participants in the Round Table on Micro/Nano-Technologies for Space have been essential in the preparation of this article. P. Cordero, M. Garvin, D. Kassing, P. Plancke, P. Roussel, and G. Scoon provided input, and A. Atzei, F. Ongaro and D. Raitt provided valuable comments.

Special thanks are due to the active researchers in micro/nano-technologies who provided the photographs of their work to illustrate this article.



EUROPE IN SPACE 1960 – 1973

by John Krige & Arturo Russo

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

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

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

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

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

Europe in Space 1960-1973, ESA SP-1172

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ESA's ETOL Software in International Markets

B. Melton
Automation and Ground Facilities Division, ESTEC, Noordwijk, The Netherlands

G. Hübscher
Instituto de Pesquisas Espaciais (INPE), São José dos Campos, Brazil

Zhu Yilin
Chinese Academy of Space Technology (CAST), Beijing, China

R. Patrick
Computer Resources International A/S, Leiden, The Netherlands

The China-Brazil Earth Resources Satellite (CBERS) programme is a joint Chinese/Brazilian initiative to develop a satellite to monitor natural resources and the environment. Although the majority of the work is to be undertaken by the Brazilians and the Chinese themselves for their own technology development, some key elements of the programme have been procured through competition, on the international market. One of these items is the Overall Checkout Equipment (OCOE) to be used in the assembly, integration and test programme of the satellite. The ESA/ETOL system has been selected as the main component of the OCOE. Two flight models are currently planned, one of which will be integrated at the Integration and Test Laboratory (LIT) at the INPE premises in São José dos Campos, Brazil — the largest and most advanced integration and test facilities in the southern hemisphere. The use of ETOL in this programme represents another commercial exploitation of this highly successful European development.

ESA originally developed its Test Operations Language (ETOL) software to meet the requirements for pre-launch checkout of the Agency's own satellites. The ETOL normally forms the main component of the Overall Checkout Equipment (OCOE) used for system-level electrical testing. Many ESA and non-ESA projects have used it, including ECS, Marecs, Olympus, Hubble-FOC, Ulysses, Giotto, Hipparcos, ISO, IRAS, ROSAT, ItalSat and SAX. It has proven to be a competitive, viable and robust product for European companies interested in supporting emerging nations and industries entering the satellite development arena.

One recent example of such a successful use of the system is in the China-Brazil Earth Resources Satellite (CBERS) programme. When the Chinese Academy of Space Technology (CAST) and the Brazilian National Institute for Space Research (INPE) decided to develop jointly a satellite to monitor natural resources and the environment, they chose the ESA/ETOL standard for their OCOE. By bringing a ready-made solution to their testing activity, INPE and CAST will bring significant benefits to the development of the programme.

ESA and industry have continued to work together to bring new technology into the electrical testing domain. Extensive use of off-the-shelf software, increased commonality between test and flight operations through standardisation, together with new informatics technology, are methods being used to meet the challenges of reducing the cost of ESA's programmes and retaining European industry's competitive position in the global marketplace.

The procurement of the CBERS OCOE

Co-operation between ESTEC and INPE dates back to the mid-1980s, when INPE staff were seconded to ESTEC's Data Handling Division for a period of training. With the background of this experience of the methods and tools used in Europe, it was decided to adopt the ESA/ETOL standard, which is implemented in a wide range of products from European suppliers, for the CBERS OCOE.

In January 1994, INPE issued an international call-for-tender for the supply of two satellite-level OCOE systems. The publication of the call-for-tender raised considerable interest from a range of suppliers not only in Europe but around the world. A contract was awarded to a US company with the European company, Computer Resources International A/S (CRI), to supply and customise the ETOL software.

The other elements of the OCOE have been supplied by:

- DBA Systems Inc, Melbourne, Florida — OCOE hardware, the TM/TC station, and overall OCOE prime contractor
- Satellite Services BV, Katwijk aan Zee, The Netherlands — Colour Synoptic Display Subsystem.

The award of the prime contract to a company from a non-member state of ESA raised, for ESA, the question of access to European technology by non-ESA member states. It was necessary to obtain the approval of ESA's delegate committee for transfer of technology. In order to protect the rights of European industry, it was a condition of the software licence issued by ESA that only executable code would be delivered, thus protecting the position of European suppliers in subsequent tendering actions on the world market.

The international context of the contract brought added complications. It was necessary to configure the software for the CBERS characteristics on a computer platform in Europe, to deliver and perform acceptance in the United States on the target hardware, and to train users who would eventually exploit the system in Brazil and China.

This could only be achieved with confidence by starting from a stable product with a proven history of success, and by paying attention to a thorough rehearsal of tests and procedures before facing the customer.

In addition, the user documentation had to be of a high standard to ensure that extensive support was not required in the utilisation phase.

The total development time was five months, with a further one month of OCOE acceptance and training activities in the USA prior to delivery of the systems to the customers. This is being followed up with further training and support activities by CRI, both in China and

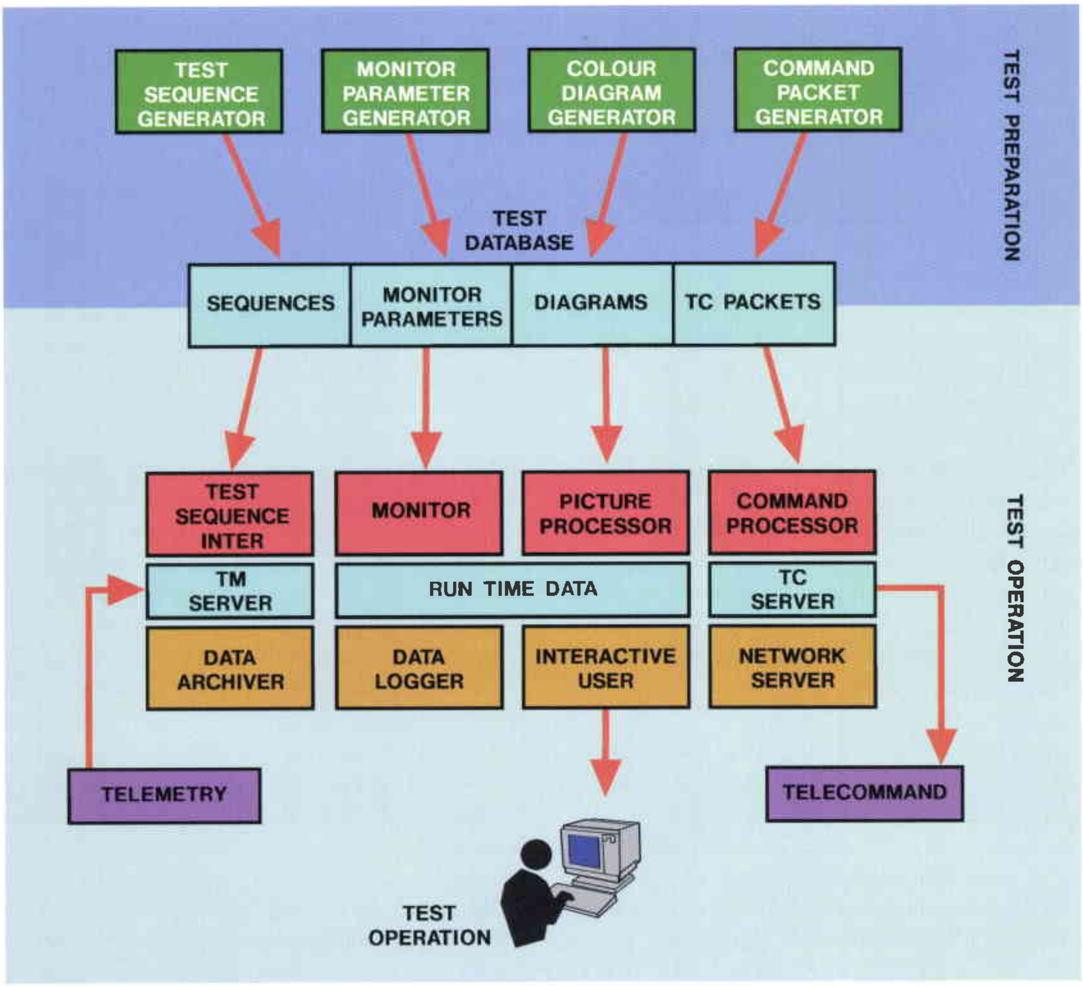

Figure 1. Structure of the ETOL system

Brazil. The software was also installed in the EGSE reference facility at ESTEC.

The CBERS ETOL software

The ETOL system supports the following main functions (Fig. 1):

- Monitoring of telemetry data
- Monitoring of the execution of telecommands
- Automatic test sequencing
- Colour synoptic display
- Archive and replay facilities

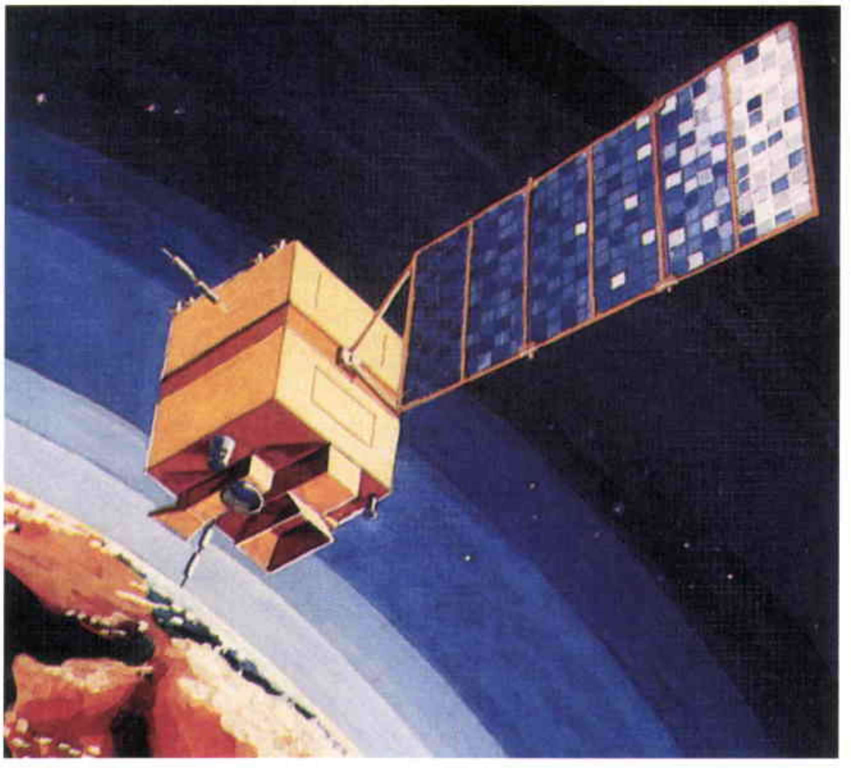

Figure 2. An artist's impression of the CBERS satellite

- Interface drivers for acquisition of data (telemetry) and transmission of data (telecommands)
- Input/output supervisor for the Man-Machine Interface.

The software was originally developed by CRI for ESA/ESTEC in the late 1970s. Since that time, it has been used on numerous ESA and non-ESA missions. During its lifetime it has undergone numerous enhancements, both functionally and technologically, being currently available on VAX computers under the VMS operating system.

One of the main features of the CBERS OCOE is that it eliminates the need for specialised hardware, both for the data acquisition interface and the Colour Display Subsystems. The telemetry acquisition and telecommand sending to the TM/TC station is achieved by means of an Ethernet-TCP/IP interface. This is also the case for the interface to the Special Checkout Equipments (SCOEs). The Colour Display Subsystem is implemented as a software package running under MS-DOS on an IBM-compatible PC. The OCOE is therefore made up of a standard VAX computer and IBM-compatible PCs, both with Ethernet-TCP/IP interfaces.

The ETOL software has also been updated to meet the CBERS data-handling requirements. The housekeeping telemetry data is sent to the ground at two different bit rates, 625 and 2500 bits/s. The science data is sent to the ground via higher speed telemetry links. The telecommand link uses a mixture of simple telecommands and block telecommands. Both the telemetry and telecommand conform to ESA PCM Standards.

The CBERS mission

In the past decade, remote-sensing technology has been applied to studies of natural resources and is proving to be the most efficient way to collect data for monitoring and planning national development. Given the importance of remote-sensing data, a co-operative programme was signed in July 1988, between the People's Republic of China and Brazil, to develop two Earth resources satellites. The organisations involved are the Chinese CAST and the Brazilian INPE. The CBERS programme thus pools the financial resources and skilled manpower of two developing countries to establish a complete remote-sensing system.

The satellite will provide an effective and rapid tool to survey Earth resources and monitor disasters, contamination and the ecological environment. Both countries will use the results obtained by the mission in a wide variety of areas, including agriculture, forestry, mining, geology, meteorology, environment, water conservation, and mapping.

The use of satellite-based Earth resources monitoring can be highly effective. For example, to survey the whole of China's territory, only about 500 photos are needed and the task can be accomplished in several days. An equivalent aircraft survey would require over a million photos and take ten years to complete. A satellite-based system permits monitoring of areas not yet thoroughly investigated because of their vast expanse and inaccessibility such as oceans, deserts or forests. The use of a satellite also allows repeated and regular observations to be made, periodic surveys being necessary to provide information on plant growth, deforestation, river course changes, the forming and melting of ice and snow, to give but a few examples.

This cooperative programme is based on the principles of mutual aid and mutual benefit. It has also promoted and stimulated the development of space technology and satellite applications in both countries. This cooperation between the two countries sets a precedent for international cooperation in space and other high technology spheres, setting a valuable example to other developing countries as to what can be achieved by pooling of resources.

The project is funded 70% by China and 30% by Brazil. The first satellite will be integrated in China at the CAST facility in Beijing. The second will be integrated in Brazil at the Integration and Test Laboratory (LIT) in São José dos Campos. The first CBERS satellite is scheduled to be launched in 1997, by a Chinese Long March launcher from the Taiyuan Launching Site, in the People's Republic of China. The second is to follow two years later. Each satellite will have an expected lifetime of two years.

Satellite description

The CBERS satellite (Figure 2) consists of a payload module and a platform. The main body is a box measuring 2.0 m × 1.8 m × 3.2 m, with the width increasing to 8.4 m with the solar array deployed. CBERS weighs 1450 kg in initial orbit. It has a single solar array on one side of the satellite.

The satellite is designed to operate in a sun-synchronous orbit of 778 km altitude with a 98.5 degree inclination. The local time at the descending node is 10:30 a.m. The repeat cycle is 26 days and the satellite can provide global imaging coverage.

Payload

The characteristic of CBERS that differentiates it from existing Earth resources satellites, is its multisensor payload with different spatial resolutions and data-collection frequencies. The three imaging sensors on board are:

— the Wide-Field Imager (WFI)
— the CCD Camera (CCD)
— the Infrared Multi-Spectral Scanner (IR-MSS).

Their characteristics are shown in Figure 3. The WFI has a large swath of 900 km which gives a synoptic view with a ground resolution of 250 m and covers the Earth surface during a period of less than five days. In addition, the CCD and the IR-MSS sensors provide detailed information of a sampled area of 120 km (20 m and 80 m respectively). The CCD has a pointable capability of $\pm 32°$, providing an increased observation frequency or stereoscopic capability for a given region. Thus, any phenomenon detected by the WFI may be zoomed in on by the oblique view of the CCD with a minimum time lag of three days. These multisensor data are especially interesting for ecosystem monitoring where a high frequency of information is required.

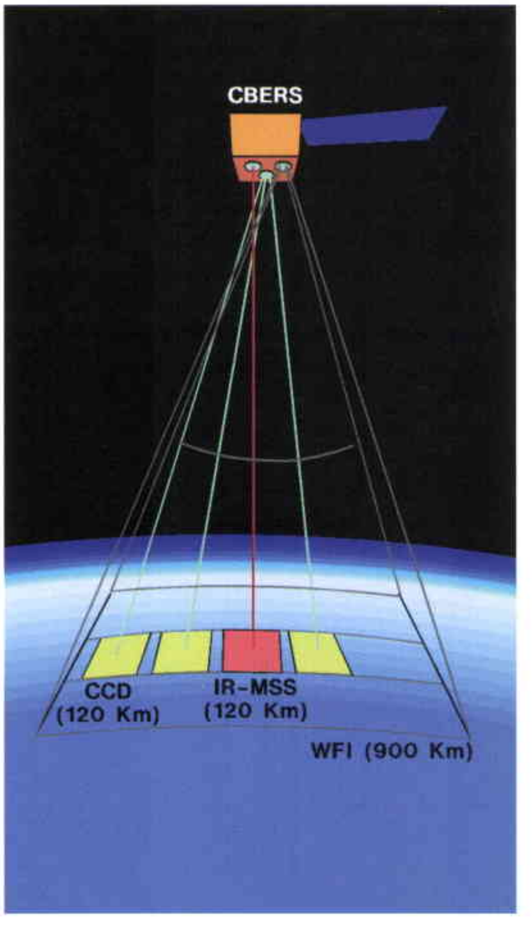

Figure 3. Ground coverage provided by the satellite's main instruments: CCD, IR-MSS, and WFI

Wide Field Imager (WFI)

The WFI is used to get low-resolution, wide-field image information in two visible spectral bands: 0.63 to 0.69 μm and 0.77 to 0.89 μm. The ground resolution is 250 m and the swath width is about 900 km. The repeat cycle is reduced to five days owing to the wide swath width.

CCD camera

The CCD camera is used to acquire high-resolution remote-sensing image information about the Earth in visible and near-infrared spectral bands. It has five spectral bands: 0.45 to 0.52 μm, 0.52 to 0.59 μm, 0.63 to 0.69 μm, 0.77 to 0.89 μm, and 0.51 to 0.73 μm.

The ground resolution is 20 m and the swath width is 120 km. Earth images in the five spectral bands can be obtained simultaneously. The CCD camera, using scanning pushbroom techniques, mainly takes images of the areas around nadir, but also has side-looking capabilities to cover any specified area within a three-day period.

Infrared Multi Spectral Scanner
The IR-MSS obtains medium resolution phanochromatic image information in four spectral bands: 0.5 to 1.1 µm, 1.55 to 1.75 µm, 2.08 to 2.35 µm and 10.4 to 12.5 µm. The ground resolutions are 80 m for the first three bands and 160 m for the last band. The temperature sensitivity for the last and far-infrared band is 1.2 K. The instrument only takes the images of the areas around nadir. Its imaging mode can be performed by ground command in real time or deferred by time tagging.

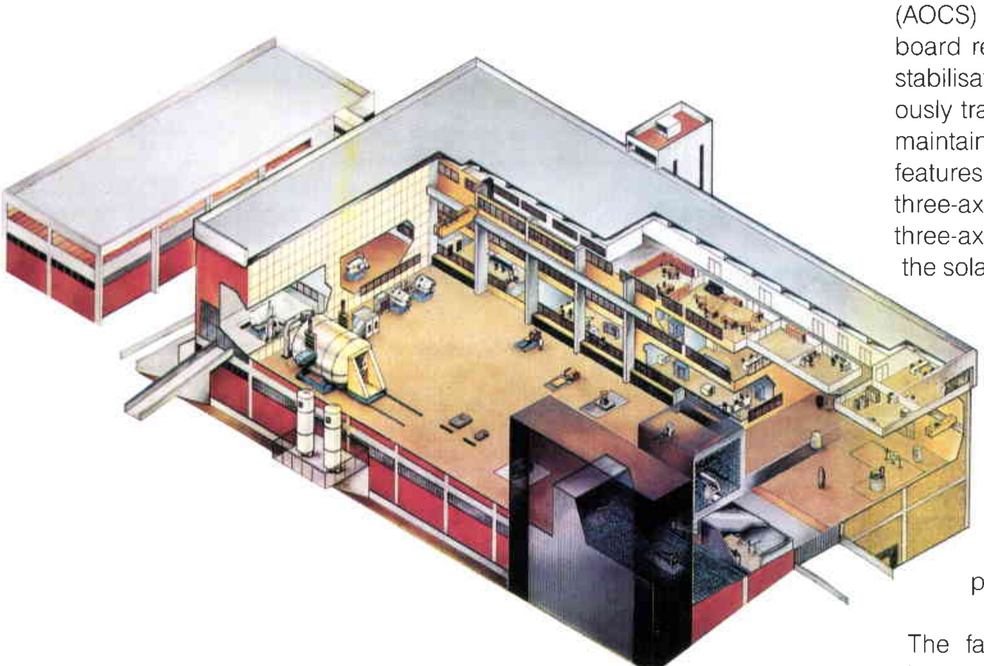

Figure 4. INPE's Integration and Test Laboratory (LIT)

Other payloads
In addition to the imaging payload, the satellite carries a Data Collection System (DCS) for environmental monitoring; a Space Environment Monitor (SEM) for detecting high-energy radiation in space; and an experimental High Density Tape Recorder (HDTR) to record imagery on board.

The platform

The platform consists of the structure subsystem, the thermal-control subsystem, the electrical power supply subsystem, the attitude-and-orbit-control subsystem, the on-board-data-handling subsystem, and the tracking, telemetry and command subsystem.

Thermal control is implemented mainly by passive methods such as using thermal coatings, multi-layer insulation blankets, and heat pipes. Only in special circumstances is the active method of using an electric heater employed. The temperatures inside the satellite are generally maintained within a range of 0°C to 45°C, except for the Nickel-Cadmium (NiCd) battery which is kept at a range from −5°C to +15°C.

The function of the electrical power supply subsystem is to provide all the instruments and equipment on board the satellite with the required electrical power. The subsystem includes the solar array, the NiCd battery, regulators and converters. The output of the solar array will be 1100 W at the end of its lifetime, which is designed to be two years.

The attitude-and-orbit-control subsystem (AOCS) realises the Earth pointing of on-board remote sensors and three-axis attitude stabilisation, to keep the solar panel continuously tracking and pointing to the Sun, and to maintain the Sun-synchronous orbit. The main features of the AOCS are to achieve the three-axis pointing accuracy of 0.2 to 0.3°, the three-axis measuring accuracy of 0.15° and the solar panel accuracy of 5°.

The LIT facility

The Integration and Test Laboratory (LIT) at INPE was designed and built to meet the needs of the Brazilian space programme (Fig. 4). It represents one of the most sophisticated and powerful facilities in the qualification of industrial products that demand a high reliability.

The facility has two main areas in which integration and test activities are carried out. The larger is a class 100 000 clean area of 1600 m², with a useful crane height of 10 m. The types of tests performed there include thermal vacuum, climatic, vibration/shock, Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC). The second area is smaller, 450 m², with a crane hook height of 6 m and operates under class 10 000 conditions. Tests performed there include alignment measurements, centre of gravity and moment of inertia. There are also checkout equipment rooms, test control rooms, and additional laboratories.

The total area of the facility is 10 000 m² with all the necessary utility infrastructure. This includes a filtered compressed air system, closed circuit water system, grounding system with less than 1Ω resistance and an uninterruptable power supply.

Le Conseil réuni au niveau ministériel: son histoire, son évolution

G. Lafferranderie
Affaires juridiques, ESA, Paris

On pourrait s'étonner que la Convention de l'Agence ne comporte pas d'article dédié à un Conseil — ou Conférence, peu importe — ministériel et qu'il faille scruter l'article XI.2 de la Convention ou l'article 10 du Règlement intérieur pour voir mentionner l'expression 'Conseil réuni au niveau ministériel'. Certains pourraient être surpris que certaines matières ne soient pas réservées aux Ministres, et qu'aucune périodicité ne soit mentionnée. C'est là une des originalités de la Convention de n'avoir établi qu'un seul organe souverain, le Conseil, tout en lui laissant la possibilité de se réunir, quelle que soit la matière, soit au niveau des délégués, soit au niveau ministériel (ministres qui sont aussi des délégués), ce qui sous-entend une gradation dans la difficulté de trouver une solution. C'est un choix délibéré qui a été fait par les rédacteurs qui s'explique par l'histoire et par le concept recherché de l'institution.

L'histoire

Au début des années 1960, deux organisations sont mises en place: le CERS/ESRO et le CECLES/ELDO, avec des missions différentes, des Etats membres et un fonctionnement différent. Il a fallu y ajouter la CETS (Conférence européenne des télécommunications par satellites) pour coordonner les positions des pays européens dans le cadre des négociations des Accords Intelsat intérimaire. Très vite la nécessité d'une coordination politique à haut niveau s'est faite sentir: ce fut d'abord la Conférence des Ministres de l'ELDO (non prévue par la Convention de l'ELDO) en juillet 1966 puis la mise sur pied de la Conférence spatiale européenne qui réunissait pour la première fois à Paris en décembre 1966 les ministres des Etats membres de l'ELDO, le Danemark et l'Espagne, plus l'Autriche, l'Irlande, la Grèce, la Suède et la Suisse comme observateurs.

La Conférence spatiale européenne

Il convient de s'arrêter un moment sur la CSE: une 'Conférence' et non une nouvelle Organisation intergouvernementale appelant un nouveau traité soumis à ratification, rappeler quelques dates et résultats car le souvenir de la CSE plane peut-être encore.

A Rome en juillet 1967 la Conférence mentionnée ci-dessus décidait de devenir un organe permanent. Tous les Gouvernements membres de l'ESRO, de l'ELDO et de la CETS étaient invités à se joindre. Le mandat de la CSE était 'd'élaborer une politique spatiale européenne coordonnée et de veiller à son exécution'. Les décisions y sont prises à l'unanimité.

La troisième réunion de la CSE, tenue à Bad Godesberg en novembre 1968, a fait date avec des décisions de principe sur les programmes, les lanceurs (la clause des 125%) et les institutions avec référence à une Organisation spatiale européenne unique. Mais quelques semaines après, le compromis était remis en cause! Puis ce fut la crise à l'ESRO, les 'package deals', les réunions de Bruxelles de 1970, 1972, 1973 et 1975 (avril 1975 fut la dernière réunion de la CSE) et enfin le bout du tunnel avec la signature à Paris en mai 1975 de la Convention de l'ESA. La CSE se composait notamment d'une Conférence des Ministres, se réunissant une fois par an et prenant ses décisions à l'unanimité (ce qui obligeait les Gouvernements à donner des instructions conformes à leurs représentants auprès de l'ELDO, de l'ESRO et de la CETS). L'achèvement des négociations en 1971 sur les Accords Intelsat conduisit à la disparition de la CETS. A noter que la CSE avait mis en place un groupe de travail chargé de suivre les travaux des Nations Unies à un moment important de préparation des grands traités sur l'espace. Le Secrétariat était assuré alternativement par les services de l'ELDO et de l'ESRO.

L'objectif de créer une Organisation spatiale européenne unique (qui apparaît à Bad Godesberg en 1968, confirmé en 1973) ne pouvait qu'entraîner une première question: fallait-il conserver dans cette nouvelle Agence un niveau 'ministériel' ou pas? Si oui, faillait-il que ce niveau soit partie intégrante de l'Organisation ou devait-il en demeurer extérieur?

Avril 1974, le projet de Convention était prêt comme demandé par la CSE. Une dernière révision du projet de Convention à l'initiative de la France en reportait la signature; elle avait parmi ses objectifs celui de faire du Conseil l'organe souverain et suprême (suppression de la référence aux Conseils directeurs de programme). En avril 1975, la CSE transmettait le texte arrêté pour qu'il soit soumis à une Conférence des Plénipotentiaires.

Le Conseil dans la Convention de l'Agence

La conception retenue de l'ESA, d'en faire une Organisation prenant la suite de l'ESRO et de l'ELDO, ayant une compétence en R&D allant du programme scientifique aux applications en passant par les lanceurs, faisait qu'un mécanisme de coordination politique externe ne se justifiait plus (la CETS ayant disparu et aucune autre Organisation 'spatiale' n'existant). Point majeur, l'ESA recevait le mandat exprès de traiter de la politique spatiale européenne à long terme (cf. article II.a. de la Convention). Le Conseil est l'organe politique souverain; il cumule les compétences de caractère politique qui étaient celles de la CSE et les compétences d'exécution. Pourquoi dès lors aurait-on eu besoin d'une autre instance politique, extérieure? Les Communautés européennes n'attachaient alors guère d'attention à l'espace et la création de l'ESA n'y fut pas mentionnée comme à l'ESA celle d'un possible rôle de la Commission . . . dans les questions spatiales.

Un seul point donna vraiment lieu à débat: la périodicité des réunions ministérielles. Finalement, les partisans d'une non-périodicité (comme la Suisse) l'emportèrent, arguant du risque de politisation de toute question et de déshabillage du Conseil ordinaire si des réunions régulières ministérielles étaient instituées.

Un point de vue contraire est défendu par M. A. Lebeau dans son ouvrage *L'Espace en héritage* (Editions O. Jacob, Paris, février 1986): '... le système coopératif actuel souffre d'une faiblesse spécifique, la confusion, dans le Conseil de l'Agence spatiale européenne, de deux fonctions: une fonction de Conseil d'administration et une fonction de concertation politique entre les Etats membres' (page 370).

La Convention de l'Agence était ouverte à la signature le 30 mai 1975 avec cette disposition originale, d'un Conseil qui peut se réunir soit au niveau des délégués soit au niveau des Ministres. Comment cette disposition a-t-elle joué?

Les textes

Le Conseil au niveau ministériel est une formation du Conseil, organe souverain.

(a) L'article X de la Convention crée deux organes: le Conseil et le Directeur général. L'article XI est consacré au Conseil. La mention d'un Conseil ministériel apparaît au paragraphe 2 simplement comme une option, une formation du Conseil: 'Le Conseil se réunit en tant que de besoin soit au niveau des délégués soit au niveau des Ministres'.

Nouvelle mention du Conseil ministériel est faite au paragraphe 4 pour distinguer un Président du Conseil au niveau ministériel. Mais le paragraphe 5 de l'article XI sur les fonctions du Conseil ne fait aucune distinction entre les deux formations et ne réserve au Conseil ministériel aucune compétence particulière.

Conférence Plénipotentiaire le 30 mai 1975 à Paris

A son tour le Règlement intérieur du Conseil (article 10) précise certains points de procédure lorsque le Conseil se réunit au niveau ministériel; aussi, le Conseil est le Conseil et peut traiter de tout sujet quelle que soit sa composition et selon les règles de procédure et de vote du Conseil.

La Convention laisse ouverte toutes possibilités, n'édicte aucune frontière, aucune périodicité, rien de ce qui aurait pu rigidifier ce mécanisme et créer des conflits. Par là la Convention fait en sorte que le Conseil au niveau ministériel soit le niveau de recours politique, stratégique.

(b) Réunions et présidence du Conseil ministériel
Le Président est élu à l'ouverture de la réunion ministérielle et reste Président jusqu'à l'ouverture de la réunion ministérielle suivante qu'il convoque. Bien sûr la fonction est remplie par le titulaire du portefeuille auquel est rattaché l'Espace au

sein du gouvernement. Il s'ensuit que la durée de la fonction de Président du Conseil ministériel va varier, qu'il n'y a pas de réélection et que pendant cette période le Conseil aura deux présidents, l'un au niveau des délégués, l'autre au niveau des Ministres (il ne prend pas part au Bureau, n'assiste pas aux réunions du Conseil ordinaire, etc.). Il peut recevoir une mission politique comme celle de résoudre un point de négociations (cf. la mission du Ministre Riesenhuber à Washington en février 1987). La jurisprudence revêt alors toute son importance pour prévenir des conflits toujours possibles.

La pratique: Comment et quand une réunion du Conseil au niveau ministériel est-elle convoquée?

La réunion de Toulouse des 18-20 octobre 1995 fut la sixième, si on considère comme première la réunion de février 1977, alors que la Convention de l'ESA n'était pas encore formellement en vigueur mais appliquée de facto. La Résolution n° 1 de l'Acte final de la Conférence des plénipotentiaires de mai 1975 le permettait, il n'y avait pas de contradiction avec les Conventions en vigueur, celles de l'ESRO et de l'ELDO, qui étaient bien sûr muettes sur un niveau ministériel.

(i) Paris, février 1977

Cette réunion (prévue pour le deuxième semestre 1976) se tint à Paris au siège de l'Agence les 14 – 15 février 1977 et le Ministre italien de la recherche, Mario Pedini fut élu Président du Conseil ministériel. Cette réunion avait été préparée par un groupe de travail (présidé par M. Van Eesbeeck, Belgique) créé par le Conseil en octobre 1976 qui avait identifié les points à soumettre et préparer des projets de Résolutions. La réunion ministérielle adopta des Déclarations et quatre Résolutions (on peut se demander aujourd'hui quelles furent les raisons de faire de certains sujets des préoccupations stratégiques, si peu de temps après la signature d'une toute neuve Convention).

(ii) Rome, janvier 1985

Il faudra attendre les 30 – 31 janvier 1985 pour assister à la deuxième réunion ministérielle qui se tint à Rome, à la splendide Villa Madama et qui fut convoquée par le Ministre italien de la recherche, L. Granelli. Elle porta à la présidence le Ministre néerlandais Van Aardenne.

Les grands programmes arrivaient à leur terme; le Président Reagan avait invité 'amis et alliés' à participer à l'aventure de la Station spatiale. Le XXème anniversaire de l'Europe spatiale célébré à l'ESTEC donna l'occasion d'un échange de vues officieux le 9 mai 1984 et le Conseil, le lendemain, enregistrait le souhait général de voir se tenir une réunion ministérielle. Les 25—27 juin 1984 le Conseil créait un groupe de travail chargé de préparer la réunion ministérielle. Tout d'abord le Président du Conseil, le Prof.

Première réunion du Conseil, Paris, février 1977

SESSIONS DU CONSEIL DE L'ESA AU NIVEAU MINISTERIEL*

1) Date: Février 1977
Ville: Paris
Présidence: Conseil des Ministres: Mario Pedini (I)
Conseil des Délégués: Wolfgang Finke (D)

Textes adoptés**:
Résolution sur le programme Earthnet
Résolution sur un programme de satellite européen de télédétection
Résolution sur l'Agence et les systèmes opérationnels
Résolution sur l'Agence et ses relations extérieures

2) Date: Janvier 1985
Ville: Rome
Présidence: Conseil des Ministres: G.W.V. van Aardenne (NL)
Conseil des Délégués: Harry Atkinson (R-U)

Textes adoptés**:
Résolution No. 1 Plan spatial européen à long terme
Résolution No. 2 Participation au programme de Station spatiale

3) Date: Novembre 1987
Ville: La Haye
Présidence: Conseil des Ministres: Heinz Riesenhuber (D)
Conseil des Délégués: Henrik Grage (DK)

Textes adoptés**:
Résolution No. 1 Plan spatial européen à long terme et programmes
Résolution No. 2 Participation au programme de Station spatiale

4) Date: Novembre 1991
Ville: Munich
Présidence: Conseil des Ministres: Claudio Aranzadi (S)
Conseil des Délégués: Francesco Carassa (I)

Textes adoptés**:
Résolution No. 1 Plan spatial européen à long terme 1992-2005 et programmes
Résolution No. 2 Programmes d'observation de la Terre et de son environnement

5) Date: Novembre 1992
Ville: Grenade
Présidence: Conseil des Ministres: Hubert Curien (F)
Conseil des Délégués: Francesco Carassa (I)

Textes adoptés**:
Résolution No. 1 Mise en oeuvre du Plan spatial européen à long terme et des programmes
Résolution No. 2 Coopération internationale
Résolution No. 3 Coopération spatiale avec la Fédération de Russie

6) Date: Octobre 1995
Ville: Toulouse
Présidence: Conseil des Ministres: Yvan Ylieff (B)
Conseil des Délégués: Pieter Gaele Winters (NL)

Textes adoptés:
Résolution No. 1 Décisions sur les programmes, les finances et la politique industrielle de l'Agence
Résolution No. 2 Orientations de la politique et des programmes futurs de l'Agence

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* Seules les sessions du Conseil au niveau ministériel ont été prises en compte (voir articles XI.2 et 4 de la Convention, et les Règlements et Procédures, article 10) et non les réunions de la CSE.

** Voir *Textes fondamentaux ESA*, Volume 4.

Réunion du Conseil, Rome, janvier 1985

Atkinson en assumait la présidence qui était ensuite confiée au délégué néerlandais M. De Bruine. Le Conseil, à la mi-décembre 1984, enregistrait l'état d'avancement des travaux ainsi que la demande de la France de traiter également du programme Hermes. La réunion était formellement appelée le 21 décembre 1984.

Comme l'on sait, elle a adopté deux Résolutions: pour la première fois une Résolution sur le plan spatial européen à long terme, qui entérina des objectifs de programmes plus que des programmes, et une Résolution n° 2 sur la réponse à fournir au Président Reagan.

(iii) La Haye, novembre 1987

Le Conseil créa un groupe de travail chargé de préparer la réunion ministérielle, Ce groupe tint treize réunions (et une réunion informelle la veille, chargée de connaître les derniers développements s'il y en avait). Le groupe de travail se consacra aux deux sujets stratégiques, la proposition du Directeur général de Plan spatial européen à long terme et les négociations avec les Etats-Unis sur la Station spatiale internationale. Encore une fois des doutes sérieux apparurent dans le mois précédant la réunion ministérielle quant à une issue positive. Les documents n'étaient distribués qu'au début de la semaine précédant celle de la réunion ministérielle.

Le Conseil ministériel établit un groupe de travail chargé de finaliser le texte du projet de Résolution n° 1, objectif auquel il parvint à l'issue d'une séance de nuit. Finalement, compte tenu de contacts entre la Présidence et les délégations, le Conseil ministériel vota les deux Résolutions (le Royaume-Uni s'abstenant quant à la Résolution n° 1) ainsi que la Déclaration finale mise au point par un petit groupe de rédaction.

(iv) Munich, novembre 1991

On y retrouve les mêmes ingrédients et un déroulement similaire. Mais cette fois-ci l'environnement international a changé avec la chute du mur de Berlin, la remise en cause de la configuration de la Station spatiale internationale, et surtout les contraintes économiques et financières des Etats membres. Le Directeur général attirait d'ailleurs, avant la réunion ministérielle, l'attention du personnel sur ces divers éléments. Comme cela était devenu usuel, le Conseil créa, le 13 décembre 1990, un groupe de travail chargé de préparer la réunion ministérielle. Ce groupe de travail porta à sa présidence M. E. Triana (Espagne) et prépara sept projets de Résolutions. De ces sept projets, il n'en resta que trois qui furent adoptés par le Conseil ministériel après d'ultimes négociations et 'confessions'. Le Ministre espagnol Aranzadi fut élu Président. Ici encore la tenue de la réunion fut incertaine; les dernières hésitations furent levées par un accord entre le Chancelier Kohl et le Président Mitterrand sur les objectifs à atteindre. Le Conseil ministériel décida essentiellement de revoir le plan à long terme — trop cher — et de se revoir un an après. Le temps des vaches grasses était terminé pour faire place à celui d'une gestion rigoureuse.

(v) Grenade, novembre 1992

Selon l'accord de Munich, le Conseil au niveau ministériel se tint donc une année plus tard, en Espagne, à Grenade. Le Conseil établit un groupe de travail le 16 juillet 1992 sous la présidence de M. Mennicken. Le Ministre français de la Recherche, le Prof. Curien fut élu à la présidence du Conseil ministériel.

Le Conseil ministériel adopta trois Résolutions, sur le Plan spatial européen à long terme, sur la coopération internationale et sur les relations avec la Fédération de Russie. Le Conseil abandonna quasiment le projet Hermes qui fut 'réorienté', et réduisit également le projet Columbus. Les Ministres annoncèrent, en annexe de la Résolution n° 1, leur 'intention' de souscrire les Déclarations et des taux de contributions, entre crochets ou avec des fourchettes.

On a également présenté cette réunion comme un échec. Ce n'était pas l'impression de ceux qui y participèrent: une décision sur un plan à long terme, la confirmation de certains objectifs politiques essentiels (coopération à la Station spatiale, coopération avec la Russie, poursuite du programme scientifique sans coupure, etc.). Mais ces 'décisions' restaient à être mises en oeuvre dans les Déclarations de programme et c'est là que le bât blessa.

Un mot sur un groupe de travail créé par la Résolution n° 1, celui sur la gestion des grands programmes facultatifs (Ariane, Hermes, Columbus, DRS). Ce groupe de travail du Conseil fut dirigé par M. Inglis (Royaume-Uni) et ses recommandations endossées par le Conseil. Que recommandait-il? Une couverture de l'enveloppe financière de programme aussi complète que possible, quitte à réduire le contenu initial du programme, un contrôle rigoureux des dépenses. Un deuxième groupe de travail du Conseil fut institué pour réfléchir sur le système financier; il fut placé sous la présidence de M. Hofman (Suisse). Il est à l'origine du système dit du 'tout ECU'.

(vi) Toulouse, octobre 1995

Cette réunion était prévue par la Résolution n° 1 adoptée à Grenade (pour avoir lieu en février 1995). En décembre 1994, le Conseil adopte une Résolution qui crée le groupe de travail habituel chargé de préparer la réunion ministérielle (avec mention de 14 points!). M. J.D. Levi (France) en est élu Président. Le Groupe de travail tint quelque treize réunions, mit au point le projet d'ordre du jour, et prépara deux projets de Résolutions, l'une sur les décisions, l'autre sur les directions et bien sûr suivit les progrès dans les négociations sur les amendements de l'IGA et du MOU, sur les Déclarations de programme. Le Conseil au niveau des délégués se réunit à Toulouse le 17 octobre 1995 pour faire le point sur les positions et les textes. La réunion ministérielle fut ouverte par le Ministre français chargé de l'espace, M. F. Fillon, et porta à sa présidence le Ministre belge, M. Yvan Ylieff.

Les doutes sur la tenue de cette réunion subsistèrent (il suffit de renvoyer aux titres de certains articles: *'L'Agence spatiale dans la tourmente'* ou *'No station, no ESA')* jusqu'à la dernière minute, ainsi que sur la présence de délégations de pays de poids. Finalement les choses se passèrent plutôt bien. Les nuages noirs se dissipèrent devant la volonté commune de faire de cette réunion un succès. Un groupe de travail (de nuit) fut établi pour mettre au point le passage de la Résolution n° 1 qui traitait de la politique industrielle. Les deux Résolutions furent adoptées à l'unanimité ainsi que la Déclaration finale préparée par l'Exécutif. Les Ministres précisèrent le mandat donné aux négociateurs de l'IGA et du MOU sur deux points essentiels pour l'Europe; ils adoptèrent l'ECU comme monnaie de l'Agence et s'intéressèrent au futur de l'Europe spatiale. De nouvelles réunions nous attendent; le Président Ylieff invitait ses collègues à se réunir en 1998 à Bruxelles (une réunion officieuse sur les rapports de deux groupes de travail devant avoir lieu auparavant à l'ESA). Toulouse aura eu le mérite de stabiliser l'Agence, de lui redonner confiance.

Réunion du Conseil, Munich, novembre 1991

(On trouvera dans le tableau toutes ces données: Présidents des réunions ministérielles, lieux et dates, Résolutions adoptées).

Une analyse

(i) A part le Conseil ministériel de 1977, les débats ont porté sur: le plan spatial européen à long terme et les objectifs de l'Agence, les programmes, la politique industrielle, la politique en matière de lanceur, les questions financières, la coopération internationale.

En 1985, à Rome, pour la première fois, l'Agence se dotait d'un plan spatial européen à long terme comme cadre stratégique de ses actions, repris à La Haye en 1987. Ce plan sera profondément revu à Munich puis réajusté à Grenade (il perdit à Toulouse son qualificatif de 'stratégique').

A côté de ces questions répétitives sur l'Agence, ses objectifs et son fonctionnement (notamment à la suite des revues effectuées en interne et par un consultant), on trouvera constamment la question de la Station spatiale internationale (réponse à l'offre du Président Reagan, mandat de négociation 1985 et 1987, puis élargissement du partenariat à la Russie et révision de l'IGA et du MOU), question limitée au développement de la contribution européenne et au rôle de l'Europe dans le partenariat, puis élargie à l'utilisation et à l'exploitation.

La Résolution sur le plan spatial européen général et les programmes ou sur les décisions, la Résolution n° 1, énonce les grands objectifs, les programmes, etc. Dans certains cas, certains chapitres de la Résolution valent Résolution 'habilitante' ouvrant la période de trois mois permettant à un Etat membre non intéressé de ne pas participer (La Haye pour Ariane-5, Columbus, Hermes, DRS). Un tableau de souscriptions attendues est joint avec des niveaux qui restent à confirmer (Grenade, 1992). Le Conseil de Munich s'attacha en outre à l'observation de la Terre et à la coopération internationale. Mais quelques semaines après on pouvait assister à une remise en cause des financements. Le travail était à refaire. Le Conseil de Toulouse a tiré les leçons de cet exercice en faisant en sorte que les taux de contributions soient affichés et la souscription des Déclarations et leur entrée en vigueur immédiate (même si elle est assortie d'une clause suspensive pour laisser à un pays le temps de consulter ses autorités ou sous réserve de l'achèvement des procédures internes) et non plus des souscriptions attendues, des taux indicatifs entre crochets.

(ii) La périodicité: seule la réunion de Munich l'évoque pour envisager des réunions annuelles. N'est-ce pas plutôt en raison de n'avoir pas pris de décisions? Il appartient à chaque réunion de fixer l'échéance suivante en fonction des résultats atteints et à venir. Le succès ou l'échec d'une réunion ministérielle peut tenir à plusieurs facteurs: la maturité du dossier, son importance politique stratégique, sans oublier les contacts entre le Président et les Ministres (petits déjeuners ou même 'confessions' comme à Munich), la force d'entraînement d'un pays moteur (comme à Toulouse), jusqu'au temps et à la voix du Président.

(iii) Dossier stratégique s'il en est et point d'appui d'une réunion ministérielle: le Plan spatial européen à long terme, essentiel pour le fonctionnement de l'Agence et qui ne devrait pas être revu, réorienté, tous les ans, tous les deux ans pour pouvoir garder son caractère de plan à long terme et de base de projets. La périodicité devrait y perdre de son intérêt (sans oublier le temps, les forces consacrées à une réunion ministérielle par tous et qui ne le sont plus à d'autres sujets).

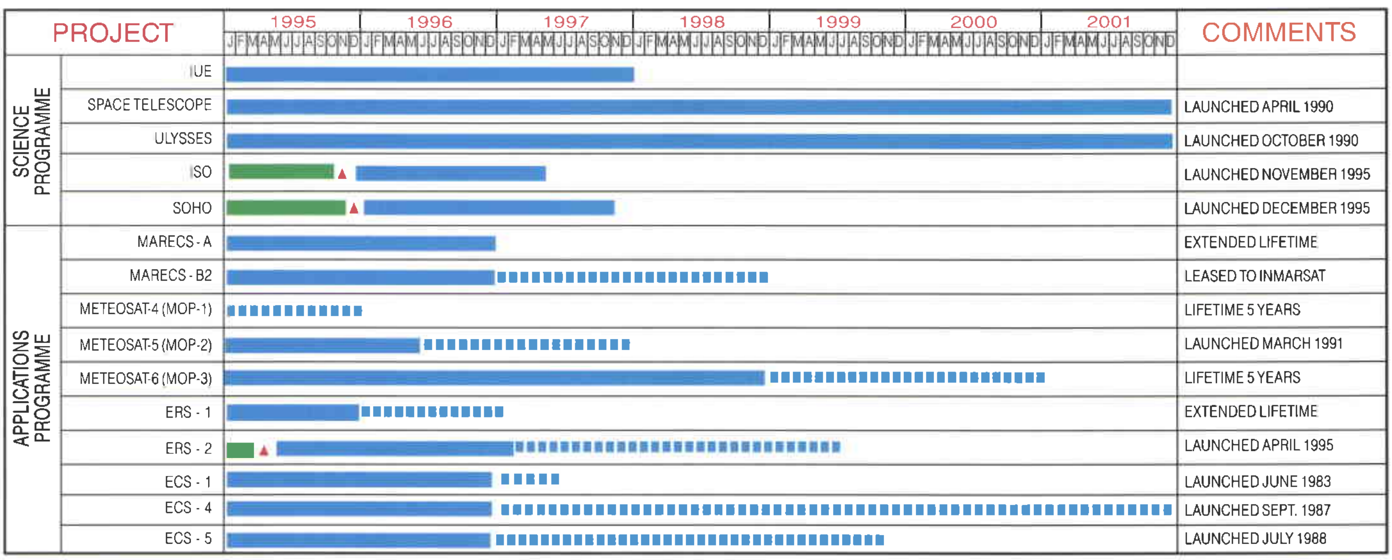
(iv) Le succès d'une réunion ministérielle c'est avant tout la solidarité, l'unanimité autour de décisions claires, fermes et exécutoires, endossées au plus haut niveau politique. Malheureusement, ce souci permanent exprimé à l 'ouverture de chaque réunion n'est pas toujours réalisé et parfois la procédure de traduction de la volonté ministérielle débouche, on l'a vu, sur un coup d'arrêt, si ce n'est une remise en question. Il est certains sujets qui pour diverses raisons ne peuvent être démêlés qu'au niveau ministériel, comme la politique industrielle. Aussi les réunions du Conseil ministériel doivent rester relativement espacées, pour que le Conseil soit un succès et pour aussi restaurer l'intérêt du Conseil au niveau des délégués.

(v) Il est incontestable que le schéma institué par la Convention a porté ses fruits: un niveau politique rapidement saisissable, saisissable de questions fondamentalement stratégiques, non solubles au niveau des délégués, au point qu'on peut parfois s'étonner de voir une question qui a appelé des séances sans fin, des documents sans nombre, être ici résolue en quelques heures. Les décisions prises au sommet de la pyramide doivent se répercuter alors rapidement à chaque échelon avec l'autorité de la chose jugée.

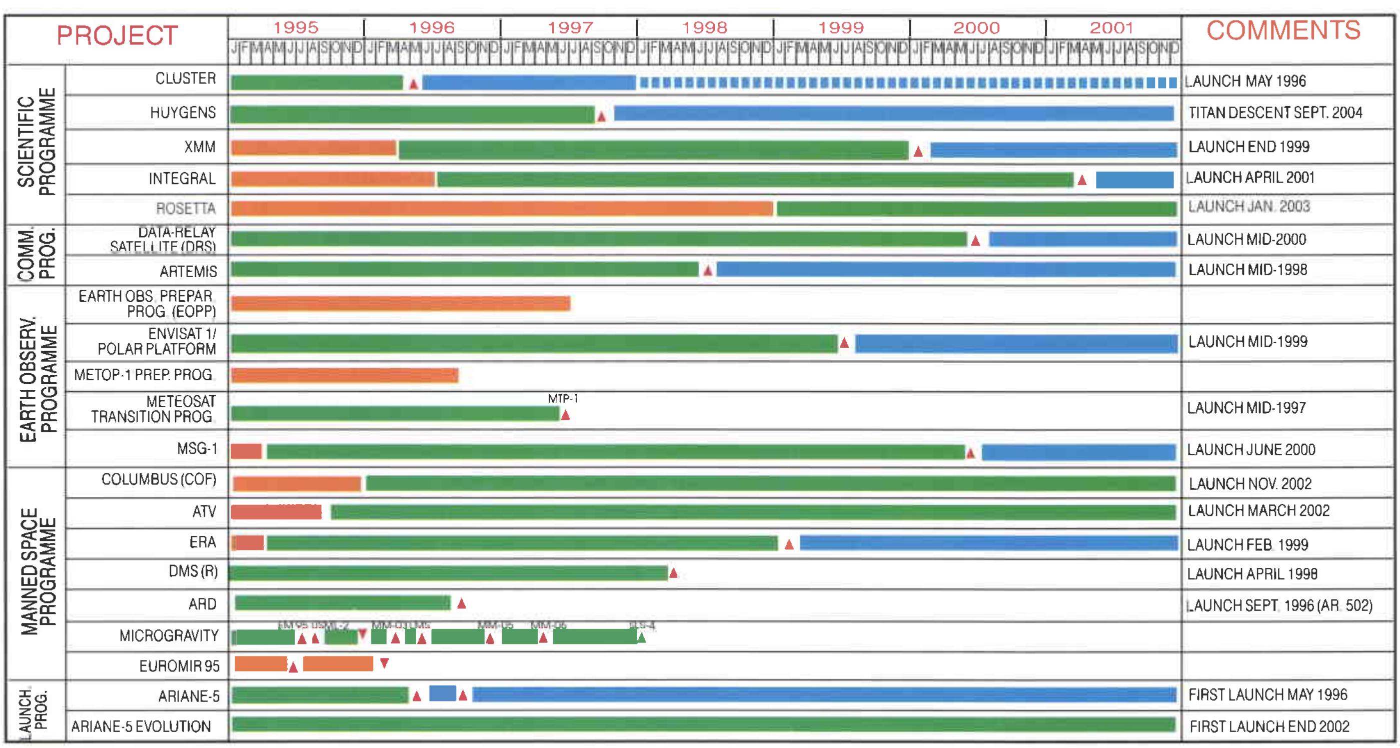
Mais il est tout aussi incontestable que ce schéma a ses limites aujourd'hui, compte tenu de la multiplication des acteurs sur la scène européenne (Commission européenne, Eutelsat, Eumetsat, Arianespace, etc.). Les activités spatiales s'appréhendent comme un tout, du développement aux activités commerciales, du civil à la défense et se déroulent dans un cadre législatif et réglementaire largement ouvert à l'extérieur, ce qui diffère du schéma initial lors de son édification.

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

In Orbit / En orbite



Under Development / En cours de réalisation



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

OPERATIONS — ADDITIONAL LIFE POSSIBLE — ▼ RETRIEVAL

IUE

Depuis son lancement le 28 janvier 1978, l'IUE est exploité de manière continue et en commun par la NASA, l'ESA et le Royaume-Uni (représenté à l'origine par le SRC, puis par le SERC et aujourd'hui par le PPARC). L'observatoire IUE de l'ESA a été installé à la station de poursuite des satellites de l'Agence (VILSPA), à Villafranca, près de Madrid. Un nouveau 'schéma d'exploitation hybride' a été adopté par le Comité du programme scientifique de l'ESA (SPC) en mai 1995, et les activités nécessaires ont été entreprises au cours des mois d'été pour lui permettre de fonctionner à partir du 1er octobre 1995.

Avec ce nouveau système 'hybride', la période quotidienne d'observation, qui était auparavant de 24 heures, a été ramenée à 16 heures durant lesquelles l'IUE est soustrait à l'influence des ceintures de radiation de la Terre. Au cours de ces seize heures, le satellite et son exploitation scientifique sont contrôlés par le VILSPA. Pendant les huit heures restantes, le satellite est placé sous le contrôle du Goddard Space Flight Center (GSFC) de la NASA, à Greenbelt (Maryland).

Un certain nombre d'activités supplémentaires ont été nécessaires pour assurer la mise en oeuvre en temps voulu de l'exploitation hybride, à savoir:

(a) répartition du temps d'observation pour l'année 1996 (et pour l'année 1997)

L'ensemble des propositions européennes et américaines ont été traitées au VILSPA, au moyen d'un nouveau dispositif électronique de soumission des propositions, afin de pouvoir respecter le calendrier très serré établi à l'intention du Comité conjoint de répartition des temps d'observation de l'IUE. Ce comité s'est réuni à Paris les 17 et 18 juillet pour évaluer les 170 propositions reçues, représentant quelque 19 300 heures d'observation. Le SPC avait convenu que l'appel à des propositions d'observations devait tabler sur une fin de vie du satellite IUE fixée à la fin de l'année 1997. C'est sur cette base que le comité a été invité à sélectionner des programmes d'observation pour un 'Programme de recherche scientifique final de l'IUE' destiner à durer jusqu'à la fin de 1997. Dans cette perspective, il a attribué 9500 heures de temps d'observation, gardant quelque 1500 heures en réserve. Quatorze propositions ont été considérées comme 'de première importance' (programmes clefs).

(b) procédures opérationnelles et organisation

Les procédures opérationnelles de l'observatoire IUE de l'ESA et la structure de son organisation ont été profondément remaniées. Des moyens de contrôle direct du satellite et des solutions de secours ont été adoptés. Les installations de gestion des opérations scientifiques ont été modifiées et les dispositifs de planification, d'accès et de soutien des utilisateurs, ainsi que de fourniture des données ont été remplacés par des systèmes plus simples et plus efficaces, utilisant les technologies les plus avancées.

(c) traitement des données

Les capacités supplémentaires nécessaires à l'augmentation du traitement des données ont été intégrées au sein d'un système à flux continu permettant le cheminement automatique des données depuis le système de soutien en temps réel jusqu'à deux systèmes de traitement, avec un contrôle complet de la qualité intégré dans le processus global.

Fonctionnement du satellite
Une nouvelle anomalie affecte l'une des antennes de liaison descendante en bande S (n°4) qui avait déjà souffert de problèmes intermittents par le passé. Son rendement a aujourd'hui diminué de façon permanente de 30%. Les analyses suggèrent que ce problème est causé par une défaillance dans la chaîne d'amplification, une seule des deux chaînes d'origine demeurant opérationnelle. Les incidences de cette défaillance sur l'exploitation sont cependant limitées puisqu'elles n'entraînent qu'à une baisse de 15% du diagramme d'antenne utile observé du sol. Il peut parfois s'avérer nécessaire, cependant, de réorienter le satellite pour permettre la transmission de données.

Principaux résultats scientifiques
Les premières observations de la comète Hale-Bopp ont été réalisées avec succès. Bien qu'une pollution de fond d'origine solaire existe dans le spectre, le continuum de la comète a été convenablement détecté et il semble que l'on soit en présence de l'un des taux de production de poussière les plus élevés jamais observé; aucune trace d'évaporation d'eau (qui se traduit par des émissions d'OH) n'a été décelée à une limite supérieure relativement élevée de 1E29 mol/s. Un noyau sphérique sombre et glacé produirait ce type d'évaporation s'il avait un rayon de quelque 400 km.

La campagne de réverbération menée dans la galaxie à haute luminosité Seyfert-1 F-9 s'est achevée et révèle des retards dans les raies d'émission par rapport aux variations du continuum beaucoup plus courts que les 400 jours prévus d'après les résultats précédents obtenus dans cette galaxie.

Archivage
Le traitement des données de VILSPA pour l'archivage définitif des données IUE (IUEFA) s'est poursuivi parallèlement à la mise en place des innovations prévues dans le cadre de l'exploitation hybride. La conception du système de diffusion IUEFA, qui devrait faciliter l'utilisation à long-terme des archives IUE, en est à son stade final.

HST

L'exploitation de l'observatoire HST se poursuit de manière très efficace, avec seulement quelques dysfonctionnements mineurs, sans conséquence pour les recherches scientifiques réalisées au cours des derniers mois. Plus d'un millier de propositions pour le prochain cycle d'observations (Cycle 6) ont été reçues avant la date-limite de soumission fixée à la mi-septembre.

La préparation et la planification de la mission de maintenance et de réparation prévue en 1997 se poursuit selon le calendrier fixé. Deux nouveaux instruments — le spectrographe imageur (STIS) et la caméra travaillant dans le proche infrarouge (NIC) — ainsi qu'un système de pointage de précision (FGS) seront installés lors de cette mission, au cours de laquelle seront également remplacés un certain nombre de sous-systèmes. Les plans actuels envisagent 6 heures d'activités extra-véhiculaires (EVA)

IUE

IUE has been in continuous operation as a joint project by NASA, ESA and the United Kingdom (initially SRC, later SERC, and now PPARC) since the satellite's launch on 28 January 1978, the ESA IUE Observatory being located throughout at the Agency's Villafranca Satellite Tracking Station (VILSPA) near Madrid (E). Following the approval of a new 'hybrid operations scheme' by ESA's Science Programme Committee (SPC) in May 1995, the necessary developments were carried out over the summer months to allow this new operating scheme to start on 1 October 1995.

Under this revised 'hybrid' system, the total observing time (previously 24 h) has been restricted to the 16 h per day when IUE is outside the influence of the Earth's radiation belts. During this 16 h observing period, both the spacecraft and science operations are under VILSPA's control. For the remaining 8 h each day, the spacecraft is controlled from NASA's Goddard Space Flight Center (GSFC) in Greenbelt MD.

A number of additional activities were needed to assure a timely implementation of the hybrid operations, namely:

(a) Observing-time allocation for 1996 (and 1997)

All European and US proposals were processed at VILSPA using a new electronic proposal-submission system in order to meet the very tight schedule set for the Joint IUE Observing Time Allocation Committee. This Committee met in Paris on 17/18 July to assess the 170 proposals that had been received, corresponding to 19 300 h of observing time. Based on the agreement by SPC that this Call for Observing Proposals would assume an end-1997 end of life for the IUE satellite, the Committee was asked to select observing programmes for a 'Final IUE Science Programme' lasting until the end of 1997.

In the event, it assigned 9500 h of observing time, maintaining some 1500 h in reserve, and 14 proposals were given 'lasting value' (i.e. key programme) status.

(b) Operational procedures and organisation

The operational procedures for the ESA IUE Observatory and its organisational structure were thoroughly revised. Direct spacecraft control and emergency back-up capabilities were introduced. Science operations facilities were modified and the systems used for scheduling, user access and support, and for data delivery were replaced by simpler, more efficient systems making use of up-to-date technology.

(c) Data processing

The additional capacity required for increased data processing has been integrated into a continuous-flow system, whereby data will go automatically from the real-time support system into two processing systems with full quality control as part of the overall process.

Spacecraft status

A new anomaly is affecting one of the S-band downlink antennas (no. 4) which has had intermittent problems in the past; its output has now decreased permanently by 30%. Analysis suggests that this is caused by a failure in the amplification chain, whereby only one of the original two amplification chains remains operational. The impact on operations is limited since it corresponds to only a 15% decrease in the useful antenna pattern as seen from the ground. Occasionally, however, the spacecraft may have to be reoriented for data transmission.

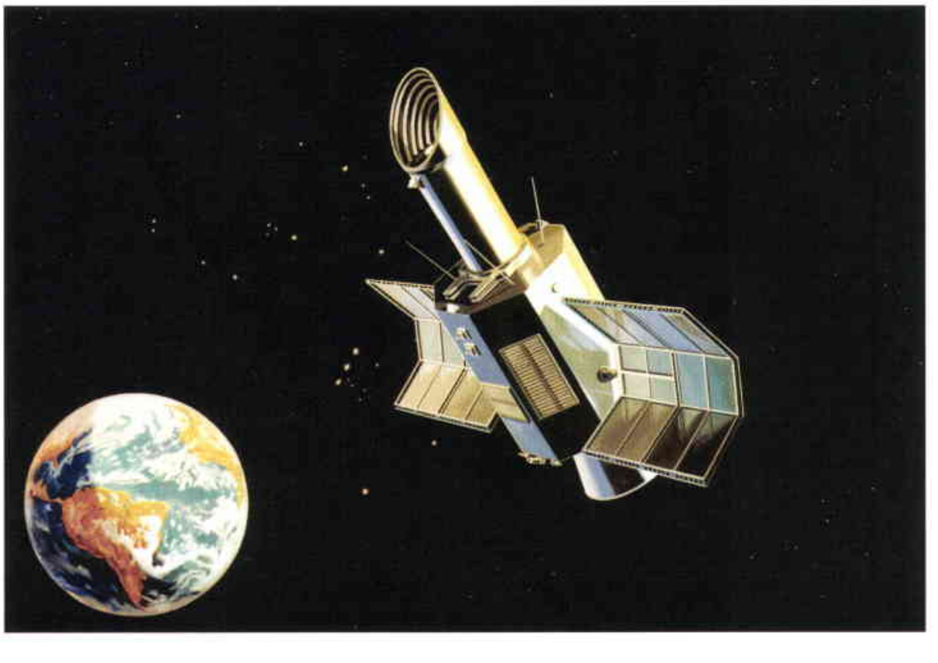
Scientific highlights

The first observations of Comet Hale-Bopp have been successfully completed. Even though some solar background contamination is present in the spectrum, the continuum of the comet was well detected and suggests one of the largest dust-production rates ever observed; no water evaporation (as manifested by OH emission) was found at a relatively high upper limit of 1E29 mol/s. A dark, icy spherical nucleus would yield this evaporation, if it had a radius of some 400 km.

The reverberation campaign on the high-luminosity Seyfert-1 galaxy F-9 has been completed and shows considerably shorter emission-line delays with respect to the continuum variations than the 400 days anticipated from previous results for this galaxy.

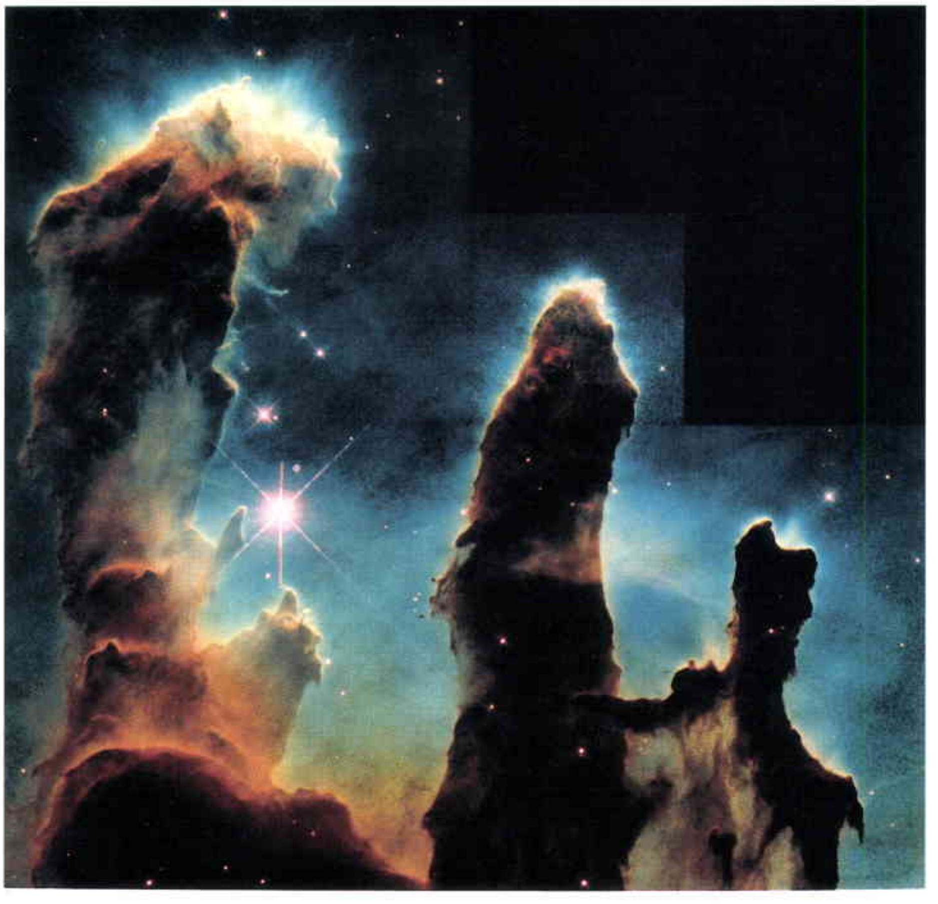
Archiving

The processing of the VILSPA data for the IUE Final Data Archive (IUEFA) has continued in parallel with the innovations that were introduced in connection with the hybrid operations. The IUEFA distribution system, which is expected to support the long-term usage of the IUE Archives, is in its final design stages.



The International Ultraviolet Explorer (IUE)

Satellite international d'exploration dans l'ultraviolet (IUE)



'Gaseous pillars' in the Eagle Nebula, imaged by HST

Les 'piliers gazeux' dans la Nébuleuse de l'Aigle, vus par l'observatoire HST

pendant quatre jours consécutifs, avec une EVA supplémentaire non planifiée en cas de besoin. Le Centre européen de coordination du télescope spatial (ST-ECF) est associé, aux côtés de l'Institut scientifique du télescope spatial, aux préparatifs de la mission de desserte de 1997. Ces préparatifs comprennent une participation aux activités du Bureau de desserte de la mission et plus particulièrement, un soutien aux procédures avancées d'étalonnage et d'analyse des données des instruments scientifiques de nouvelle génération (STIS et NIC). Ces travaux s'appuieront sur l'expérience actuelle en matière de restauration d'image et sur les travaux similaires réalisés par le STECF pour le spectrographe à objets de faible luminosité.

Principaux résultats scientifiques

Les résultats scientifiques les plus récents comprennent l'observation d'objets du système solaire (résolution de la surface de Vesta, découverte de lunes de Saturne), la cartographie d'objets protostellaires ainsi que la découverte d'un nombre important de galaxies irrégulières et d'aspect particulier à des distances lointaines. Ces recherches doivent être suivie par le projet 'Hubble champ profond' conçu pour permettre une exposition très lointaine avec la plus haute résolution possible. La contribution du ST-ECF à ce dernier projet consiste à développer les techniques nécessaires à un échantillonage plus fin (fraction d'un pixel original) et à la recomposition d'images.

Nombre de ces résultats, ainsi que des informations mises à jour sur le HST et le ST-ECF, sont disponibles sur Internet, à l'adresse WWW suivante :

http://ecf.hq.eso.org/ST-ECF-homepage.html

Archivage

Plusieurs développements importants ont eu lieu récemment dans le domaine de l'archivage. Les archives ST-ECF HST ont été adaptées au nouveau format et à la norme des disques optiques du nouveau système d'archivage et de diffusion des données (DADS). En outre, l'accessibilité aux données du HST a été considérablement améliorée par la nouvelle interface utilisateur, développée par le STECF, qui s'appuye sur le protocole du World Wide Web (WWW) disponible sur Internet. Les effets positifs de cette nouvelle interface sont mis en évidence par une plus grande utilisation des archives au cours des trois premiers trimestres de 1995.

Ulysse

Missions et état du véhicule spatial

Le 30 septembre 1995, cinq ans après sont lancement, Ulysse a achevé la première phase de la très fructueuse mission d'exploration qui consiste à étudier l'environnement du Soleil depuis la perspective unique offerte par une orbite passant par les pôles du Soleil. Entre le 19 juin et le 29 septembre, un an après son passage historique au dessus du pôle sud du Soleil, l'engin spatial s'est déplacé vers les régions du pôle nord du soleil, atteignant, le 31 juillet, une latitude maximale de 80,2 degrés nord. La mission continue à se dérouler de manière satisfaisante et l'ensemble des sous-systèmes et instruments scientifiques du satellite fonctionnent normalement.

Le bilan de ces cinq premières années de la mission Ulysse révèle de nombreux progrès en matière opérationnelle. Le lancement, en octobre 1990, a offert la première occasion au personnel de l'ESA d'être responsable, pendant six heures, des opérations dl'exploitation d'une charge utile embarquée à bord de la Navette spatiale. Cette période a culminé avec le déploiement réussi du satellite et le début de son voyage vers Jupiter. L'analyse et l'explication des raisons qui ont déclenché un mouvement inattendu de nutation peu après le déploiement du mât axial du satellite ont représenté un nouveau défi. Une interprétation correcte du phénomène a permis de préparer l'apparition attendue d'un nouveau mouvement de nutation en 1994 et de le contrôler de manière appropriée pendant une période qui a duré plus d'un an. Ces opérations ont mis très fortement à contribution les installations au sol de la NASA et de l'ESA utilisées à cette fin, et réclamé des efforts considérables de la part des personnels affectés au JPL et dans les stations au sol. Le fait que les données scientifiques recueillies n'aient pas subi de dégradation atteste du succès des opérations accomplies.

HST

The HST Observatory continues to operate with excellent efficiency, with only minor malfunctions with no impact on the scientific operations reported in recent months. By the deadline of mid-September for the submission of proposals for the next observing cycle (Cycle 6), more than 1000 proposals had been received.

The preparation and planning for the 1997 Maintenance and Repair Mission is proceeding on schedule. During that mission, two new instruments – the ST Imaging Spectrograph (STIS) and Near-Infrared Camera (NIC) – and a Fine Guidance System (FGS) unit will be installed, together with a number of subsystems which need replacement. The current planning envisages 6 h of Extra-Vehicular Activity (EVA) on four consecutive days, plus an unscheduled EVA as a contingency.

Together with the Space Telescope Science Institute, the ST European Coordination Facility (ST-ECF) is involved in the preparations for the 1997 Servicing Mission. This includes participation in the activities of the ScI Servicing Mission Office and, in particular, support for advanced calibration and data-analysis procedures for the next-generation science instruments (STIS and NIC). This work will be based on the existing experience with image restoration and with similar work performed by the ST-ECF for the Faint Object Spectrograph.

Scientific highlights

The most recent scientific highlights include observations of Solar System objects (resolving the surface of Vesta, discovering moons of Saturn), mapping objects of embryonic stars, and the discovery of large numbers of irregular and peculiar galaxies at large distances. These will be followed up with the 'Hubble Deep Field' project, which is designed to provide an ultra-deep exposure of the highest possible resolution. The ST-ECF's contribution to the latter project consists of the development of techniques for the pixel sub-stepping and image recombination.

Many of these results, as well as up-to-date information about HST and the ST-ECF, can be found on Internet via WWW address:

http://ecf.hq.eso.org/ST-ECF-homepage.html

Archiving

Several important archive-related activities have taken place recently. The ST-ECF HST Archive has been adapted to the new format and optical-disk standard of the new Data Archive and Distribution System (DADS). In addition, the new User Interface developed by the ST-ECF, based on the World Wide Web (WWW) protocol and available on Internet, has considerably improved accessibility to HST data. The positive effect of the new interface has been clearly visible in increased use of the Archive during the first three quarters of 1995.

Ulysses

Mission and spacecraft status

On 30 September 1995, five years after launch, Ulysses completed the first phase of its highly successful exploratory mission to study the Sun's environment from the unique perspective of a solar polar orbit. Between 19 June and 29 September, one year after its historic south polar pass, the spacecraft flew over the Sun's northern polar regions, reaching a maximum latitude of 80.2° north of the equator on 31 July. The mission continues to go well, with all spacecraft subsystems and scientific instruments functioning nominally.

In retrospect, the first five years of the Ulysses mission have covered many ground-breaking activities from an operational standpoint. The launch in October 1990 was the first occasion on which ESA staff were operationally responsible for a Shuttle payload during an eventful 6 h period which culminated in the spacecraft's successful deployment and the start of its journey to Jupiter. The unexpected onset of nutation shortly after deployment of the spacecraft's axial boom presented a further challenge in terms of analysing and understanding the causes of the anomaly. Correct interpretation enabled preparations for the expected

Ulysses / *La sonde Ulysse*

La rencontre avec Jupiter, en février 1992, a également constitué une première pour le personnel d'exploitation de l'ESA qui a dû relever de nombreux défis. Une méthode originale de conduite des opérations a été imaginée: elle permet aux équipes gérant les expériences d'accéder à celles-ci en temps quasi-réel au cours de la rencontre. Les activités de collecte des données se poursuivront, dans une phase ultérieure, tout au long de la deuxième orbite solaire, ce qui représentera, sans nul doute, un nouveau défi au niveau des opérations.

Principaux résultats scientifiques

L'énoncé des principaux résultats scientifiques obtenus à ce jour, dans le cadre de la mission principale d'Ulysse, lors des passage hors du plan de l'écliptique, dans le plan de l'écliptique et du survol de Jupiter, figure ci-après. Bien que cette énumération ne soit pas exhaustive, elle illustre la richesse et la diversité de la moisson scientifique obtenue à ce jour par la mission. Les résultats les plus importants ont été obtenus, presque sans exception, par l'analyse et l'interprétation de la combinaison des différents ensembles de données fournies par divers instruments, conséquence naturelle du haut degré d'intégration et de collaboration régnant au sein de l'équipe scientifique d'Ulysse.

Plus de 400 articles, traitant de ces découvertes et de nombreux autres résultats obtenus au cours de la mission Ulysse, ont été publiés depuis le lancement, et notamment sept séries d'articles dans des numéros spéciaux de publications scientifiques. Une huitième série d'articles est actuellement sous presse pour la publication 'Geophysical Research Letters', *et il est prévu de publier les résultats de l'atelier 'passage au pôle nord', organisé en Californie en octobre dernier, dans un numéro spécial de la revue* 'Astronomy and Astrophysics'.

Deuxième orbite solaire d'Ulysse

La sonde et sa charge utile scientifique sont aujourd'hui en excellente condition et prêtes à entamer une seconde orbite autour du Soleil. L'objectif ultime de cette prochaine phase de la mission qui culminera par des passages au-dessus des pôles en 2000 et 2001 — est d'étudier les régions polaires du Soleil, dans des conditions d'activité solaire

Principaux résultats obtenus hors du plan de l'écliptique

- *Caractérisation de deux régimes fondamentalement distincts du vent solaire, avec limites chromosphériques et coronales communes nettement délimitées: vent lent provenant de la ceinture de particules, vent rapide soufflant des trous coronaux (polaires).*
- *Mise en évidence de l'absence de concentration de flux magnétique dans le champ magnétique héliosphérique situé aux pôles, ce qui implique que la configuration de type dipolaire des champs de la surface solaire ne subsiste pas dans le vent solaire.*
- *Observation de changements de direction de large amplitude dans le champ magnétique héliosphérique situé au dessus des pôles.*
- *Mise en évidence d'un influx de rayons cosmiques moins important que prévu aux latitudes élevées.*
- *Première observation de la structure tri-dimensionnelle des régions en interaction et en rotation couplée.*
- *Découverte d'une nouvelle classe d'éjections de masse coronale (CME), observées aux latitudes élevées.*
- *Première télédétection de sursauts d'ondes radio kilométriques de type-III observés à partir d'une position avantageuse privilégiée à une latitude élevée.*
- *Observation d'accroissements récurrents (de l'ordre de 26 jours) du flux de particules de faible énergie (MeV) jusqu'aux latitudes élevées, suggérant l'existence d'une accélération non-locale suivie d'un transport d'une latitude à une autre.*
- *Observation d'une modulation (décroissance du flux) récurrente (de l'ordre de 26 jours) des particules de haute énergie (supérieures à 100 MeV/n) s'étendant à toutes les latitudes.*
- *Observation de grains de poussière interstellaire et de particules d'une taille inférieure au micron, ces dernières susceptibles d'être originaire du nuage zodiacal.*
- *Identification (provisoire) de modes solaires 'p' et 'g' par l'analyse de séries temporelles de données de flux de particules énergétiques.*

Principaux résultats obtenus dans le plan de l'écliptique

- *Première caractérisation du médium interplanétaire dans l'écliptique, entre 1 et 5 UA près du maximum solaire.*
- *Première mesure in-situ de paramètres de flux d'hélium interstellaire neutre.*
- *Premières mesures de l'ensemble des principales catégories d'ions implantés interstellaires.*
- *Premières observations de l'accélération d'ions implantés interstellaires lors de chocs interplanétaires.*
- *Observation de courants récurrents de poussière interplanétaire originaire de la magnétosphère jovienne.*
- *Première mise en évidence avec certitude d'émissions d'ondes radio de type-III d'origine locale.*
- *Observations détaillées d'importants événements dans le domaine des particules solaires, liés à l'activité solaire intense de mars/avril 1991.*

Principaux résultats obtenus lors du survol de Jupiter

- *Premier passage au travers du secteur crépusculaire inexploré de la magnétosphère jovienne.*
- *Première mesure directe des états de charge des ions magnétosphériques, fournissant des informations sur l'origine et l'histoire du plasma jovien.*
- *Mise en évidence, au moyen de tubes de flux, du franchissement, lors de l'entrée, d'une calotte ou d'une région de type cuspide polaire profondément située dans la magnétosphère jovienne (15 R_j de Jupiter).*
- *Observation de sources discrètes d'émissions radio 'en bande kilométrique étroite' réparties le long du tore de plasma d'Io, et tournant avec lui, impliquant une structure non-homogène du tore.*
- *Observation de faisceaux intenses d'ions et d'électrons énergétiques s'écoulant vers l'intérieur et l'extérieur, le long de lignes de force, à des latitudes élevées, dans le secteur crépusculaire.*
- *Observation de courtes bouffées d'électrons énergétiques et d'émissions radio associées, peutêtre liées à l'activité aurorale jovienne.*
- *Mise en évidence, par la déflection en direction de sa queue du champ magnétique jovien dans le secteur crépusculaire, de l'influence plus forte qu'escomptée du vent solaire sur la structure de la magnétosphère jovienne.*

return of nutation in 1994 to be carried out in an orderly manner, allowing its successful control during a period of over one year. These activities stretched to the limit the NASA and ESA ground facilities used for the task, as well as the operational staff located at JPL and at the ground stations. The fact that the scientific data acquired were not degraded is proof of the success of these operations.

The encounter with Jupiter in February 1992 was also a first for ESA operations staff and presented many challenges. A unique method of conducting the operations was devised which provided the experiment teams with the ability to access their experiments in near-real-time during the actual encounter. Looking ahead, science data-gathering activities will continue throughout the entire second solar orbit, no doubt leading to new operational challenges.

Scientific highlights

Highlights from the out-of-ecliptic, in-ecliptic and Jupiter fly-by parts of the prime Ulysses mission to date are listed in the accompanying panels. Although the list is by necessity not exhaustive, it serves to illustrate the richness and diversity of the scientific harvest from the mission so far. Almost without exception, the most important results have come from the analysis and interpretation of combined data sets from different instruments, a natural consequence of the high degree of integration and collaboration within the Ulysses science team.

More than 400 papers discussing these and many other findings from the Ulysses mission have been published since launch, including seven collections of papers in special issues of scientific journals. An eighth is currently in press in Geophysical Research Letters, and it is planned to publish the results from the North Polar Pass Workshop, held in California last October, in a special issue of 'Astronomy and Astrophysics'.

Ulysses' second solar orbit

With the spacecraft and its scientific payload in excellent condition, Ulysses is all set to embark on its second orbit of the

Out-of-Ecliptic Highlights

- Characterisation of two fundamentally distinct solar-wind regimes with common, sharply delineated chromospheric and coronal boundaries: slow wind from the streamer belt, fast wind from the (polar) coronal holes.
- No concentration of magnetic flux at the poles in the heliospheric magnetic field, implying that the dipole-like configuration of the Sun's surface field is not maintained in the solar wind.
- Observation of large-amplitude directional fluctuations in the heliospheric magnetic field over the poles.
- Observation of a smaller-than-predicted influx of cosmic rays at high latitudes.
- First observations of the three-dimensional structure of Co-rotating Interaction Regions (CIRs).
- Discovery of a new class of Coronal Mass Ejections (CMEs) observed at high latitudes.
- First-ever remote sensing of kilometric Type-III radio bursts from a high-latitude vantage point.
- Observation of recurrent (order 26 day) increases in the flux of low-energy (MeV) particles up to high latitudes, suggesting non-local acceleration followed by latitudinal transport.
- Observation of recurrent (order 26 day) modulation (decreases in flux) of high-energy (greater than 100 MeV/n) particles extending to all latitudes.
- Observation of interstellar dust grains and submicron particles, the latter possibly originating in the zodiacal cloud.
- (Tentative) identification of solar p- and g-modes through time-series analysis of energetic particle flux data.

In-Ecliptic Highlights

- First characterisation of the interplanetary medium in the ecliptic between 1 and 5 AU near solar maximum.
- First in-situ measurement of interstellar neutral helium flow parameters.
- First measurement of all major species of interstellar pick-up ions.
- First observations of the acceleration of interstellar pick-up ions at interplanetary shocks.
- Observation of recurrent interplanetary dust streams originating in Jupiter's magnetosphere.
- First clear evidence of locally generated Type-III radio emission.
- Detailed observations of large solar-particle events related to the intense solar activity of March/April 1991.

Jupiter Fly-by Highlights

- First pass through the unexplored dusk sector of the Jovian magnetosphere.
- First direct measurement of the charge states of magnetospheric ions, providing information on the origin and life history of the Jovian plasma.
- Evidence for passage through a polar cap or cusp-like region, with open magnetic flux tubes, deep within the magnetosphere (15 R_j from Jupiter) on the inbound pass.
- Observation of discrete sources of 'narrow band kilometric' radio emission distributed along, and rotating with, the Io plasma torus, implying an inhomogeneous structure for the torus.
- Observation of intense beams of energetic ions and electrons streaming inward and outward along magnetic field lines at high latitudes in the dusk sector.
- Observation of short bursts of energetic electrons and associated radio emission, possibly related to Jovian auroral activity.
- Evidence for an unexpectedly strong influence of the solar wind on the structure of the Jovian magnetosphere seen in the tailward deflection of the Jovian magnetic field in the dusk sector.

élevée. Bien avant cette phase, lors de la lente descente d'Ulysse vers des latitudes plus basses après son passage au dessus du pôle nord, se présentera cependant l'occasion unique d'observations coordonnées avec le satellite de l'ESA SOHO qui emmène à son bord une importante série complémentaire d'expériences consacrées à l'étude de la couronne et du vent solaire. La période entourant l'aphélie (1997/1998) présentera également un grand intérêt. Ulysse passera à ce moment là de nombreux mois à proximité de l'écliptique, à une distance radiale presque constante du Soleil (quelque 5 UA), permettant ainsi d'étudier l'évolution temporelle de nombreux phénomènes planétaires, sans avoir à se préoccuper des variations spatiales.

Ulysse se trouve de toute évidence en position unique, au propre comme au figuré, pour étudier l'évolution de l'héliosphère dans les trois dimensions, depuis le minimum d'activité solaire actuel jusqu'aux conditions d'activités maximales. Aucune mission spatiale ne pourra, dans un futur prévisible, atteindre de tels objectifs.

Météosat

Le contrôle en orbite de l'ensemble des satellites Météosat a été transféré fin novembre à Eumetsat. Le service de fourniture d'images de base est actuellement assuré par Météosat-5, le satellite Météosat-6 étant en réserve.

La conception du MOP (Programme opérationnel Météosat) sera utilisée pour au moins un satellite supplémentaire, qui portera le nom de satellite du Programme de transition Météosat (MTP). Son radiomètre est en cours de fabrication et sera livré au début de l'été 1996. Le lancement du satellite MTP est prévu à l'été 1997.

ISO

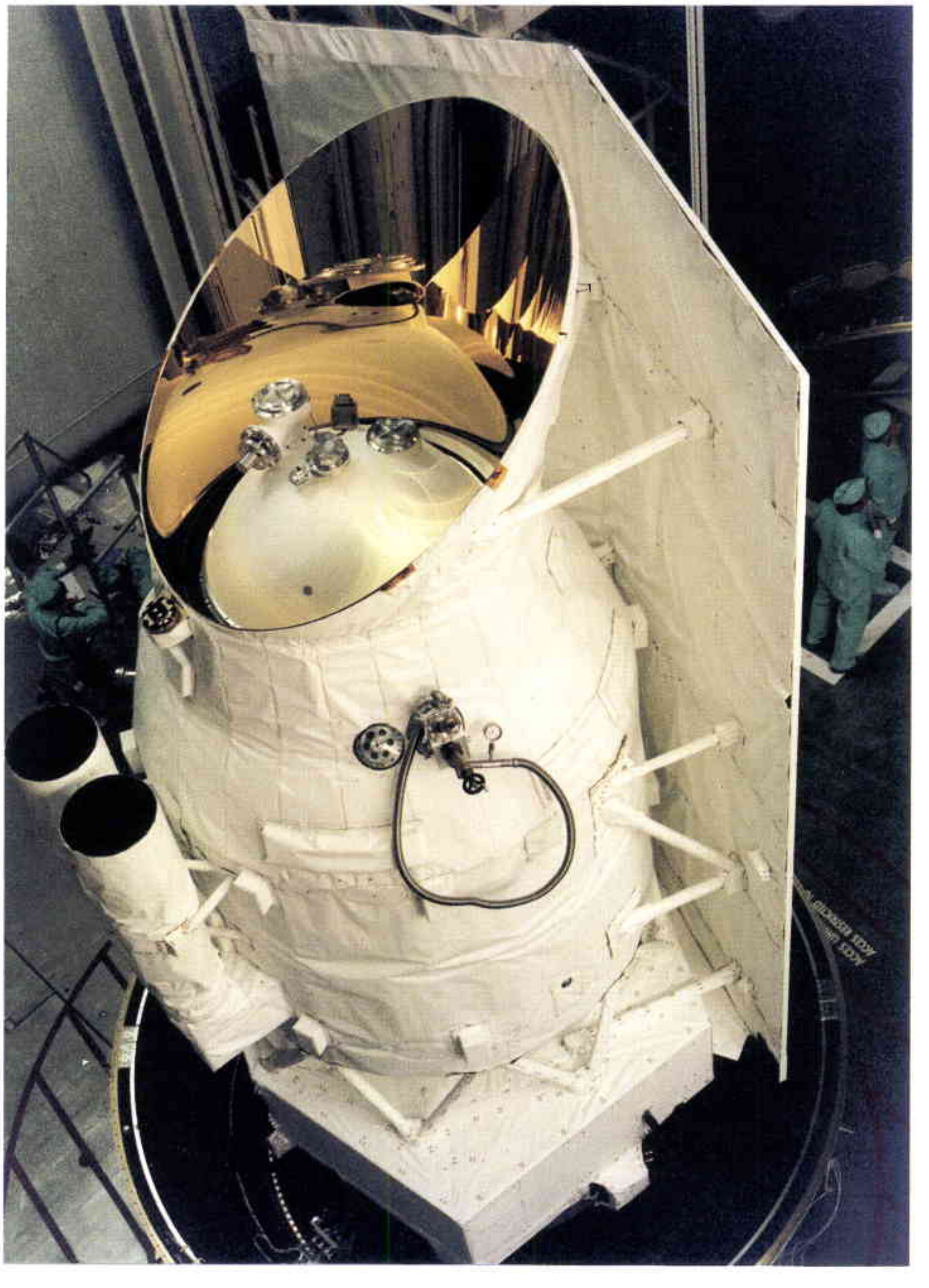
L'Observatoire spatial dans l'infrarouge a été lancé avec succès le 17 novembre 1995 à 01h42 TU, à l'ouverture de la fenêtre de lancement prévue quotidiennement. Le lancement s'est déroulé sans à coups, exactement selon l'horaire fixé, et la mise sur orbite s'est déroulée avec une très grande précision. C'est le Centre des opérations en vol de l'ESOC, à Darmstadt (D) qui a assuré le contrôle du satellite pendant les quatre premiers jours qui ont succédé au lancement, durant la Phase de lancement et de début de fonctionnement en orbite (LEOP). L'état des sous-systèmes du satellite a été vérifié puis l'altitude du périgée à a été portée de 518 à 1030 km.

Par la suite, pendant la phase de recette qui s'est déroulée du 21 novembre au 8 décembre, le satellite et son instrumentation scientifique ont été placés sous la responsabilité du Centre de contrôle des missions de l'ESA, à Villafranca, près de Madrid (E).

L'ensemble des sous-systèmes du satellite ont été testés avec succès et mis en service au cours de cette phase. L'altitude de l'apogée a été corrigée afin d'atteindre l'orbite définitive de 24 heures (70 611 km d'apogée et 1004 km de périgée). Le couvercle du cryostat a été éjecté dix jours après le lancement. Tous les instruments scientifiques ont été testés depuis et ont été utilisés pour l'observation de différents objets dans l'espace. Le satellite et ses instruments scientifiques fonctionnement de manière excellente.

The ISO spacecraft, just prior to launch

Le véhicule spatial ISO prêt au lancement



Sun. The ultimate goal of this next phase of the mission is the study of the Sun's polar regions under conditions of high solar activity, culminating in polar passes in 2000 and 2001. Much before this, however, as Ulysses descends slowly in latitude after the northern polar pass, there will be a unique opportunity to make coordinated observations with ESA's SOHO spacecraft, which carries an extensive complement of experiments dedicated to studying the Sun's corona and the solar wind. The period around aphelion (1997/98) will also be of great interest. During this interval, Ulysses will spend many months close to the ecliptic at almost constant radial distance (some 5 AU) from the Sun, enabling the temporal evolution of many interplanetary phenomena to be studied free of concern about spatial variations.

Ulysses is clearly in a unique position, literally and figuratively, to study the evolution of the three-dimensional heliosphere from the current solar minimum to maximum activity conditions. No other space mission in the foreseeable future will address these goals.

Meteosat

The control of all Meteosat spacecraft in orbit was transferred to Eumetsat at the end of November. The primary imaging service is currently being provided by Meteosat-5, with Meteosat-6 on stand-by.

The MOP (Meteosat Operational Programme) design will be used for yet one more spacecraft, to be known as the Meteosat Transition Programme (MTP) satellite. Its radiometer is currently being manufactured and will be delivered in early summer 1996. Launch of the MTP spacecraft is planned for summer 1997.

ISO

The Infrared Space Observatory was launched successfully at the opening of the daily launch window at 01.42 h UT on 17 November 1995. The launch sequence proceeded smoothly, exactly to schedule and orbit insertion was extremely precise.

During the first four days after launch, covering the Launch and Early Orbit Phase (LEOP), the satellite was controlled from the ESA Flight Operations Centre at ESOC, in Darmstadt (D). The health of the satellite's subsystems was checked and then the perigee altitude was raised from 518 to 1030 km.

During the subsequent Commissioning Phase between 21 November and 8 December, the satellite, with its scientific instruments, was controlled from the ESA Mission Control Centre at Villafranca, near Madrid (E). All satellite subsystems were successfully tested and commissioned during this phase. The apogee altitude was adjusted to achieve the final orbit of 24 h period (70 611 km apogee and 1004 km perigee). The cryostat cover was ejected 10 days after launch and all scientific instruments have since been tested and have been making observations of various objects in space. Both the satellite and the scientific instruments are performing extremely well.

All flight operations and the ground segment, including the two ground stations at Villafranca (E) and at Goldstone (USA) are also working extremely well.

The Observatory Performance Verification Phase, during which the scientific instruments will be thoroughly characterised and calibrated and all critical automatic sequences tested, began on 9 December. It is planned to start the Routine Operations Phase in early February 1996.

Huygens

The system-level Critical Design Review process reached a climax with the meeting of the Review Board, chaired by ESA's Director of Scientific Programmes, R. Bonnet, and ESA's Inspector General, M. Trella, at ESTEC on 12 October.

The majority of the small number of issues needing the Board's attention resulted in actions of a more or less 'normal work' type, but two issues were highlighted for particular attention. Problems identified during the so-called 'Titan Entry Test', or low-temperature pressurised-atmosphere test, necessitated further study of the behaviour of the Probe's insulating foam.

The effects of pyrotechnic shocks upon electrical units were also deemed to require further examination. Study contracts to examine these two areas have therefore been let to specialist organisations, whose findings are due to be reported by the end of 1995.

Integration of the flight-model Probe continues at DASA (D). Some delayed deliveries of Probe hardware have necessitated work-around solutions, but integration in general has not been held up.

Delivery for integration of the flight-model experiments is deviating somewhat from the nominal plan and the resulting work-around solutions and erosion of contingencies has put pressure on the overall schedule. However, the Probe's delivery date to the launch site is not endangered.

Integral

The first part of the industrial design phase (Phase B) has been concluded with the System Requirements Review, with the Board meeting on 18 December. This review confirmed the concept of commonality of the Integral Service Module with that being developed for XMM. The Review also clearly identified key system-level points that require special emphasis at the start of the second part of Phase B.

Payload instrument design by the scientific collaborations is proceeding in parallel with the spacecraft development. Instrument system design has converged to a point where the spacecraft configuration and electrical architecture can be frozen.

The work on the interface with the Proton launcher is progressing slowly, still being hampered by the lack of a formal ESA/RKA Arrangement for Integral.

ERS-2

All of the ERS-2 instruments and the spacecraft platform continue to operate nominally.

Les opérations de vol et le secteur sol, comprenant les deux stations sol situées à Villafranca (E) et Goldstone (USA), donnent entière satisfaction.

La phase de vérification du fonctionnement de l'observatoire, au cours de laquelle seront caractérisés et calibrés en détail l'ensemble des instruments scientifiques et seront testées toutes les séquences automatisées critiques, a débuté le 9 décembre. La phase d'exploitation de routine devrait être engagée début février 1996.

Huygens

La réunion, le 12 octobre à l'ESTEC, de la commission de revue, placée sous la présidence du Directeur des programmes scientifiques de l'Agence, M. R. Bonnet et de l'Inspecteur général de l'ESA, M. M. Trella, a marqué le point culminant de la procédure de revue critique de conception au niveau système.

La majorité des quelques questions réclamant l'attention de la commission ont abouti à des actions qui ressortent plus ou moins d'un 'travail normal', mais deux problèmes nécessitant une attention particulière ont été mis en avant. Les problèmes recensés pendant ce que l'on a nommé 'les essais d'entrée dans l'atmosphère de Titan', ou essais en atmosphère pressurisée à basse température, ont nécessité une nouvelle étude du comportement de la mousse isolante de la sonde. On a estimé également que les effets des chocs pyrotechniques sur les unités électriques réclamaient un examen supplémentaire. Des contrats d'étude pour l'examen de ces deux questions ont donc été passés avec des organisations spécialisées. Leurs conclusions étaient attendues pour la fin de 1995.

L'intégration du modèle de vol de la sonde se poursuit à la DASA (D). Certains délais dans la livraison de matériels destinés à la sonde ont nécessité des solutions de repli, mais, de manière générale, l'intégration n'a subi aucun retard.

La livraison pour intégration des expériences du modèle de vol ne se déroule pas totalement selon le plan prévu et l'adoption de solutions de repli, ainsi que le rétrécissement de la marge d'aléas, ont rendu plus difficile le respect du calendrier global. La date de livraison de la sonde sur le site de lancement n'est toutefois pas compromise.

Integral

La première partie de la phase de conception industrielle (phase B) s'est conclue par la revue des impératifs système et la réunion de la commission le 18 décembre. Cette revue a confirmé le concept de communité entre le module de servitude Intégral et celui développé pour XMM. La revue a permis également d'identifier clairement les éléments clefs des sous-systèmes nécessitant une attention particulière lors du démarrage de la deuxième partie de la phase B.

La conception de l'instrumentation de la charge utile par les différentes collaborations scientifiques se poursuit parallèlement à la réalisation du satellite lui-même. La conception du système d'instrumentation a atteint un stade permettant d'arrêter définitivement la configuration et l'architecture électrique de la plate-forme.

Les travaux relatifs à l'interfaçage avec le lanceur Proton progressent lentement, toujours entravés par l'absence d'un arrangement officiel entre l'ESA et la RKA pour Integral.

ERS-2

L'ensemble des instruments ERS-2 et la plate-forme elle-même continuent de fonctionner de façon nominale.

Le fonctionnement du satellite demeure très bon et similaire à celui d'ERS-1, ce qui permet de poursuivre la phase unique d'exploitation en tandem ERS-1/ERS-2 qui a débuté en septembre. L'objectif principal consiste à réaliser une imagerie interférométrique de la surface des terres à l'échelle du globe, permettant, entre autres objectifs importants, de réaliser une cartographie de terrain à une échelle quasi-planétaire.

La campagne d'investigations sur le diffusiomètre s'est achevée avec succès fin novembre, avec l'adoption d'une solution de repli face à l'anomalie technique et la définition d'une démarche opérationnelle stable. Bien que la qualité des données et la stabilité à long terme fassent toujours l'objet d'une évaluation, les chances de voir l'instrument d'ERS-2 devenir pleinement opérationnel sont aujourd'hui considérées comme très bonnes.

La recette du diffusiomètre ERS-2, suspendue lors de l'intervention relative à la panne, devait débuter en janvier 1996 et durer au moins trois mois.

La revue de la phase de recette d'ERS-2, couvrant l'ensemble des instruments aussi bien que le secteur sol de l'ESA, a eu lieu en octobre. A l'exception du diffusiomètre, le fonctionnement nominal de tous les éléments du système a été confirmé.

Les instruments issus d'ERS-1 — SAR, RA et MWR, ont pu être déclarés opérationnels; les 'nouveaux' instruments — GOME, PRARE et ATSR-2 — n'ont pas encore achevé les procédures initiales de recette, bien que les résultats très encourageants déjà disponibles aient confirmé les prévisions les plus ambitieuses. La diffusion des données provenant de ces instruments commencera début 1996.

EOPP

Programmes futurs

A la suite de l'approbation d'un mécanisme et d'une procédure de sélection des missions d'exploration de la Terre les plus prioritaires, les principales actions menées au cours de la période de référence ont consisté à lancer toutes les activités propres à favoriser la production des rapports d'évaluation de chacune des neuf missions candidates afin de choisir celles qui permettront d'engager la phase A.

L'extension de l'EOPP au delà de la mi-1996 est toujours en cours de discussion avec les Délégations.

Campagnes

Tandis que continue l'analyse des données provenant des campagnes précédentes et en particulier celles de la campagne ELITE qui doivent permettre d'améliorer la conception fondamentale du lidar de rétrodiffusion — les travaux de définition des futures campagnes se sont poursuivis.

The satellite performances remain very good and similar to those of ERS-1, making possible the unique nine-month ERS-1/ERS-2 Tandem Operation phase, which started in September. The main objective is to perform interferometric imaging of the land surface on a global basis leading to, among other important goals, a quasi-global digital terrain map.

The Scatterometer investigation campaign was successfully concluded at the end of November with the development of a work-around for the technical anomaly and the achievement of a stable operational approach. Although data quality and long-term stability are still under evaluation, the chances of the ERS-2 instrument achieving full operational status now look very good.

The commissioning of the ERS-2 Scatterometer which was delayed during the trouble-shooting will start in January 1996 and last for three months.

The ERS-2 Commissioning Phase review, covering all of the instruments as well as the ESA ground segment, took place in October. With the exception of the Scatterometer, all other elements of the system were confirmed as operating nominally.

The recurrent (from ERS-1) instruments – SAR, RA and MWR – could be declared operational: the 'new' instruments – GOME, PRARE and ATSR-2 – were still in the first stages of commissioning, although very promising results were already available, confirming the high expectations. Release of data from these instruments will be authorised at the beginning of 1996.

EOPP

Future programmes

Following the establishment of an agreed mechanism and procedure for the selection of first-priority Earth Explorer missions, the major activity during the reporting period has been to initiate all activities appropriate to the production of assessment reports on each of the nine candidate missions to support the selection of the missions to proceed to Phase-A.

The future extension of EOPP beyond mid-1996 is still being discussed with Delegations.

Campaigns

While the analysis of data from previous campaigns continues – particularly the ELITE campaign which is expected to improve our fundamental understanding of backscatter lidar design – work has proceeded on defining future campaigns.

Envisat-1/ Polar Platform

Envisat-1 payload

All instrument negotiations, with the exception of those for ASAR, have now been completed. Delivery dates have been agreed which are consistent with a mid-1999 launch. Most ASAR subsystem contracts have also been negotiated. The ASAR instrument contract negotiation, and that with the mission prime contractor, will be completed in early 1996.

Structural models of MIPAS and the SCIAMACHY Optics Assembly have been delivered to the Polar Platform prime contractor. Other structural models, including ASAR, will complete their mechanical test programme and be delivered in early 1996.

Manufacture of engineering-model subsystems continues in accordance with negotiated schedules, with deliveries due in many cases in the first quarter of 1996. Integration of the engineering-model AATSR instrument is nearing completion, as are all the electronic subsystems of SCIAMACHY.

The withdrawal by CNES of the ScaRaB radiation-balance instrument and its associated shared Instrument Control Unit has necessitated some technical reconfiguration.

Manufacture has started of a number of elements of the Flight Model Instrument structure. A number of associated low level Critical Design Reviews have been held. On 9 November, a detailed presentation of the technical status of the Envisat Programme was made to the delegates of the Data Operations Scientific and Technical Advisory Group of the Agency's Earth Observation Programme Board. The DOSTAG concluded that 'a solid technical baseline existed for the Programme'.

Detailed investigations have been made into cost-saving measures which could be applied to the baseline programme. These measures are being investigated in parallel with the ongoing technical work. Conclusions in this area are expected in early 1996.

Polar Platform

Activities are proceeding as planned. The static load test of the PPF structure has been completed. Good correlation was achieved with predictions and the structure was submitted to the maximum loads currently predicted for the Ariane-5 environment and the latest payload mass distribution. The proto-flight structure has been delivered by CASA (E) to MMS-B (B) for structural-model integration. Structural-model tests are planned to start at the end of March at ESTEC (NL).

For the Critical Design Review (CDR) for the service module has been completed successfully and electrical integration has started.

The Payload Electronics Bay (PEB) electrical integration is in progress. Acceptance testing is scheduled for the first quarter of 1996, followed by the PEB's CDR and delivery to the prime contractor.

Envisat-1 ground segment

The Payload Data Segment (PDS) development activities were kicked-off with the prime contractor, Thomson-CSF (F), in early October.

METOP

The METOP design phase (Phase-B), kicked-off in July 1995, has progressed up to the Preliminary Review, which is planned for completion in January 1996.

Envisat-1/Plate-forme polaire

Charge utile Envisat-1

Toutes les négociations ayant trait aux instruments sont désormais achevées, à l'exception de celle concernant l'ASAR. Les dates de livraison ont été arrêtées d'un commun accord pour un lancement à la mi-1999. La plupart des contrats relatifs aux sous-systèmes de l'ASAR ont également été négociés. La négociation relative à l'instrument ASAR lui-même et celle menée avec le maître d'oeuvre de la mission devraient être conclues au début de 1996.

Les modèles structurels du MIPAS et l'ensemble optique SCIAMACHY ont été livrés au maître d'oeuvre de la plate-forme polaire. D'autres modèles structurels, dont celui de l'ASAR, doivent parachever leurs programmes d'essais mécaniques et seront livrés début 1996.

La fabrication des sous-systèmes des modèles d'identification se poursuit conformément aux calendriers négociés et leur livraison devrait intervenir dans de nombreux cas au cours du premier trimestre de 1996. L'intégration du modèle d'identification de l'instrument AATSR est presque achevée, de même que celle de tous les sous-systèmes électroniques de l'ensemble optique SCIAMACHY.

La décision du CNES de retirer l'analyseur du bilan radiatif ScaRab et l'unité partagée de commande des instruments qui lui est associée a imposé une reconfiguration technique.

La fabrication d'un certain nombre d'éléments de la structure des instruments du modèle de vol a commencé et a donné lieu à des revues critiques de conception de niveau inférieur.

Les délégués du Groupe consultatif 'Données, Exploitation et Questions scientifiques et techniques' (DOSTAG) du Conseil directeur du Programme d'Observation de la Terre de l'ESA ont suivi, le 9 novembre, une présentation détaillée de l'état d'avancement technique du programme Envisat. Le DOSTAG a estimé en conclusion 'qu'il existait une base de référence technique solide pour le programme'.

Des recherches détaillées ont été entreprises pour recenser les mesures d'économies susceptibles d'être appliquées au programme de référence. L'étude de ces mesures se poursuit parallèlement au travail technique. Des conclusions sont attendues dans ce domaine au début de 1996.

Plate-forme polaire

Les activités se déroulent comme prévu. Les essais de charge statiques de la structure de la PPF sont terminés. Leur corrélation avec les prévisions a été bonne et la structure a été soumise aux charges maximales actuellement prévues pour l'environnement d'Ariane-5, en fonction de la dernière répartition en date de la masse de charge utile. CASA (E) a livré la structure du prototype de vol à MMS-B (B) pour intégration du modèle de structure. Les essais du modèle de structure devraient être réalisés fin mars à l'ESTEC (NL).

La revue critique de conception du module de servitude s'est déroulée avec succès et l'intégration électrique a débuté.

L'intégration électrique du compartiment de l'électronique de la charge utile (PEB) est en cours. Les essais de recette sont prévus pour le premier trimestre de 1996 et seront suivis par la revue critique de conception du PEB et la livraison au maître d'oeuvre.

Secteur sol d'Envisat-1

Le maître d'oeuvre, Thomson-CSF (F) a donné le coup d'envoi, début octobre, des activités de développement du système de gestion des données de la charge utile (PDS).

METOP

La phase de conception (phase B) de METOP, lancée en juillet 1995, a progressé jusqu'au stade de la revue préliminaire, prévue en janvier 1996.

Les incertitudes entourant la définition du programme de développement principal (phase C/D) ont cependant conduit à interrompre les activités de cette phase B jusqu'à l'obtention d'un consensus. En conséquence, une phase 'd'attente' de deux mois a été mise en place jusqu'à la mi février 1996, à l'issue de laquelle il sera possible, avec une incidence minimale, de réorienter les activités industrielles.

Les autres activités entreprises dans le cadre du Programme préparatoire METOP progressent de manière satisfaisante. L'intégration du modèle de démonstration de l'instrument ASCAT est presque achevée et celle du modèle de démonstration MIMR a été lancée.

De nouvelles réunions relatives à la phase C/D de METOP-1 et au programme de système polaire Eumetsat ont eu lieu en présence des participants potentiels et d'Eumetsat, et d'autres sont prévues. La consolidation du programme de référence n'a pas encore fait l'objet d'un accord et un programme radicalement révisé à la baisse est envisagé.

Météosat de deuxième génération (MSG)

La phase de développement principale (phase C/D), marquée par l'organisation d'un examen de la configuration de base à la mi octobre 1995, se déroule selon le calendrier prévu. Une série de revues préliminaires de conception de niveau inférieur ont été lancées à la suite de cet examen, avec pour objectif principal de lancer la fabrication du modèle d'identification et du modèle thermique/mécanique au niveau des équipements et des sous systèmes.

Le Conseil d'Eumetsat a approuvé, lors de sa session du mois de novembre, le principe du financement par l'organisation des modèles récurrents MSG-2 et 3 ainsi que de leur approvisionnement industriel par l'ESA en tant qu'agent chargé de l'approvisionnement d'Eumetsat.

Avec le lancement des satellites de l'ESA MSG-1, prévu à la mi-2000, et MSG-2, prévu en 2002 en tant que secours en orbite de MSG-1, le programme de mise au point et de fabrication du satellite s'étend aujourd'hui jusqu'à 2003, année qui verra la livraison de MSG-3 pour un stockage au sol qui doit normalement durer cinq ans. Ce scénario est nécessaire à Eumetsat pour que l'organisation puisse garantir un service

Due to uncertainties in the definition of the main development (Phase-C/D) programme, it has proved necessary to interrupt the Phase-B activities until a consensus can be found. Accordingly a 'holding' phase of two months has been introduced which will then permit a re-direction of the industrial activities, with minimum impact, up to mid-February 1996.

The other activities within the METOP Preparatory Programme are progressing well, with the ASCAT instrument demonstrator nearing the end of its integration and the MIME demonstrator having started this phase.

Further meetings of Potential Participants and of EUMETSAT regarding the METOP-1 Phase-C/D programme and the EUMETSAT Polar System programme have been held and more are planned. A consolidation of the baseline programme has not yet been agreed and a radically descoped programme is being considered.

Meteosat Second Generation (MSG)

The main development phase (Phase-C/D) has been proceeding on schedule, with a successful Baseline System Review being held in mid-October 1995. A series of lower-level preliminary design reviews follows, with the main objective of releasing engineering-model manufacture and thermal/mechanical-model manufacture at equipment and subsystem level.

For the MSG-2 and 3 recurrent models, the Eumetsat Council, at its November session, approved in principle their financing by Eumetsat and their procurement from industry by ESA as Eumetsat's procurement agent.

With ESA's MSG-1 to be launched in mid 2000, and MSG-2 in the year 2002 for in-orbit standby to MSG-1, the spacecraft development and manufacturing programme now extends until 2003, the year in which MSG-3 will be placed into ground storage nominally for five years. This scenario is needed by Eumetsat to guarantee an uninterrupted operational geostationary imaging and data dissemination service from the year 2000 until 2012, each spacecraft having a design lifetime of seven years.

Manned Space Programme

European contribution to International Space Station Alpha (ISSA)
Following the adoption of the Declaration on the Manned Space Programme at the ESA Council Meeting at Ministerial Level in Toulouse (F) in October, the planning for the initiation of the new programme elements was reviewed to ensure a smooth transition from the approved ongoing programme slices.

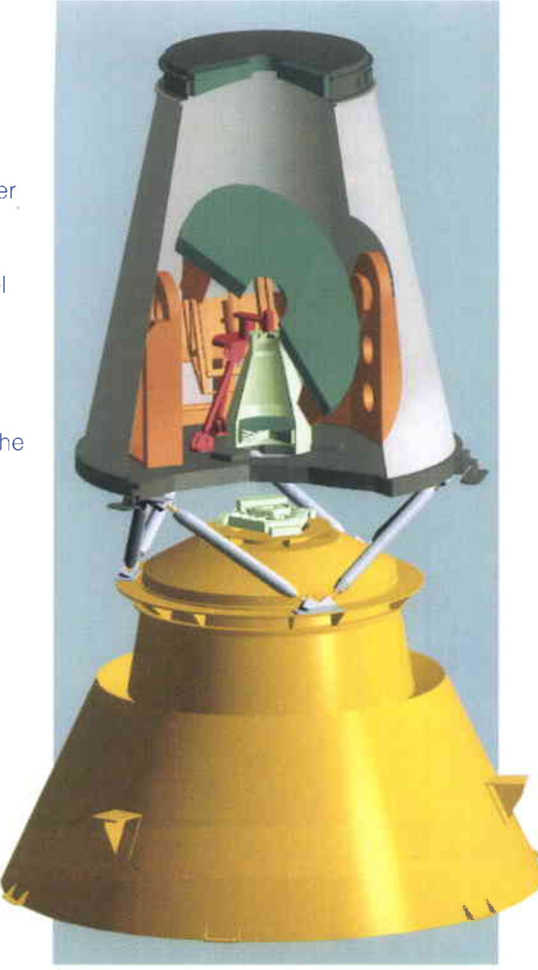
Columbus Orbital Facility (COF)
The primary emphasis in the technical area focussed on closing out the remaining technical non-compliances against the ESA/NASA joint requirements baseline. Some detailed design aspects of the COF/ISSA interface were addressed in a multi-lateral International Interface Working Group meeting between ESA, NASA and NASDA in Houston during the last two weeks of October, where all Interface Control Documents involving the COF were reviewed and updated in line with the latest ISSA baseline.

In the programmatics area, the primary emphasis was directed towards adaptation of the overall development schedule to take into account the shifting of the COF launch from February to November 2002 within the overall funding and payment profile constraints as defined by the Programme Proposal.

MSTP Technology Programme
The programme has continued with studies and technology experiments concentrating on:
- aerothermodynamics and navigation/guidance/control
- communications and functional electronics
- thermo-mechanical systems
- thermal protection systems.

Atmospheric Re-entry Demonstrator (ARD)
The failure of the ARD drop test was a disappointment and various alternative means and tests necessary for parachute qualification were reviewed. It was concluded that a drop test with a representative mockup from a balloon was the only test that would allow full qualification of the parachute in the appropriate flight domain, and so a further test will be scheduled in the spring of 1996.

Automated Transfer Vehicle (ATV)
Following the System Requirements Review, the system specifications, element architecture and project plans were consolidated. The re-boost/refuelling/pressurised cargo mission to the Russian segment of the Space Station, which is the baseline mission in the Programme Proposal, will be further studied in the January – May 1996 Phase-B extension with Russian and European contractors.



The MSG optical instrument SEVIRI (Scanning Enhanced Visible and Infra-Red Imager)

L'instrument optique du MSG (SEVIRI: Imageur à balayage fin dans le visible et l'infrarouge) *opérationnel ininterrompu de fourniture d'images et de diffusion de données à partir de l'an 2000 jusqu'en 2012, chacun de ces satellites géostationnaires ayant une durée de vie prévue de sept ans.*

Programmes spatiaux habités

Contribution européenne à la Station spatiale internationale Alpha (ISSA)

A la suite de l'adoption de la Déclaration sur les programmes spatiaux habités, lors de la réunion du Conseil de l'ESA qui s'est tenue au niveau ministériel à Toulouse en octobre, la planification du lancement des nouveaux éléments de programme a été réexaminée afin d'assurer une transition sans heurts avec les tranches de programme approuvées et déjà en cours d'exécution.

Elément orbital Columbus (COF)

Dans le domaine technique, l'accent a principalement porté sur l'élimination des points de nonconformité technique avec les impératifs de la base de référence commune ESA/NASA. Certains aspects détaillés de la conception de l'interface COF/ISSA ont été examinés durant la première quinzaine d'octobre, lors de la réunion à Houston d'un groupe de travail multilatéral 'interface', rassemblant l'ESA, la NASA et la NASDA. L'ensemble des documents de contrôle d'interface intéressant le COF ont été examinés et mis à jour, conformément à la dernière base de référence ISSA.

Dans le domaine programmatique, l'accent a été mis, notamment, sur l'adaptation du calendrier global de développement après le report de la date de lancement du COF de février à novembre 2002, en tenant compte des contraintes générales en matière de financement et de profil de paiements définies dans la Proposition de Programme.

Programme de technologie MSTP

Le programme s'est poursuivi avec des études et des expériences technologiques portant principalement sur les domaine suivants:

- *aérothermodynamique et navigation/guidage/contrôle*
- *télécommunications et électronique fonctionnelle*
- *systèmes thermo-mécaniques*
- *systèmes de protection thermique*

Démonstrateur de rentrée atmosphérique (ARD)

L'échec de l'essai de largage de l'ARD a constitué une déception et les différents moyens et essais de remplacement nécessaires à la qualification du parachute ont été examinés. On est parvenu à la conclusion que seul un essai de largage d'une maquette représentative depuis un ballon permettrait une qualification complète dans le domaine de vol approprié. Un nouvel essai sera ainsi programmé au printemps 1996.

Véhicule de transfert automatique (ATV)

Les spécifications du système, l'architecture des éléments et les plans du projet ont été consolidés à la suite de la revue des impératifs système. Les études relatives à la mission de rehaussement d'orbite, de réapprovisionneme nt en ergols et de livraison de cargaisons pressurisées à la composante russe de la Station spatiale, qui constituent la mission de référence dans la Proposition de Programme, seront poursuivies entre janvier et mai 1996, au cours de l'extension de la phase B conduite avec les contractants russes et européens.

Les activités préparatoires relatives à l'ATV se poursuivent, l'accent étant mis sur les interfaces entre le noyau central, les détecteurs et les récepteurs destinés au système américain de localisation mondiale par satellite (GPS). Le premier modèle de développement de récepteur GPS a été préparé en vue des essais systèmes et la fabrication du modèle de développement du détecteur de rendez-vous laser a été autorisée. Les activités centrales de l'ARP continuent à être axées sur la préparation de démonstrations en vol avec le système de transport spatial de la NASA et sur les interfaces avec le programme ATV.

Véhicule de transport d'équipages (CTV)

Sur le plan industriel, les activités menées dans le cadre de l'extension de la phase A se sont concentrées sur un concept de véhicule unique associant une tour d'extraction, un module d'équipage et un module de ressources/propulsion spécialisé ménageant un volume supplémentaire pour de possibles marges de lancement. Le précurseur du CTV, susceptible d'être utilisé pour un essai en vol orbital en 2002, a également fait l'objet d'une analyse en parallèle.

Livraisons à court terme

Base de données mission Columbus (MDB)

L'examen de pré-livraison, avant la livraison finale de la MDB à NASA/Boeing prévue aux termes des obligations de livraisons à court terme de l'ESA, s'est déroulé avec succès à Brème.

Système principal de gestion des données pour le module de servitude (DMS-R)

D'importantes réunions techniques ont été organisées en octobre à Moscou entre les industriels européens et russes et l'Agence spatiale russe (RKA). Elles ont permis de faire progresser considérablement la base de référence technique du DMS-R, en ce qui concerne notamment l'ensemble des interfaces avec la composante russe.

Bras télémanipulateur européen (ERA)

Les activités industrielles se sont poursuivies et la première des revues préliminaires de conception au niveau des sous-systèmes a été entreprise. Ces revues, qui permettent de lancer officiellement la fabrication des modèles de qualification de l'ERA, doivent se conclure par une revue de conception du Programme au niveau système, au cour du premier trimestre de 1996.

Système de régulation d'ambiance et de soutien vie pour le Mini-module logistique pressurisé italien (MPLM ECLS)

Les activités industrielles ont été officiellement lancées après la mise au point définitive de l'Arrangement de coopération entre l'Agence spatiale italienne (ASI) et l'ESA. Des réunions ont été organisées avec la participation des industries concernées, de l'ASI et du maître d'oeuvre du MPLM pour examiner le calendrier global du programme, afin d'éviter tout retard dans les dates de lancement prévues.

Equipements de soutien de laboratoire

- *Congélateur — 80°: Une série de revues réalisées avec participation de l'industrie et de la NASA ont confirmé la validité de la conception de référence du congélateur.*
- *Boîte à gants pour la recherche en microgravité: La boîte à gants a subi avec succès une revue de sécurité de niveau 0 et une revue par l'équipage*

The ATV preparatory activities continued, with emphasis on the interfaces between the kernel, sensors and receivers for the US Global Positioning Satellite System (GPS). The first GPS receiver development model was prepared for system tests, while manufacture of the rendezvous laser sensor development model was authorised. The ARP kernel activities continued to focus on the preparation of the in-flight demonstrations with the NASA Space Transportation System and interfaces with the ATV programme.

Crew Transportation Vehicle (CTV)

The Phase-A extension activities undertaken by industry have concentrated on a single vehicle concept. It comprises a launch escape tower, a crew module, and a dedicated resource/propulsion module integrating additional room for possible use of launch margins. The CTV precursor to be used for the orbital flight test in 2002 was also analysed in parallel.

Early deliveries

Columbus Mission Database (MDB)

The pre-delivery review for the final MDB delivery to NASA/Boeing under ESA's Early Delivery obligation was successfully completed in Bremen.

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

An extensive series of technical interchange meetings with European and Russian industry and the Russian Space Agency (RSA) were completed in Moscow during October. These meetings produced considerable progress in defining the detailed DMS-R technical baseline, including all interfaces to the Russian segment.

European Robotic Arm (ERA)

Industrial work proceeded and the first of the Subsystem Preliminary Design Reviews was initiated. These reviews, which serve to formally release the manufacture of the ERA qualification models, will conclude with a system-level Programme Design Review in the first quarter of 1996.

Environmental Control and Life-Support System for the Italian Mini Pressurised Logistics Module (MPLM ECLS)

Following finalisation of the Cooperative Arrangement between the Italian Space Agency (ASI) and ESA, the industrial tasks were formally initiated. Meetings were held with industry, ASI and the MPLM prime contractor to review the overall programme schedule in order to avoid any delay in the planned MPLM launch dates.

Laboratory Support Equipment

- The −80° Freezer: A series of reviews were held with industry and NASA which confirmed the validity of the freezer baseline design.
- The Microgravity Science Glovebox: The glovebox successfully passed the NASA level-0 safety review and a NASA crew review in August. The fully functional MSG Development Model is now being manufactured according to the design baseline.
- The Hexapod: The Phase-B preparation activities focussed on three areas: requirements assessment, preliminary design configuration definition, and preparation for thermal-vacuum testing.

Utilisation

A meeting on 'Space Station Utilisation for Technology' took place at ESTEC in November to discuss technology projects, technology user requirements, and access conditions to the Space Station for European projects. This meeting was complemented by a Workshop organised by ESA's Office of Space Commercialisation to review the activities of the different RADIUS (Research Associations for the Development of Industrial Use of Space) members and to discuss opportunities for future access to space for commercial users.

Euromir 95

The Euromir 95 mission, with the ESA astronaut Thomas Reiter on board the Russian space station Mir, is progressing as planned. Up to now, the overall experimental programme (life sciences, astrophysics, material sciences, technology) has been kept very close to schedule, with no major interruptions or failures. A total of 41 experiments are being carried out during the 180-day mission, which is now scheduled to end on 29 February 1996.

The major highlight of the mission to date has been the 5 h Extra-Vehicular Activity (EVA) of Thomas Reiter and his Russian colleague Sergei Avdeev on 20 October, during which elements of the European Science Exposure Facility (ESEF) were successfully deployed outside the Spektr module. Another highlight was the three-day docking of the US Space Shuttle 'Atlantis' with Mir in November. This was the first time American, Canadian and European astronauts and Russian cosmonauts had worked together aboard a space station, making it something of a preview for the International Space Station.

All of Thomas Reiter's activities are planned at and monitored from DLR's German Space Operations Centre in Oberpfaffenhofen. The mission management team is located at ESTEC in Noordwijk (NL), and an operations support team at the ZUP Russian Control Centre in Kaliningrad, near Moscow, interfaces directly with the Russian flight authorities.

Microgravity Programme

A further programme covering the development of microgravity multi-user facilities for the Space Station was approved at the ESA Council Meeting at Ministerial Level in Toulouse in October. A subscription level of 98.03% of the overall financial envelope of 202 MAU was achieved for this 'Microgravity Facilities for Columbus' (MFC) programme.

The USML-2 Spacelab mission took place from 20 October to 5 November. The two ESA microgravity payloads on board – the Advanced Protein Crystallisation Facility (APCF) and the Advanced Glove Box – both performed very well and the results of the various experiments are currently being evaluated.

The Maxus-2 sounding rocket, providing 12 min of weightless conditions, was successfully launched from Kiruna on 28 November. Four fluid-physics and four life-sciences experiments were conducted. One experiment gave only partial results due to a mechanical malfunction, but the other seven were completely successful.

réalisées en août par la NASA. La fabrication du modèle de développement pleinement fonctionnel a été lancée conformément à la conception de référence.

— *Hexapod: Les activités de préparation de la phase B ont principalement porté sur trois domaines: évaluation des impératifs, définition de la configuration du concept préliminaire et préparation des essais thermiques sous vide.*

Utilisation

Une réunion sur 'l'utilisation de la Station spatiale pour la technologie' s'est déroulée en novembre à l'ESTEC; son objectif était d'examiner différents projets technologiques, les impératifs utilisateur en matière de technologie et les conditions d'accès à la Station spatiale pour les projets européens. Cette réunion a été complétée par un atelier organisé par le Bureau de commercialisation de l'espace de l'ESA qui a examiné les activités des membres des différentes associations de recherche pour le développement de l'utilisation industrielle de l'espace (RADIUS) et a évalué les futures occasions d'accès à l'espace des utilisateurs commerciau.

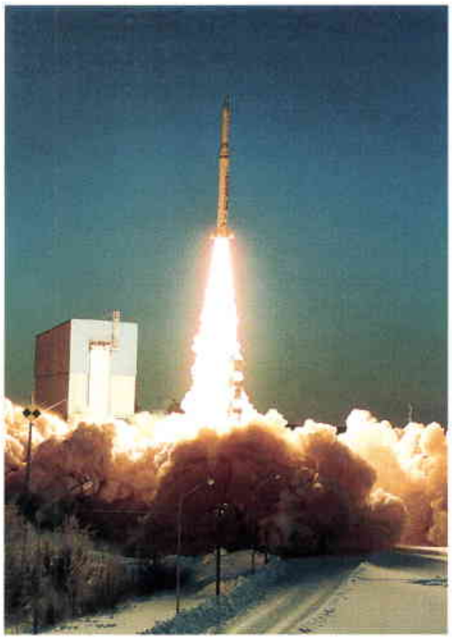
Euromir 95

La mission Euromir 95, avec la présence de l'astronaute de l'ESA Thomas Reiter à bord de la station spatiale russe Mir, se déroule conformément aux plans établis. Le programme expérimental global (sciences de la vie, astrophysique, sciences des matériaux, technologie) a jusqu'à présent été pratiquement mené à bien selon le calendrier prévu, sans interruptions ou incidents majeurs. Un total de 41 expériences doivent être réalisées au cours de cette mission de 180 jours, qui doit s'achever selon les prévisions actuelles le 29 février 1996.

Le point d'orgue de la mission a été à ce jour la sortie de 5 heures, le 20 octobre, de Thomas Reiter et de son collègue russe Sergei Avdeev, au cours de laquelle ils ont pu déployer des éléments de l'installation d'exposition scientifique européenne (ESEF) à l'extérieur du module Spektr. L'amarrage, pendant trois jours en novembre, de la navette spatiale américaine 'Atlantis' à la station Mir a constitué un autre événement important.

C'est la première fois que des astronautes américains, canadiens, européens et des cosmonautes russes pouvaient travailler ensemble à bord d'une station spatiale et procéder ainsi à une sorte de répétition de ce qui se passera à bord de la Station spatiale internationale.

Toutes les activités de Thomas Reiter sont planifiées et surveillées depuis le Centre allemand de recherches et d'opérations aérospatiales (DLR) à Oberpfaffenhoffen. L'équipe de gestion de la mission est basée à l'ESTEC, à Noordwijk (Pays-Bas), et une équipe de soutien des opérations, basée au Centre de contrôle russe (ZUP) de Kaliningrad, près de Moscou, assure directement la liaison avec les responsables russes du vol.



The Maxus-2 launch from Kiruna (S) on 28 November

Lancement de Maxus-2 depuis Kiruna (S) le 28 novembre

Programme de recherche en microgravité

Un nouveau programme, couvrant le développement des installations multi utilisateurs de recherche en microgravité destinées à la Station spatiale, a été approuvé lors du Conseil de l'ESA au niveau ministériel qui s'est tenu en octobre à Toulouse. Les Délégations ont souscrit à hauteur de 98,03% l'enveloppe financière globale de 202 MUC de ce programme 'd'installation s de recherche en microgravité pour Columbus'.

La mission Spacelab USML-2 s'est déroulée du 20 octobre au 5 novembre. Les deux charges utiles de recherche en microgravité de l'ESA embarquées à bord — l'installation de cristallisation de protéines de pointe (APCF) et la boîte à gants de pointe — ont fonctionné toutes deux de façon très satisfaisante et les résultats des diverses expériences pratiquées sont actuellement en cours d'évaluation.

La fusée-sonde Maxus-2, qui offre 12 minutes de conditions en apesanteur, a été lancée avec succès le 28 novembre de Kiruna (Suède). Quatre expériences de physique des fluides et quatre expériences de sciences de la vie ont été réalisées. Une seule de ces expériences n'a obtenu que des résultats partiels en raison d'un dysfonctionnement mécanique, mais les sept autres ont été couronnées de succès.

ESA Astronaut Thomas Reiter at work aboard Euromir 95

L'astronaute ESA Thomas Reiter au travail à bord d'Euromir 95

In Brief

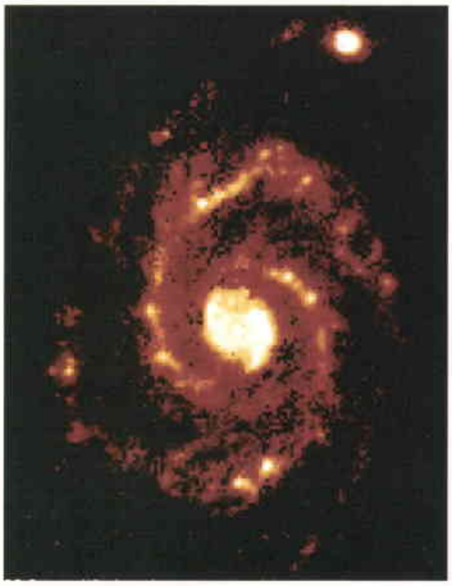
ISO Unmasks Galaxies

ISO, ESA's Infrared Space Observatory, was successfully launched on 17 November by an Ariane launcher from Europe's spaceport in Kourou, French Guiana. In the first two and a half months of operations, the commissioning of the satellite was undertaken and the performance of the scientific instruments was verified. The spacecraft and all instruments are working well. The routine operations and the observation programme began in February.

ISO is the world's first true astronomical observatory in space operating at infrared wavelengths. It will provide the scientific community with an unprecedented opportunity — the only one for the next 10 years — to observe a wide variety of weak infrared radiation sources, such as cold gases, galaxies and stars dying and being born.

Teams of astronomers have already begun receiving data from many cosmic sources. Those preliminary results confirm ISO's uniqueness as an observatory.

ISO prior to transfer to the Ariane launcher gantry, at Europe's spaceport in Kourou



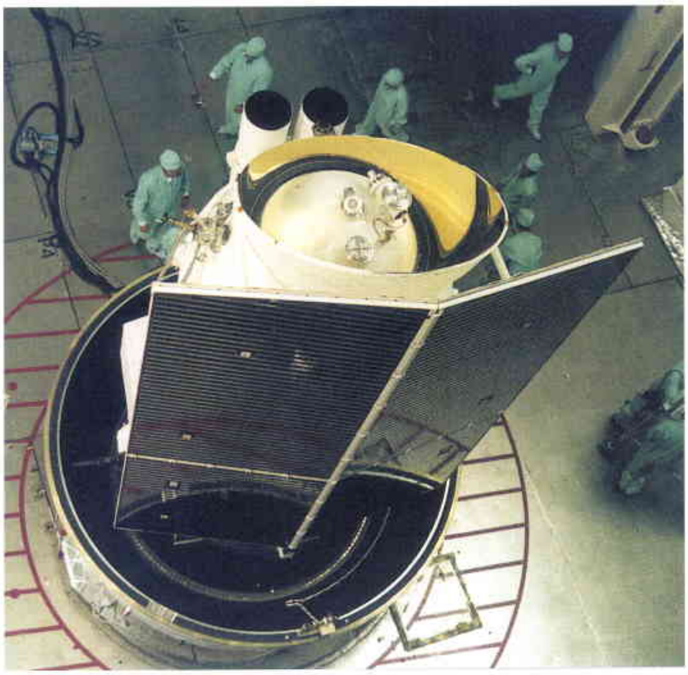
The Whirlpool Galaxy (M51) as seen by ISO at the infrared wavelength of 15 microns. At that wavelength, the Earth's atmosphere makes cosmic observations very difficult.

Star formation in progress
The ISO camera, called ISOCAM, has obtained this infrared image of star formation along the spiral arms of a galaxy 20 million light-years away.

The Whirlpool Galaxy, catalogued as M51 or NGC 5194, is a relatively near neighbour of our own galaxy, the Milky Way. While it is smaller and less massive than the Milky Way, it is much brighter due to recent intense star formation. Historically, it was the first 'spiral nebula' identified by astronomers. While very detailed images have been available for some time in the optical and radio wavelength range, infrared data in the ISO range has been very limited. In this image, not only the spiral structure but also details within it are easily visible.

Bright spots in the spiral arms correspond to warm dust clouds where star formation is proceeding on a large scale. Those areas are linked by regions of cooler dust along the spiral arms and in the spaces between the arms, where previous generations of stars have left their debris. The spiral arms can be traced right into the heart of the galaxy, where there are hot spots of star formation on either side of a bright central nucleus.

A companion galaxy (NGC 5195), at the top of the image, appears much smaller than it does by visible light because starmaking is concentrated near its nucleus.

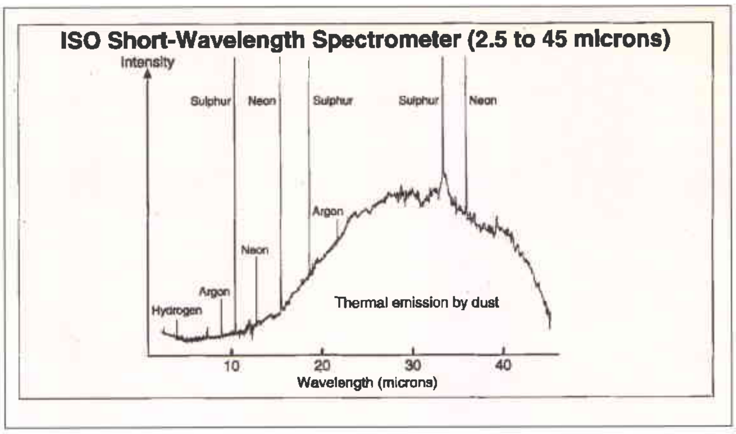


ISO mounted on the Ariane launcher prior to closing of the fairing

Lift-off of the Ariane 44P carrying ISO from Kourou

Different impressions of a dying star
When a moderate-sized star dies, it releases a cloud of chemical elements into space called a planetary nebula. These ISOCAM images of the planetary nebula NGC 6543 illustrate ISO's unique ability to range freely through the infrared wavelengths.

At 10.5 microns, ISOCAM sees emissions from charged sulphur atoms, giving the nebula a spherical appearance. At 12.8 microns, it sees radiation from charged neon atoms which gives the nebula an elongated shape. At 15 microns, arms of warm dust protrude in various directions as the ejected matter interacts with material released from the star earlier.



The spectrum from the Short-Wavelength Spectrometer shows the intensity of emission at each wavelength. Sulphur and neon are present. The 'hump' is due to warm dust in different parts of the nebula, at low but variable temperatures.

SOHO Commissioning Nears End

Since its launch on 2 December 1995, SOHO, ESA's Solar Heliospheric Observatory, has been heading towards its vantage point at 1.5 million kilometres from the Earth. From there, it will probe the interior of the Sun, addressing many fundamental questions about the star.

Two and a half months after the launch, the mission objectives are all being met or exceeded. The spacecraft has been checked and found to be in excellent condition. Specific tests on data transmission and microdisturbances (jitter), which have recently been completed, have confirmed that the environment and services offered to the scientific payload are exceeding specifications.

The scientific payload of 12 European and American experiments, covering three solar physics disciplines (solar atmosphere remote sensing, helioseismology, and solar wind investigations in situ), has been fully switched on following a quiescent period. That interval was planned to allow a complete outgassing of volatile substances to take place without affecting the instrument's final cleanliness.

All instruments have, where applicable, seen their 'first light' and are in some cases already gathering scientific data.

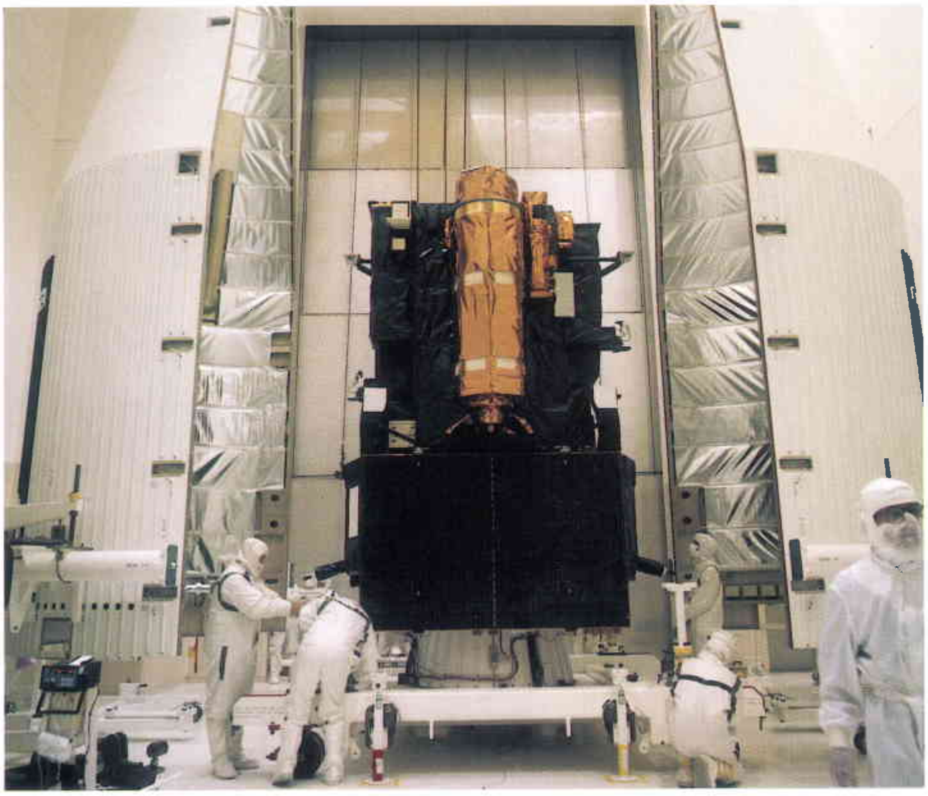
A major midcourse correction manoeuvre, executed on 4 – 5 January, has put SOHO on an optimised path towards its final orbit around the Lagrangian point L1. The injection into that halo orbit is planned for 14 February.

Further instrument and spacecraft calibrations and interaction testing will be carried out in the coming weeks, leading to the conclusion of the commissioning of the spacecraft and its payload — and the beginning of the main observation programme — at the end of March.

Arrival of the SOHO spacecraft and associated equipment — a total of 59 tons — at Kennedy Space Center (KSC) in Florida on 1 August for the start of the launch campaign

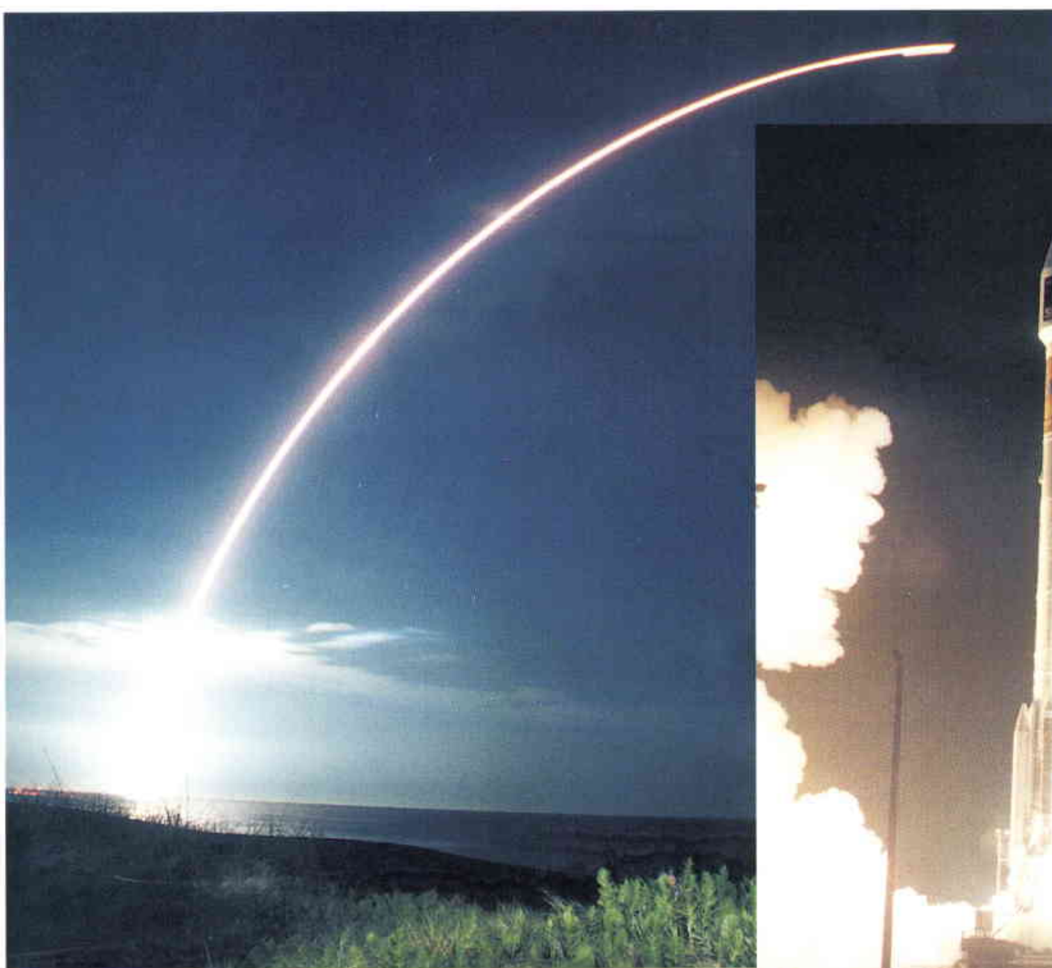
SOHO, fully assembled, in the clean tent of the SAEF-2 Facility at KSC

The SOHO spacecraft during the final solar-array deployment tests at KSC. The truss in the foreground was used to compensate for the effects of gravity on the deployed wing

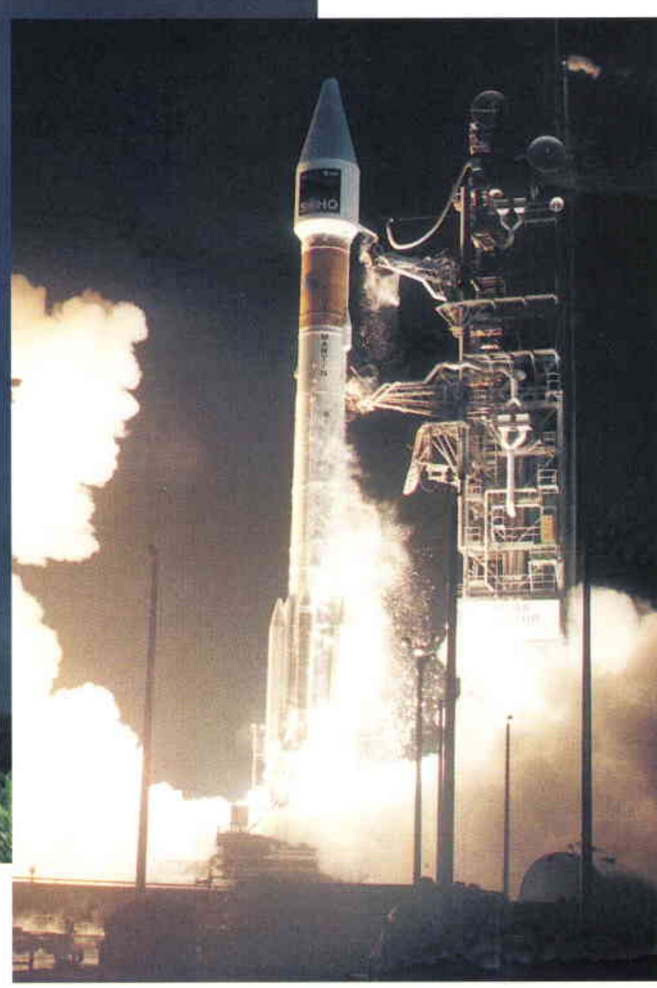


The encapsulation of SOHO beneath the fairing of the Atlas-2AS launcher on 9 November

SOHO being lifted to the top of the Atlas launcher



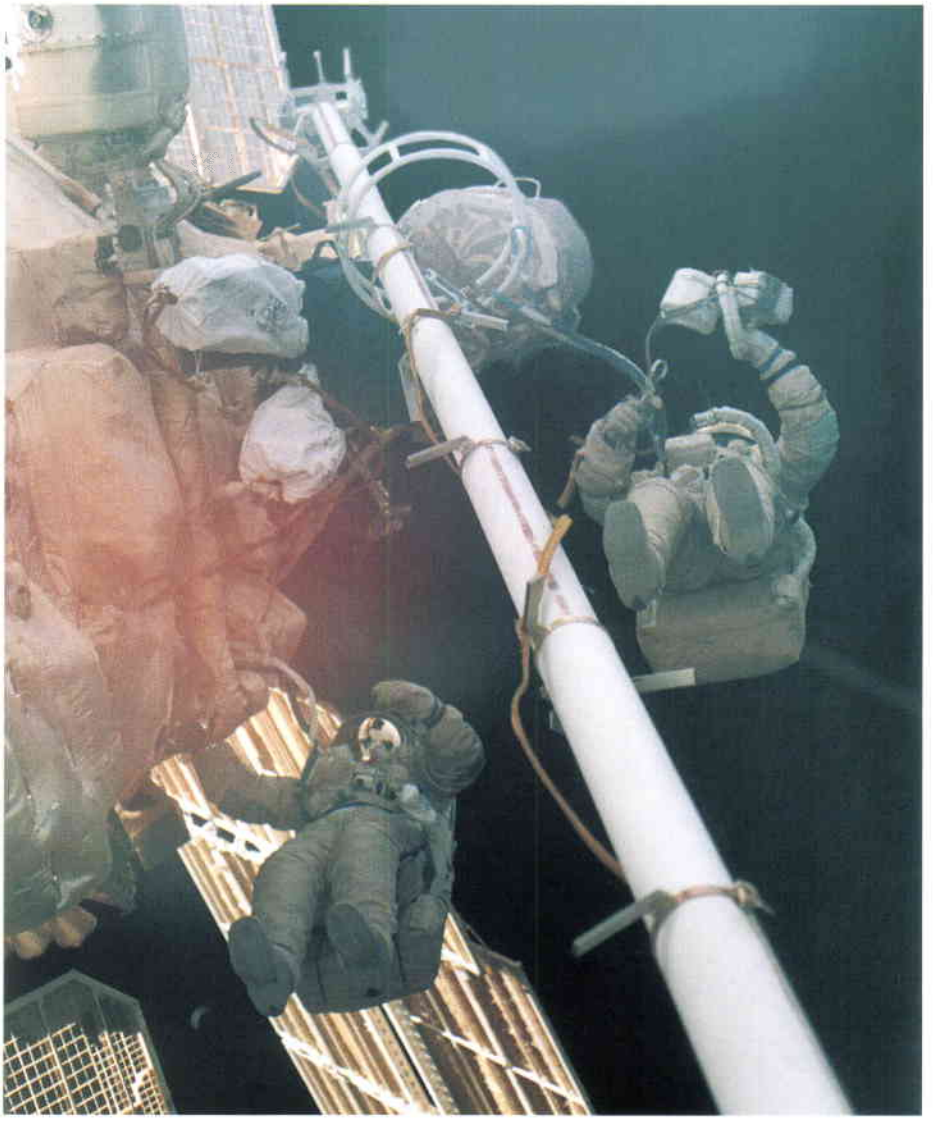
The first 5 minutes of the Atlas's flight, captured in a long-exposure image



Lift-off at 3.08 Eastern Standard Time on 2 December, as SOHO starts its long voyage to the Lagrangian point (L1) between Earth and Sun

EuroMir Astronaut Takes Second Spacewalk

Thomas Reiter, the ESA astronaut who has been on board the Russian space station Mir for more than five months, made his second Extra Vehicular Activity (EVA) or 'spacewalk' on 8 February. He made his first one last October when he installed an experiment, the European Space Exposure Facility, on the exterior of the station, as part of the EuroMir mission. He became the first ESA astronaut to perform a spacewalk.



One of the EuroMir astronauts working at the end of a manually-operated telescopic arm used to reach the work site

During the recent four-hour outing, he and a Russian cosmonaut recovered two cassettes from the facility. The cassettes had been collecting cosmic dust and man-made space debris. They can be opened and closed by remote control from within Mir. One had remained open throughout most of the mission, the other had been opened only when the Earth passed through the trail of dust left behind by comets.

They also installed a new cassette which was successfully tested during the EVA. Thomas Reiter will carry the experiment cassettes with him when he returns to Earth at the end of February.

Space scientists are eagerly awaiting them in order to study their contents. The results of the experiments should provide a better understanding of the composition of the microscopic debris that clutters low Earth orbit. This information is important for the design of the International Space Station; it will have to withstand constant bombardment by the tiny particles. Scientists will also investigate how much of the debris is man-made and how much is naturally-occurring cosmic dust. The contents of the casettes will provide the first opportunity to study cometary material in the laboratory.

The Russian space station Mir in orbit. It has a modular construction, with four scientific modules docked to the core habitation module

From the many television and voice transmissions to Earth, Thomas Reiter appears to be in very good spirits and at ease aboard Mir, his home and workplace since 5 September 1995.

The 180-day EuroMir 95 mission will end on 29 February, with the Soyuz capsule landing in Kazachstan, Russia. A new crew is scheduled to travel to Mir on 21 February.

ESA Astronauts to Fly on Tethered Satellite Mission

Two ESA astronauts, Claude Nicollier and Maurizio Cheli, will be onboard the Space Shuttle 'Columbia' when it blasts off on a unique mission that could open a new era of space tether operations.

During the 14-day mission (STS-75), a Tethered Satellite System (TSS) will be deployed for the second time and the US Microgravity Payload (USMP) will be flown for the third time. The launch is scheduled for 22 February and the landing for 7 March.

Tethered satellite to be deployed
The TSS project is a joint effort of the Italian Space Agency (ASI) and NASA. The satellite, weighing 518 kg and measuring 1.6 metres in diameter, will be deployed on the end of a conductive tether that is 20.7 km long and only 2.54 mm thick. One goal is to demonstrate that a satellite can be deployed, stabilised and retrieved. The electrodynamic effects of moving such a tether through the Earth's magnetic field will also be studied. The system also houses 12 scientific experiments.

The tethered satellite was originally flown in 1992. Because of repeated problems with the deployment mechanism, the satellite could only be partially deployed and the experiment had to be interrupted. The equipment has now been modified.

There are many potential uses for tether systems. In the future, they could be used to generate electrical power for orbiting spacecraft, including the International Space Station, or for spacecraft propulsion. They could also be used for a range of atmospheric and aero-thermodynamic investigations through long-period exploration of the Earth's outer atmosphere.

The ESA astronauts who will fly on the Tethered Satellite System mission: Maurizio Cheli (left) and Claude Nicollier (right).

Three Europeans on board
The two ESA astronauts will participate as mission specialists. Claude Nicollier, from Switzerland, will be making his third flight. He will be involved in the dynamic phases of tether deployment and retrieval; he will be the satellite 'navigator', closely monitoring its position and movement. Nicollier was a mission specialist on the first TSS flight, on board STS-46 in August 1992, during which ESA's retrievable platform Eureca was also released. During his second flight, STS-61 in December 1993, Nicollier operated the remote arm during the refurbishment of the Hubble Space Telescope.

The second ESA astronaut, Maurizio Cheli, from Italy, will be making his first flight. He will perform the role of flight engineer and will control the extending of the boom to position the satellite for release.

A third European will be part of the seven-member crew. Umberto Guidoni, also from Italy, will fly as the TSS payload specialist. He will represent the Italian Space Agency (ASI). The other four members of the crew will be NASA astronauts.

Ariane-5 Programme Progresses

Following the successful completion of the flight readiness review of the Ariane-5 launcher on 19 and 20 February, the review steering committee gave its approval for the start of the launch campaign, during which the launcher is readied for flight, on 4 March. The target date for the first launch of Ariane-5 has been set at 15 May.

The first qualification test of the cryotechnic stage was performed successfully in December at the launch site in Kourou, French Guiana. It lasted 10 minutes and 29 seconds, demonstrating the actual flight time of that stage. The second and last test was performed on 6 January. It lasted 9 minutes and 53 seconds. Both were carried out by CNES teams under the responsibility of Aérospatiale, the stage authority.

The other elements of the launcher, including the solid booster stages, storable propellant stage, fairing, Speltra, and vehicle equipment bay, have already been qualified. They were shipped to Kourou in mid-February (with the exception of the solid booster stages which are manufactured in Guiana).

ESA has delegated the management of its Ariane-5 programme to CNES, the French space agency.

New control centre opened
In preparation for the Ariane-5 flights, a new launch control operations centre has been built at the Guiana Space Centre. It features state-of-the-art technology for spacecraft tracking, data transmission and internal communications. It is already being used for Ariane-4 launches.

ERS-2 to Track Down Origins of Ozone Depletion

Following eight months of calibration and validation, the Global Ozone Monitoring Experiment (GOME) on board ESA's ERS-2 satellite is now beginning to deliver data that will enable valuable ozone monitoring. Although the ozone hole has been observed from space for nearly 10 years, it is only possible now to measure the trace gases that cause the ozone values to fluctuate.

Professor Paul Crutzen, Director of the Max Planck Institute for Chemistry in Mainz, Germany, and a winner of the 1995 Nobel Prize for Chemistry, recently presented some of the first calibrated and validated GOME data. Although it is still early in the mission, a group of researchers has already found one of the most 'hunted' trace gases, bromine oxide, in ERS-2 spectra, and another group has detected chlorine dioxide. Both are thought to affect ozone values.

The addition of GOME to ERS-2 is the major improvement that distinguishes it from its predecessor, ERS-1. ERS-2, launched in April 1995, is currently operating in tandem with ERS-1, launched four years earlier. As ERS-2 circles the Earth, GOME measures the intensity of the 'Earthshine' light over a large spectral range and at high resolution. Previous instruments have had 6 to 12 spectral channels, GOME has 3500, providing scientists with a very powerful tool for observing many rare atmospheric gases. Previously, such trace gases could only be measured from stratospheric balloons.

Prof. Paul Crutzen

RENDEZVOUS WITH THE NEW MILLENNIUM

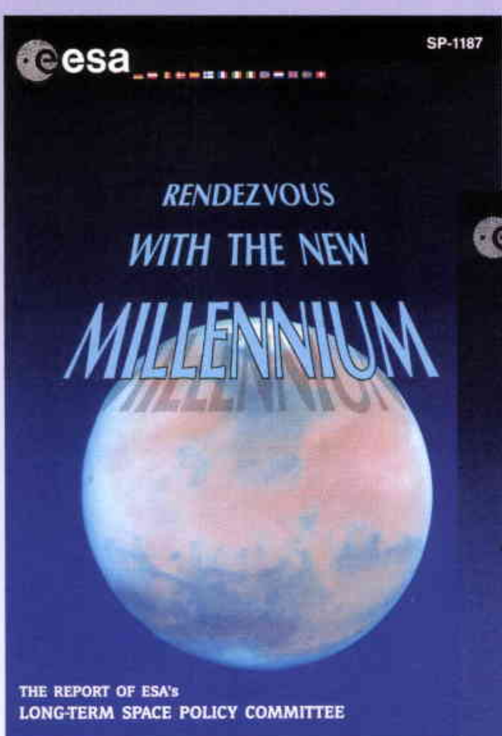
The Report of
ESA's Long-Term Space Policy Committee

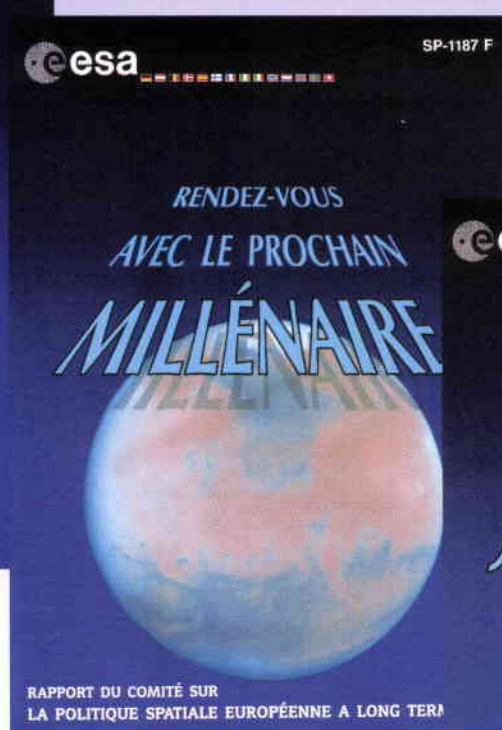
With 30 years of space activities behind us, we can now look forward to the next millennium on far more solid ground than the early pioneers ... At present, most space activities go from study phase to launch in about 10 years. The near-future is therefore already accounted for, and the major options for the next 20 years are also known. But what about the decades beyond that, and how will the world change over the next 50 years?

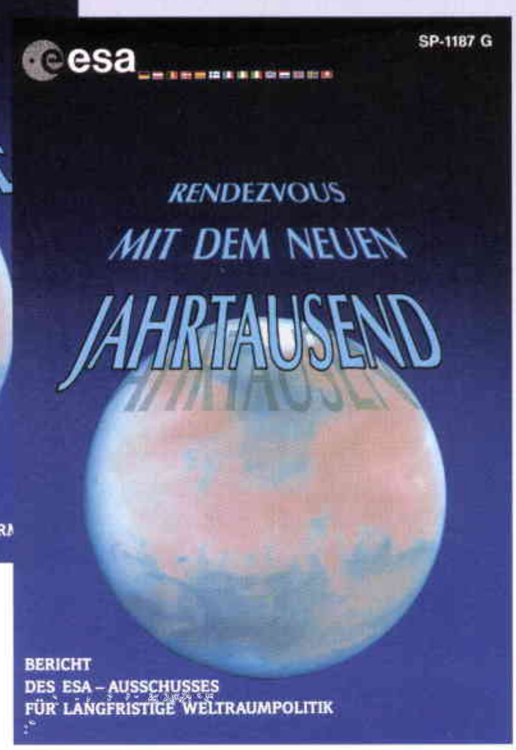
To identify a strategic vision for European space activities in the next century — one that will respond both to the challenges and threats facing humanity in the future — the ESA Council created a Long-Term Space Policy Committee (LSPC) in June 1993. The Commitee's task was to prepare a report on European space policy after the year 2000.

The LSPC chose to take a 50-year perspective in order to go beyond the mere extrapolation of current trends while still keeping in mind the present technological and financial constraints. The Committee analysed in depth the themes that it deemed to be of importance and collected the thoughts of recognised experts in relevant domains.

Its work has culminated in this report, *Rendezvous with the New Millennium*, which was presented to the ESA Council Meeting at Ministerial Level in Toulouse in October. The Ministers welcomed and endorsed the report: they expressed their satisfaction with the perspectives taken and have invited the Committee to continue to reflect on the long-term space policy for Europe.







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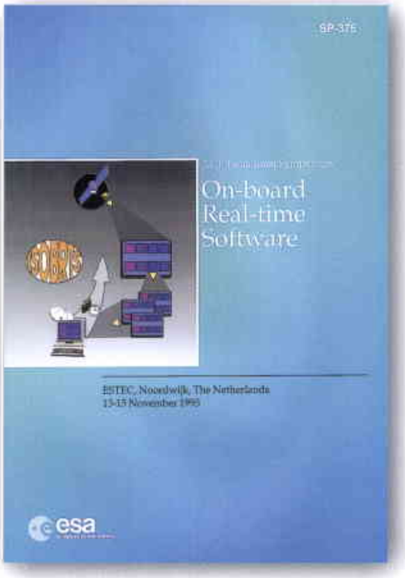

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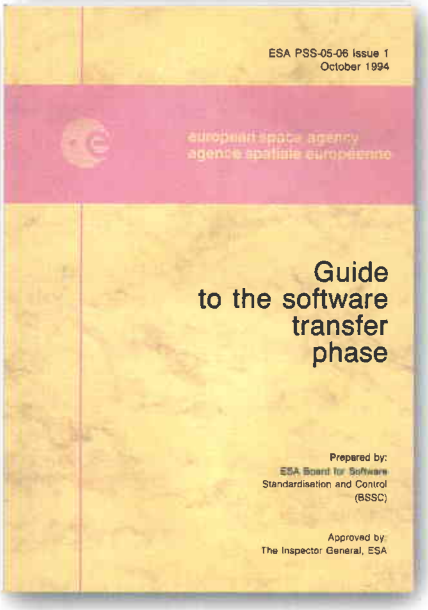

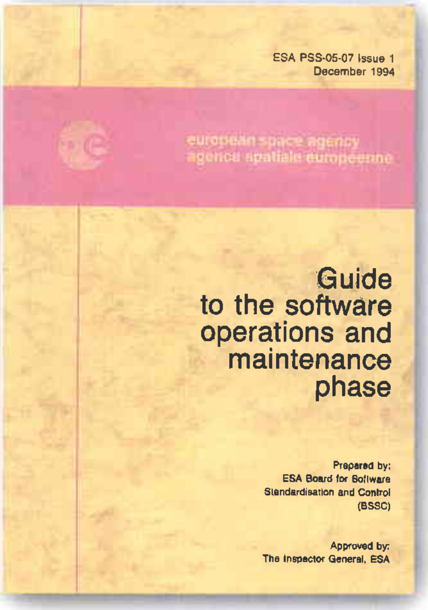

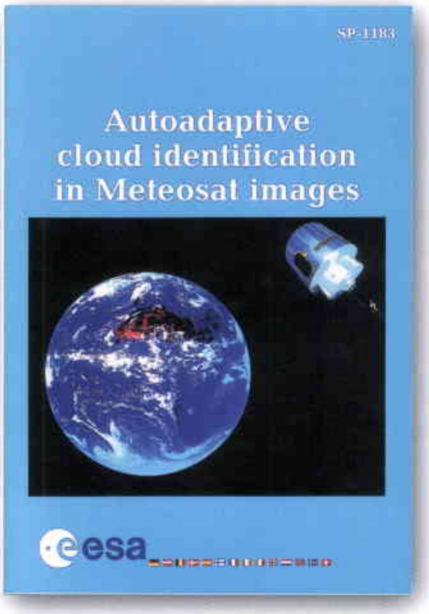

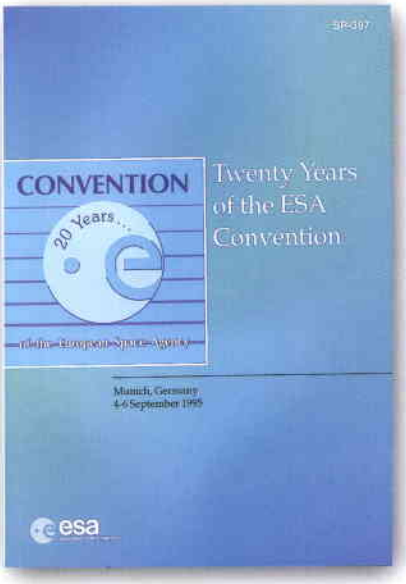

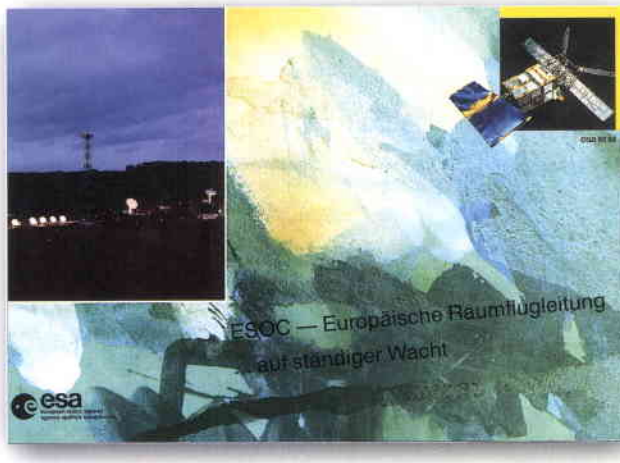

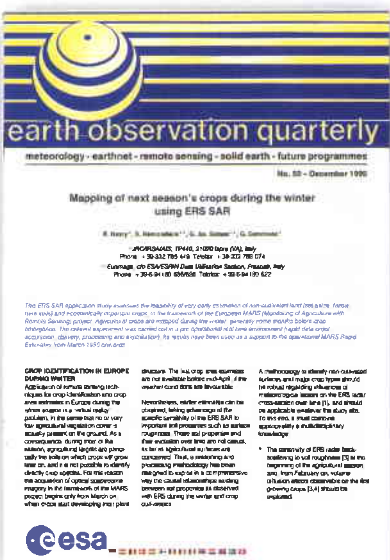

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