esa bulletin

number 94 - may 1998

European Space Agency
Agence spatiale européenne

european space agency

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: H. Parr

Director General: A. Rodotà.

agence spatiale européenne

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

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

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

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

Le SIEGE de l'Agence est à Paris.

Les principaux Etablissements de l'Agence sont:

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

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

ESRIN, Frascati, Italie

Président du Conseil: H. Parr

Directeur général: A. Rodotà.

bulletin

contents/sommaire

number 94 - may 1998

Cover: The XMM spacecraft under test at ESTEC (NL) (see page 31)

Editorial/Circulation Office

ESA Publications Division
ESTEC, PO Box 299, Noordwijk
2200 AG The Netherlands
Tel.: (31) 71 5653400

Editors
Bruce Battrick
Duc Guyenne
Dorothea Danesy

Layout
Carel Haakman

Graphics
Willem Versteeg

Montage
Paul Berkhout
Isabel Kenny

Advertising
Brigitte Kaldeich

Printed in The Netherlands ISSN 0376-4265

European Space Agency
Agence spatiale européenne

Alcatel Espacio:
Quality in Time
Payload Interface Unit
Antenna Pointing Electronic
Remote Terminal Unit
BPSK Modulator
Main Products
Digital Electronic Equipment:
• On Board Data Handling
• Base Band Processing
• Antenna Pointing and Control System
Radiofrequency Equipment:
• TTC S-Band Digital Transponder
• L-Band Transmitter
• BPSK/QPSK Modulators
• Filters, Diplexers, Multiplexers, etc.
Systems Engineering:
• On-Board Processing OBP/ Multimedia
• Communications Network for air navigation (GNSS)
• Ground support equipment and automatic test benches
ASIC-Technology
S-band digital Transporder
Ku-band input Multiplexer
C-band Filters
Alcatel Espacio is "your best partner in the Telecommunication Space field" for the design, development, and manufacturing of on-board equipment for multimedia, mobile communication, observation, broadcasting, and others applications.
The company is participating in programs, such as: Aces, Arabsat, Globalstar, Hot Bird, Sesat, Skybridge, Worldstar, Spot 5, Helios 2, Ariane V, Meteosat 2nd Generation, XMM, Integral, Envisat.
ALCATEL
The Hi-Speed Company
Alcatel Espacio, S.A. C/ Einstein, 7 - 28760 Tres Cantos (P.T.M.) Madrid - Spain. Tel. (34 1) 807 79 00 - Fax (34 1) 807 79 99

The Future ESA Earth-Observation Strategy and 'Living Planet' Programme

H. Arend & R. Bonnefoy
Directorate of Applications Programmes, ESA, Paris

D. Southwood
Directorate of Scientific Programmes, ESA, Paris

Our space capabilities are continually evolving and must be at the service of mankind both for research and for new applications. As an integral element of the Director General's proposal for a European Space Strategy, the ESA Earth Observation Strategy is an essential contribution to allow Europe to face up to the environmental, economic and political challenges of the next century. For a budget 25% less than the current annual expenditure, the 'Living Planet' programme provides the scale and the continuity for Europe to mount a broad and effective programme. It will enable Europe, its researchers and its industry to advance the use of space for obtaining critical information in many fields, such as environmental and climate change, resource and disaster management, sea, air and land transport, regional and development policies, and support to Developing Countries.

Earth observation in Europe

The 'Living Planet' programme sits firmly within the overall ESA programme, contributing strongly to each of its four primary axes:
- the pursuit of scientific knowledge
- dedication to enhancement of the quality of life
- an independent capability for Europe as the key to cooperation
- promotion of a European industry based on innovation and added-value services

as given in the ESA Director General's proposal for the next ESA Council Meeting at Ministerial Level.

Europe began to establish its position in Earth Observation (EO) in the 1970s, both through ESRO/ESA initiatives (initially with Meteosat) and via national programmes (most notably, through the French SPOT programme). It has developed strong EO capabilities since, and through programmes like ERS-1 and ERS-2, Envisat and the Meteosat series, as well as other national programmes, Europe has become a front-line player in Earth Observation.

However, Europe's position at the forefront of EO science and technology, the competitiveness of European EO industry, its presence in growing global markets and the related highly qualified employment are now in serious jeopardy. Apart from cooperative activities with Eumetsat (the European Organisation for the Exploitation of Meteorological Satellites), the present Agency EO programme has no planned space mission beyond Envisat, which is planned to be launched in 1999.

In recent months, the Agency has interrogated the major players in European Earth Observation, the Member State Delegations, Europe-wide entities like the European Commission (EC), Eumetsat, the Western European Union, and the European Environmental Agency. Both industry and the scientific community have given their inputs on what should be the future approach. The overall consensus is that the days of pure technical demonstration are over: Europe has already proved its capabilities. However, Europe's global position is also under threat.

For Europe, there are three fundamental objectives for Earth Observation:
- developing our knowledge of the Earth
- preserving the Earth and its environment
- managing life on Earth in a more efficient way.

To achieve these objectives new approaches are now needed: new ways of working, new user-orientated technical solutions, and new procedures for rapid implementation.

Decisions critical to the future of our independence in terms of industrial, research and policy-making capabilities need to be taken now. Industry has emphasised the need for immediate action. It finds itself in a very competitive situation, in a global market destabilised by newly released technology following the end of the Cold War. Furthermore, major initiatives in the USA in particular, where public money is underwriting both technical and market risk, threaten Europe's ability to

compete and there is a real risk of Europe becoming a captive market for products developed elsewhere. As we enter a new century in which increasingly there will be needs to manage the environment more effectively, to monitor resources efficiently, and to understand evolving climate conditions, Europe must react effectively to maintain its skills and independent sources of information.

The 'Living Planet' programme is the response to the challenges posed. It combines an Earth Observation Envelope Programme (EOEP) and dedicated optional Earth Watch applications missions, as we describe below. Research and applications are combined in a programme whose implementation approaches are tuned to the new user-driven requirements.

The origin of the new ESA Earth Observation Strategy

In Toulouse in 1995, the ESA Council of Ministers had already set a course for a European Earth-Observation Strategy, endorsing a 'Proposal for a European Policy for Earth Observation from Space' put forward jointly by ESA, the European Commission (EC) and Eumetsat.

Objectives were set for Europe in Earth Observation at that time: developing our knowledge of the Earth, preserving the Earth and its environment, and managing life on Earth in a more efficient way. But the meeting also set conditions. Any European Earth Observation programme must seek to satisfy user needs on a permanent basis. It should stimulate industrial profitability and competitiveness by promoting the widest possible market (including military). It should achieve strategic objectives, ensuring guaranteed access to data essential to the security of Europe and to the preservation of its environment. The aims and conditions set in Toulouse have been incorporated into the Living Planet approach and are subsumed in the three basic objectives given earlier in the introduction.

The principle of two types of Earth Observation missions was also adopted in Toulouse:

- **Earth Explorer:** research/demonstration missions to advance the understanding of the different Earth system processes, including the demonstration of new observation techniques
- **Earth Watch:** prototype operational

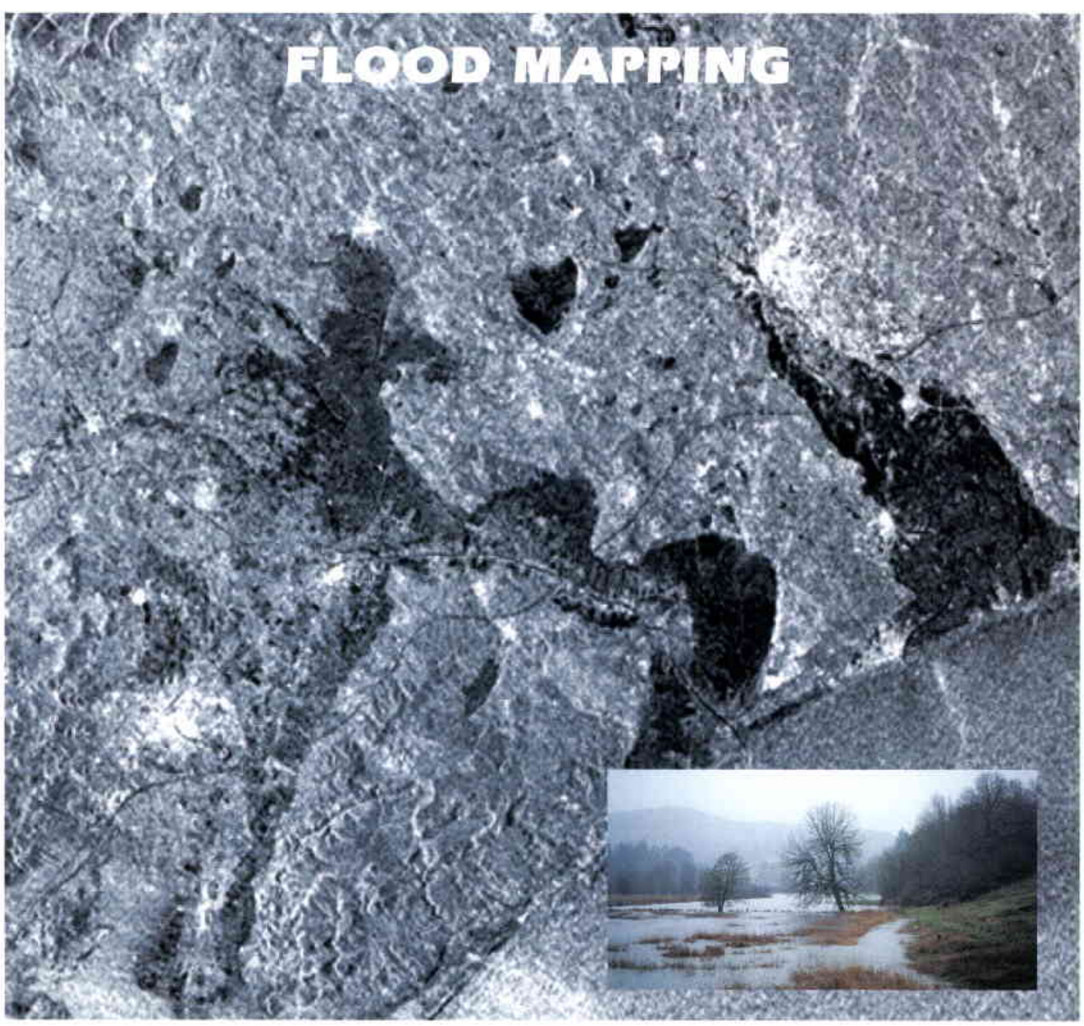
missions serving the operational applications-oriented needs of the market.

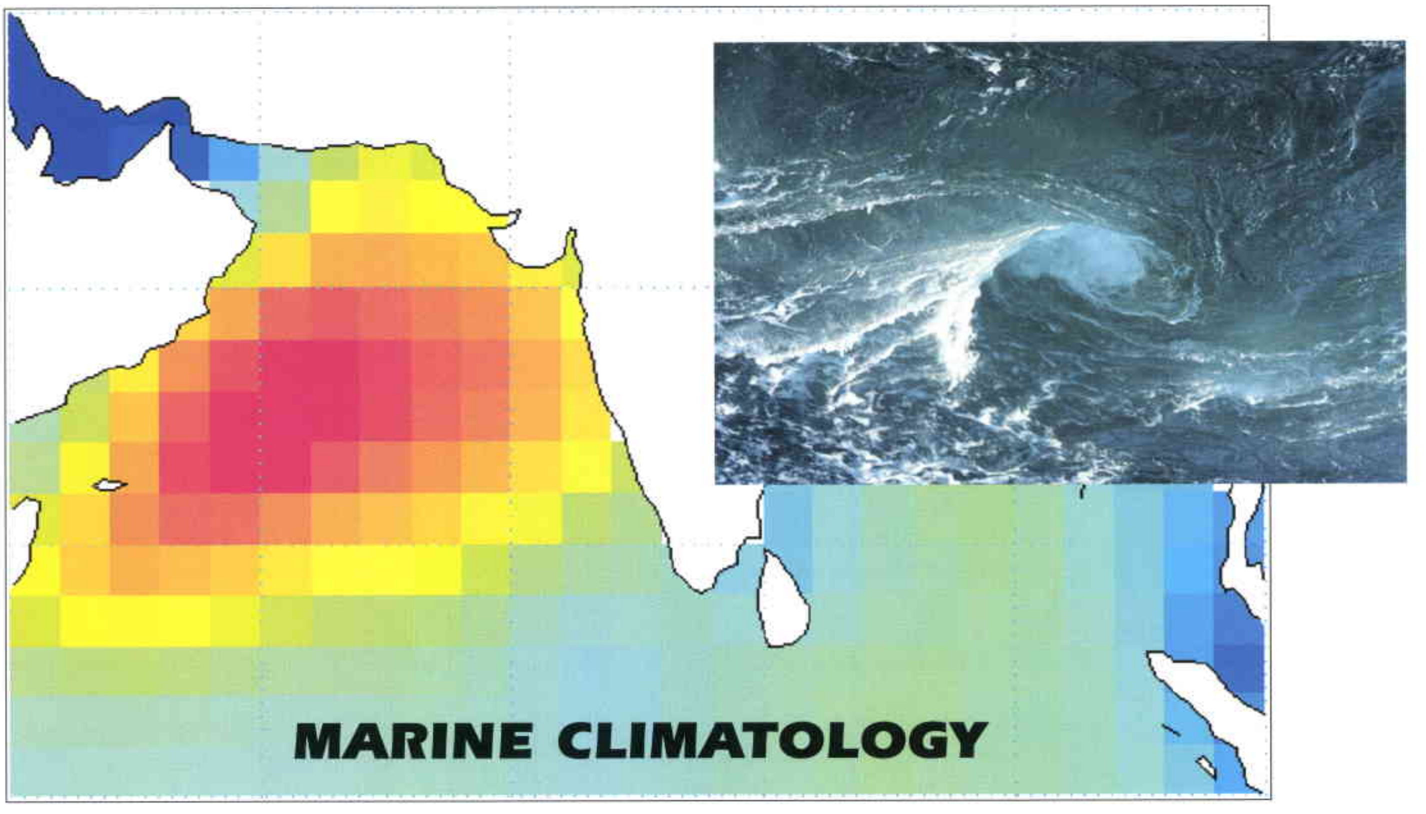
Further guidance was provided by the ESA Council at Ministerial Level in Paris in March 1997, where it was agreed that two overall principles should guide the review of the Agency's mission and strategy. These are:
- a scientific and technological policy fostering the improvement of human knowledge, innovation, quality of life and economic development in a cost-effective manner
- an industrial policy aimed at improving the worldwide competitiveness of European firms.

In order to respond to these challenging guidelines, an ESA Earth Observation Strategy Task Force was established in April 1997, which completed its work in early 1998 and outlined an ESA Strategy for Earth Observation. This Task Force was chaired by ESA's Director of Scientific Programmes (R. Bonnet) and comprised representatives of the European Commission (C. Patermann, M. Paillon) and Eumetsat (T. Mohr, D. Williams), the chairmen of, respectively, PB-EO (S. Briggs), EARSC (C. Borg) and ESAC (G. Megie), as well as a senior consultant (R. Gibson).

The Task Force was supported by an ESA Ad Hoc Industrial Working Group (see also 'Report of the ESA Ad Hoc Industrial Working Group on Earth Observation', 28 November 1997, prepared by Eurospace), a wide consultation of European and Canadian industry (undertaken by Eurospace), and by an industrial workshop held at ESTEC in October 1997. The Task Force also made use of the work of the Earth Sciences Advisory Committee (ESAC), which developed 'The Earth Explorer Document'. A further document, 'ESA Strategy for Earth Observation', builds on the tri-lateral coordination and co-operation between ESA, the European Commission and Eumetsat, which has been further strengthened since the Toulouse Ministerial Council Meeting, and on the strong support for action voiced by the European Parliament in January 1998.

In summary, the key elements of the new ESA Strategy for Earth Observation are:
- a user-driven approach through improved communication with users, better response to scientific and market requirements, and improved exploitation of Europe's scientific and technological capabilities for research and applications





- coordination of a common European Earth Observation Strategy through partnership between ESA, the European Commission, Eumetsat and other European entities, and coordination of national programmes
- coordination and cooperation on a global scale through strategic cooperation with, for example, NASA and NASDA, and active coordination, for example, in the frame of the Committee on Earth Observation Satellites (CEOS)
- a partnership approach for applications missions through partnership mechanisms and co-funding schemes with other public bodies and industry
- new modes of dialogue with industry, to stimulate a user-driven, cost-effective and entrepreneurial European industry that is competitive in global markets
- higher effectiveness of the Agency and its delegate bodies in the decision-making process and in implementation
- cheaper, more focused missions.

Programmatic implementation of the Strategy

Much thought has been given to the best manner in which to implement the new 'Living Planet' programme. The intention has been to incorporate the best approaches which have worked successfully elsewhere, and to provide cost-efficient and flexible procedures that can be implemented quickly. An overview of the programme's main characteristics is provided in Table 1.

The new Strategy recommends and explains the virtue of a programmatic approach consisting of two main elements:

- an optional Envelope Programme, comprising an Earth Explorer Component and a Development and Exploitation Component including the transition to Earth Watch; and
- a series of optional programmes for individual Earth Watch missions.

The Earth Observation Envelope Programme has a two-fold interest: for the European researchers who want to improve knowledge about the Earth or the precision and quality of observation; and for the applications of a public-service or commercial type, which aim at providing a service on a permanent basis for the customer. It is therefore necessary to satisfy these two types of use whilst still ensuring the link and the continuity between research projects and operational programmes.

The Envelope Programme features an implementation within a programmatic frame with the key characteristics that have made the Scientific Programme (which is a mandatory activity of the Agency) a success, namely continuity of activities, independent definition of requirements by the scientific community, a quick decision process and management flexibility. At the same time, it includes the advantage of an Optional Programme, i.e. the flexibility for Member States to decide on their contribution scale based on national aspirations and past investments, present assets, political, scientific, economic and industrial interests.

Table 1. The 'Living Planet' Programme	
What is different?	**What is new?**
• Offers a long-term view and continuity • Responds to the user needs • Contains more focussed and cheaper missions (50%) • Is 25% cheaper than the present set of missions and hence adds value for less money • Delegates tasks and management to Industry or other entities • Reinforces industrial competitiveness • Puts more emphasis on international cooperation and technological preparation • Secures exploitation of missions • Reduces complexity and administration	• Financial frame: - envelope for science (Earth Explorer), development and exploitation - optional for applications missions (Earth Watch) • Based on partnership with Industry for applications missions • Serves as a reference programme for Europe • Assumes full coordination, harmonisation and integration with other European national programmes • Supports Europe's commitments to international treaties • Helps transition to operational entities • Helps to develop the market for applications

Accordingly, the EOEP is proposed as an Optional Programme, with multiple reference missions (in the case of the Earth Explorer component) and a large spread of activities (in the case of the Development and Exploitation component). Through such an approach, each Participant is given a real voice in the ESA Programme Board for Earth Observation (PB-EO), corresponding to their interests and priorities, whilst at the same time the solidarity between Participants with common strategic objectives in Earth Observation will consolidate the role and position of Europe in this sector. A strong incentive to be cost-efficient is built in for Participants, the Executive, the scientific world and industry, as all savings are reinvested in the programme for new initiatives proposed by all players.

At the same time, the existence of a long-term-planning Earth Observation programme with an identified scope per phase becomes a reference for national initiatives, as the latter can take into account and complement the overall ESA programme, with a continuous dialogue between interested parties.

Industry gains very much with the envelope approach as it can plan against the evolving programme as it develops and it can target prospects in the future to build its own skills in a strategic manner.

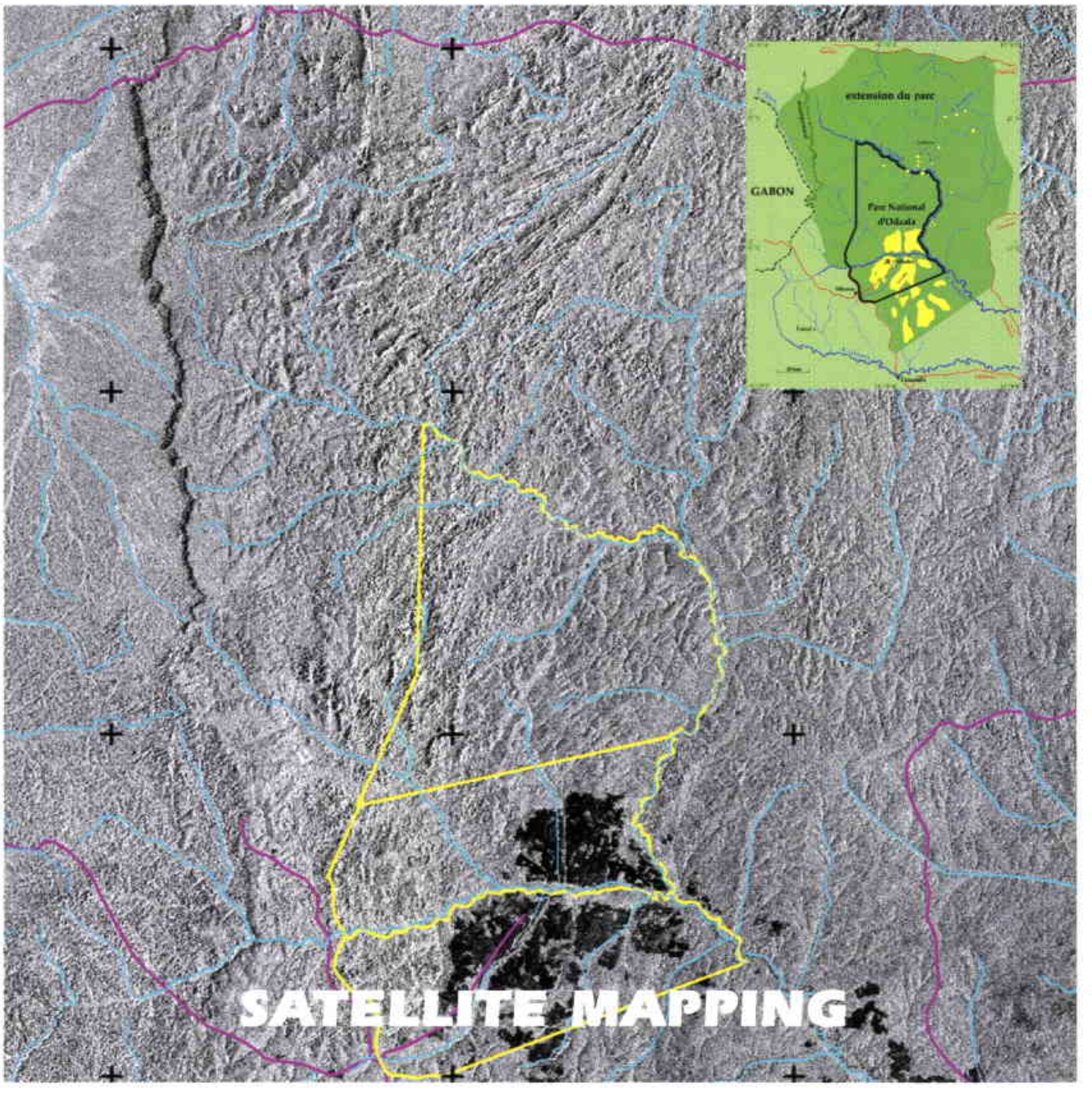
The 'Living Planet' programme will use also the more traditional optional approach, which is best suited for implementation of individual Earth Watch missions. The Phase-C/D and E implementation will be established on the basis of individual programme proposals. Proposals will include agreements with partners and will be governed by separate Declarations with separate subscription scales and geographical returns for the Participating States. The subscriptions to an individual programme are expected to reflect the national interest in the programme and the proposed structure of the external industrial partnerships that are set up.

The Earth Observation Envelope Programme

The key features of the Earth Observation Envelope Programme can be summarised as follows:

(a) It is an optional Envelope Programme, providing at one and the same time increased flexibility and responsiveness and the

Table 2. Earth Observation Envelope Programme	
Earth Explorer Component	**Development and Exploitation Component**
— Earth Explorer Definition — Earth Explorer Development — Earth Explorer Launch & Operations	— Earth Observation Preparatory Activities — Earth Watch Mission Definition — Instrument Pre-Development — Mission Exploitation/Market Development



necessary stability/continuity. It is to be implemented in five-year programmatic phases, according to Annex III of the Convention. The first phase will cover the period 1999 – 2003 and will be a build-up phase. This Envelope Programme approach includes the following main advantages for Participating States:
- stable financial planning (programme risks and associated costs taken up within envelope)
- flexibility, e.g. the possibility for extension of satellite operations without requesting a new supplementary budget
- inherent incentives for cost savings within the individual programme elements
- continuity, e.g. for long-term archiving of ESA mission data
- a long-term plan against which industry can plan strategically
- ease of setting up cooperative missions with other agencies.

(b) It comprised two main components (Table 2), namely:
- The **Earth Explorer Component,** which includes the definition, development, launch and operations (equivalent to Phases-B, C/D and E) of Earth Explorer missions.
- The **Development and Exploitation Component,** which includes:
  - Earth Explorer preparatory activities (pre-Phase-A and Phase-A) and Earth Watch preparatory activities (equivalent to pre-Phase-A and Phase-A)
  - Earth Watch type mission definition (up to preparation of dedicated programme proposals for optional Earth Watch type programmes, i.e. Phase-C/D and E)
  - Instrument Pre-development (for identified/ agreed user-driven candidates for Earth Explorer and Earth Watch type missions), and
  - Mission Exploitation (including already approved missions)/ Market Development.

(c) It comprises two types of Earth Explorer missions, namely:
- Core missions (major missions led by ESA to cover primary research objectives)
- Opportunity missions (smaller missions providing a quick reaction capability).

(d) It strongly builds on and exploits the cross-fertilisation between research (Earth Explorer) and applications (Earth Watch type).

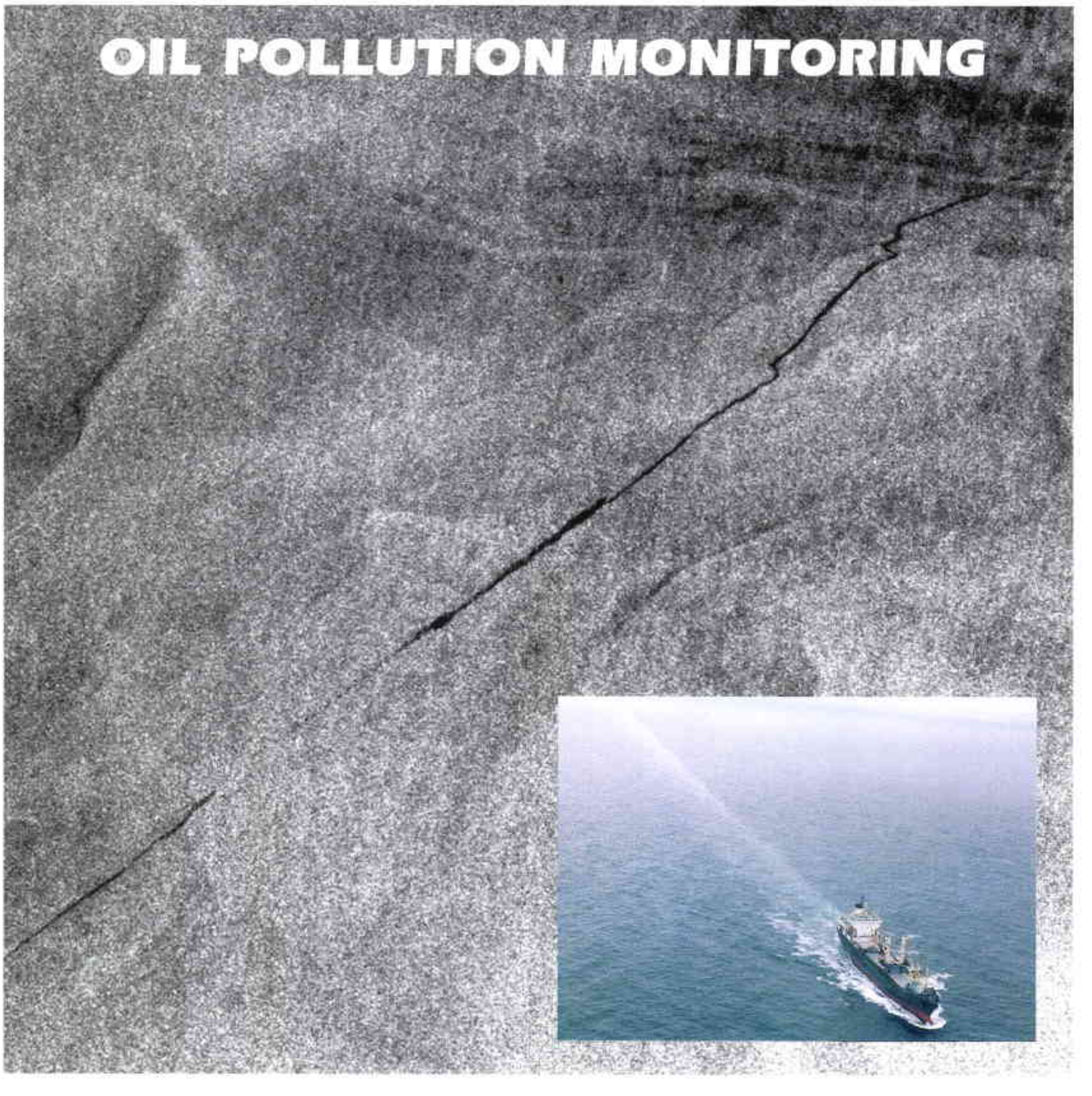
(e) It is user and market driven: all mission themes and partnership schemes are based on user proposals and market requirements, i.e. those of scientists, the European Commission, Eumetsat, other European and national entities, industry, etc.

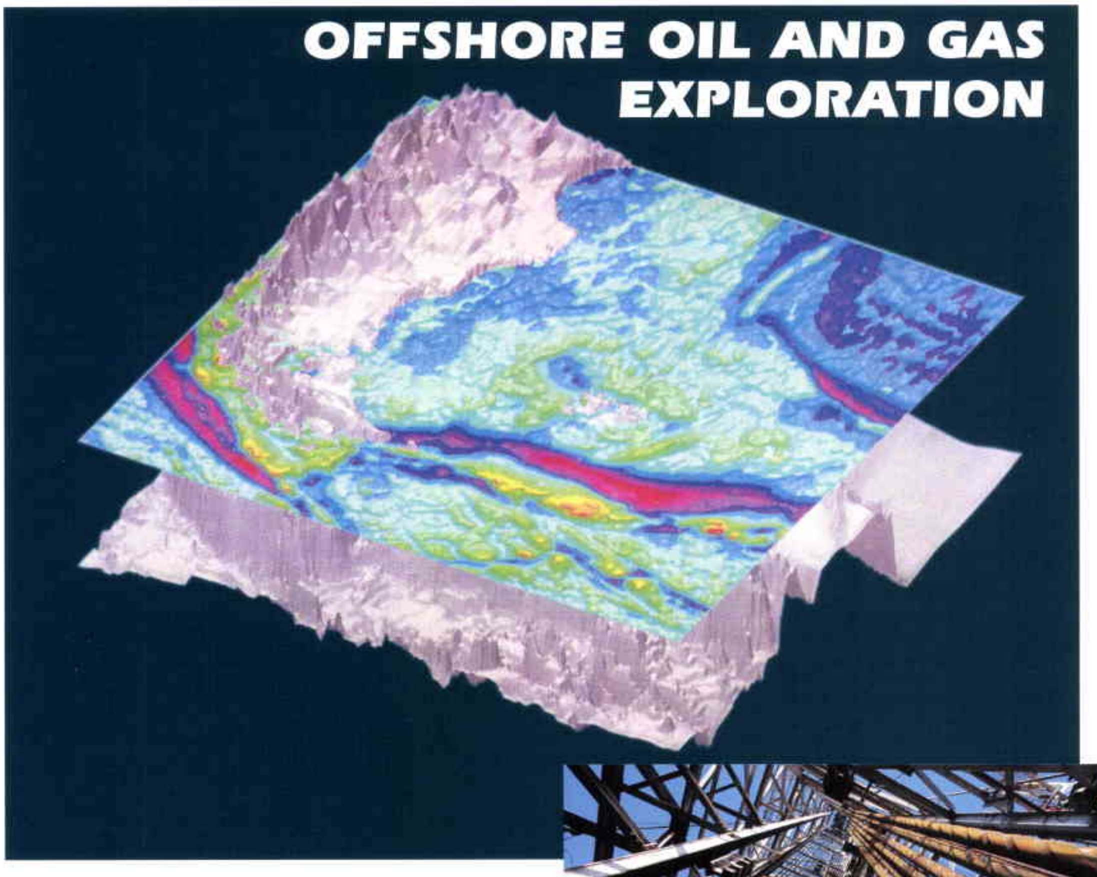
The Programme is based on a reinforced coordination and cooperation between ESA, the European Commission and Eumetsat with the recognised role of ESA to concert and progressively integrate European-level EO activities in pursuance of the principles of Annex IV of the Convention. This cooperation is open for further widening to, for example, the ECMWF, EEA, etc. The programme is further based on reinforced coordination between ESA and Member States' EO strategies and programmes. It will also build on the proposed space-technology harmonisation, both within ESA and with other European and national entities.

It demonstrates a new way of working with industry, both 'upstream' and 'downstream', including the industrial co-financing of Earth Watch type missions from the beginning of study activities, and stimulates industrial initiative and competitiveness through technology development and demonstration support and Earth Watch partnership schemes. It is orientated towards end-to-end applications systems, thus representing a large step from data provision (current) to market-oriented service provision (future).

It reduces complexity and administrative burdens and increases transparency through the gradual integration of currently seven individual optional EO programmes into a single EO Envelope Programme.

The Programme supports international cooperation on a global scale and maintains Europe's strong role in EO in the worldwide arena, including the necessary provisions for cooperation with Developing Countries.





Earth Watch

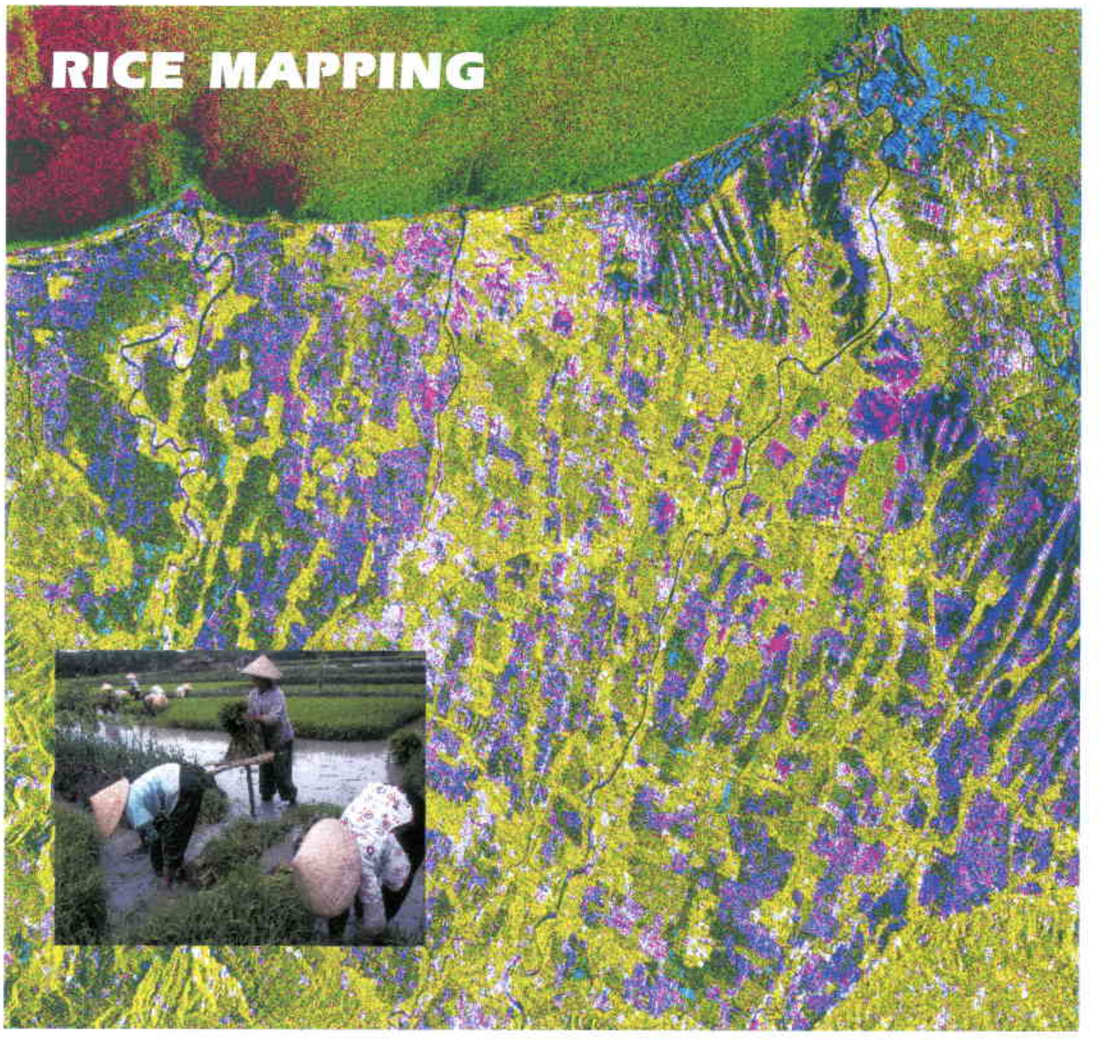
The second major space element of the 'Living Planet' programme is Earth Watch. Earth Watches are directed at developing operational systems for monitoring the Earth, usually on a near-continuous basis, and represent the first steps by the Agency to effect the transition to service provision. The programme will be designed, from the start, to respond to user requirements and to develop a competitive and independent industry. An eventual phased withdrawal of ESA involvement, and indeed of all public R&D support, once a sustainable operational system is up and running, is a fundamental premise of this approach. Users, or their agents, must be involved closely with the development of each mission and a plan for how the service can sustain itself in the long run must be made at the start.

The Agency will only undertake Earth Watches in partnership. The partnerships will be with industry, commercial ventures, agencies (such as Eumetsat) or other public entities (such as the European Commission) who will provide an interface to users and market requirements. This partnership is the key, even in the feasibility-study phase.

Industry in Europe today is capable of fully implementing an Earth-Watch-type mission. ESA's development of Earth Watches must not get in the way of truly commercial activity that does not call on public funding.

The first steps to implementing the approach envisaged for the future were taken with the 'Call for Outline Mission Proposals for Earth Watch Partnership' issued in December 1997. Industry was invited to submit proposals for partnership with the Agency and potential user entities. A key element in the evaluation is to assess the self-standing operational capability as the end result. This process will be repeated in the future. The scale of the response to the first Call indicates that industry is ready to work in the new ways envisaged. A total of 20 industrial proposals have been received covering a wide range of applications, including high-resolution land monitoring (optical and SAR), coastal-zone monitoring, multi-spectral vegetation monitoring, atmospheric profiling and disaster monitoring.

Earth Watch partnerships, in which both risk and benefit are equitably shared, must be set up quickly; national involvements must match closely the industrial balance required to



implement the programme efficiently. Accordingly, risks, responsibilities, data rights and revenue sharing must be agreed in early planning.

It follows that for each Earth Watch mission, an individual approach will be adopted to data policy. The type of partners (public or private), the levels of commercial risk envisaged, and the level of investment required from ESA will determine the policy. The basic principle should be to let the entity having the responsibility for the exploitation of this mission and the distribution of the data set the policy. ESA, on behalf of Member State research and development interests, would normally expect the right of data use for non-conflicting objectives.

Next steps
Concrete programmatic decisions on the 'Living Planet' approach, and in particular on the Earth Observation Envelope Programme (EOEP), need to be taken at the next ESA Council Meeting at Ministerial Level. This will allow the EOEP activities to start in 1999. During a build-up phase, the activities currently covered by other approved ESA Earth Observation programmes will be gradually and smoothly integrated into the EOEP. The Programme is planned to reach its steady-state level around 2004/2005. Concerning Earth Watch, it is envisaged to present the first dossier of an optional Earth Watch programme, based on the industrial responses to the ESA Call for Earth Watch Outline Mission Proposals, to ESA Member States in 1999 for decision and commencement of the industrial development activities.

The Earth Observation Data User Programme

J-P. Guignard & G. Pittella
ESA Directorate of Applications, ESRIN, Frascati, Italy

S. Hougs
ESA Directorate of Applications, ESA, Paris, France

The Data User Programme (DUP), an ESA optional programme, is designed to encourage and support Earth-observation-related industry in Participating States to bridge the gap between research and the establishment of operational services based on thematic information products. In addition, the DUP supports the preparations for operational exploitation of future satellites such as Envisat-1. Since its inception at the end of 1996, fourteen projects have been awarded.

Introduction

In general, value-adding suppliers of information products face a significant increase in requirements between performing research or demonstrating pilot projects and offering operational services within current competitive conditions. The latter may involve critical changes in the way in which activities are defined and financially secured. It also implies investment in final product development, the establishment of processing facilities and the necessary marketing activities. This is also evident within ESA's Member States where the industry is too small and dispersed to be able to undertake these activities without support.

In view of growing world-wide competition, ESA's Earth Observation Programme Board decided to remedy the situation by proposing an optional programme as a mechanism to provide the necessary initial support for value-adding companies, service providers and research laboratories within the Member States. The Data User Programme (DUP) was established at the end of 1996. Its aims are to:

- define, establish and validate market-oriented services for information products derived from Earth-observation data
- develop those services at a European level, with the potential for extension to the rest of the World market, including Developing Countries
- capitalise on existing ERS-1 and ERS-2 data and prepare for exploitation of the Envisat-1 satellite, which is due to be launched by the end of 1999.

This support should build on existing research such as the results of pilot projects and make maximum possible use of data from ESA missions. In preparation for exploitation of the Envisat-1 mission, data from third-party missions could also be used.

Although these missions are predominantly experimental, it is expected that preparation for operational and commercial use of their data will, as a spin-off, lead to the definition and consolidation of requirements for future satellite missions that are entirely operational.

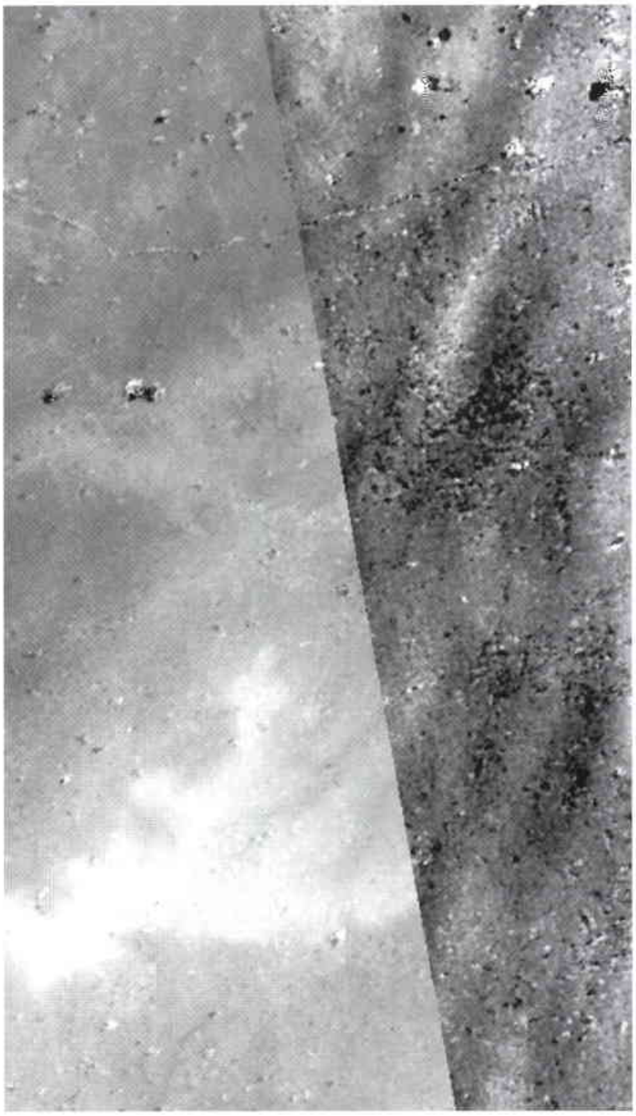
Value-adding companies should be encouraged to regard Earth-observation data as one of several information sources from which to build a marketable product. The inclusion of non-space data will result in a higher level of information and render products more readily applicable and, consequently, more useful.

The first steps towards the establishment of an operational service are typically completely funded by the DUP, but it is envisaged that an increasing financial contribution from the value-adding companies themselves will be requested for subsequent stages. Confidentiality and intellectual property rights are safeguarded under the Agency's rules. Contracts specifically include the cost of data, which must be purchased through authorised distributors.

The DUP is structured as an optional programme in five-year phases. The present Participating States are Belgium, the Netherlands and Switzerland. Other States are currently considering joining the programme or already preparing to do so.

How are projects selected?

Each year the Agency issues a Call for Proposals from value-adding companies and service providers in Participating States. The selection procedure is in two rounds, both of which are competitive. In the first round, candi-



Project example 1

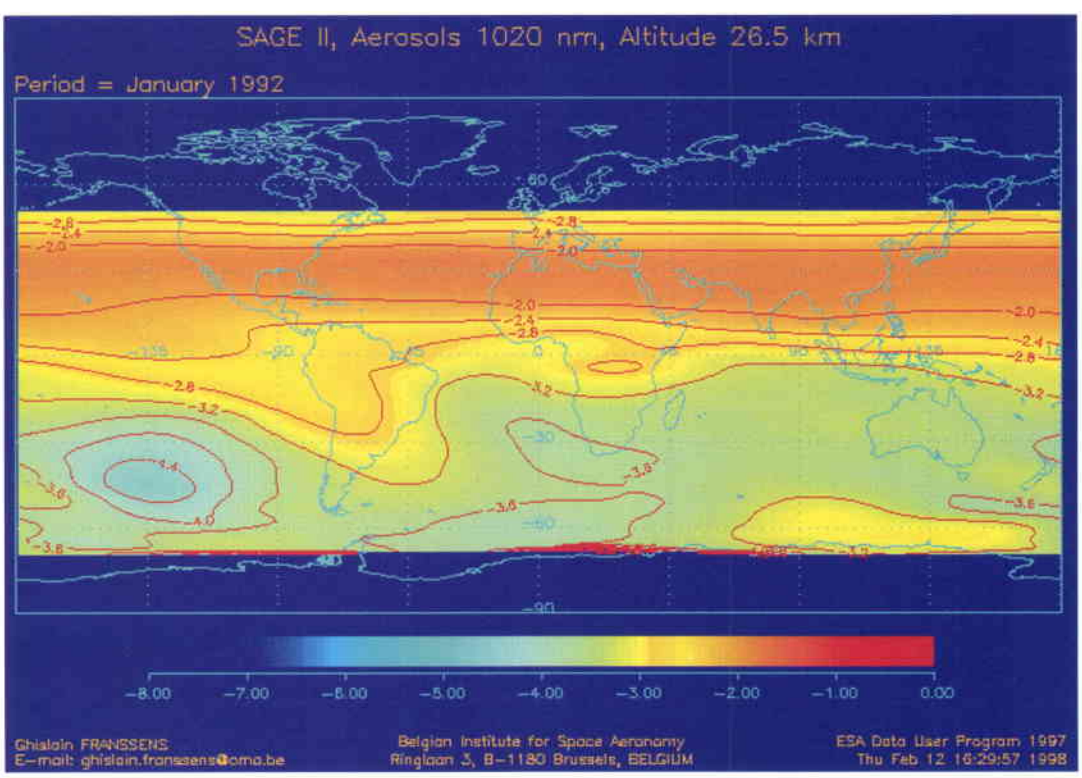
Quality assessment of SAR DTM

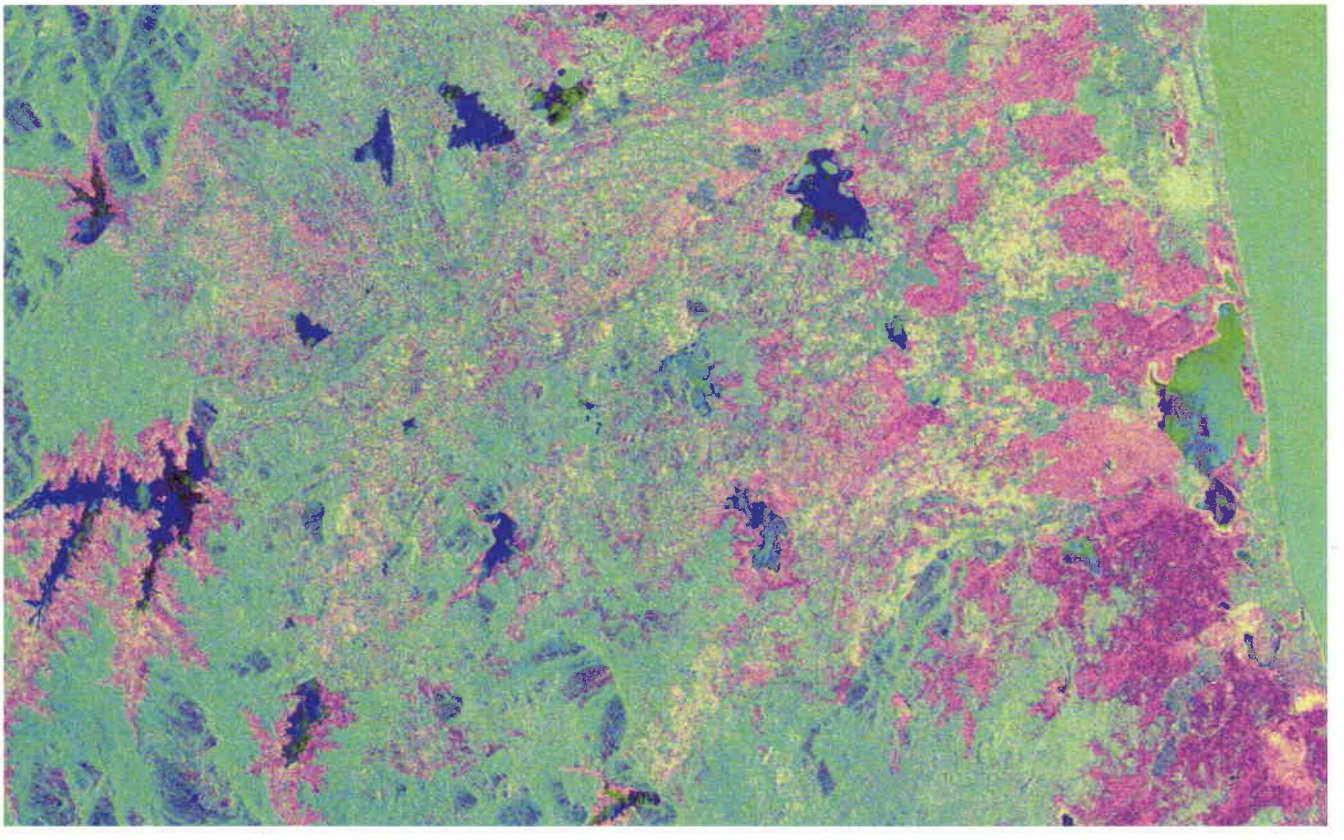
The ability of Synthetic Aperture Radar (SAR) Interferometry to derive Digital Terrain Models has already been demonstrated by several projects using data from ERS-1 and ERS-2. One of the main difficulties in bringing this application into operational service has been the correct quantitative determination of the quality (i.e. accuracy) achieved in the product in relation to the various error sources and, specifically, to the effect of atmospheric disturbance. This project has yielded a method for the objective qualification of the DTM Insar product and validated it over the full coverage of Belgium. Present work includes the application and demonstration of the method on additional geographical areas selected as significant targets.

Project example 2

Development of global aerosol mapping from satellite level-2 products

The new ERS-2/GOME instrument and the package of atmospheric instruments under development for the Envisat-1 satellite will provide an unprecedented capability to study and monitor the Earth's atmosphere and its chemical constituents. With a view to operational use by meteorological and environmental users, the instrument derived geophysical information as aerosol parameters is to be put in the form of a global map. In order to achieve this, the measurements taken by the instrument over limited areas and at different times need to be suitably integrated into a 3-D product by means of physical models. The project aims at prototyping a service-oriented product of this kind by initially using data from non-ESA missions (e.g. SAGE) and later aerosol GOME products derived from ERS-2.

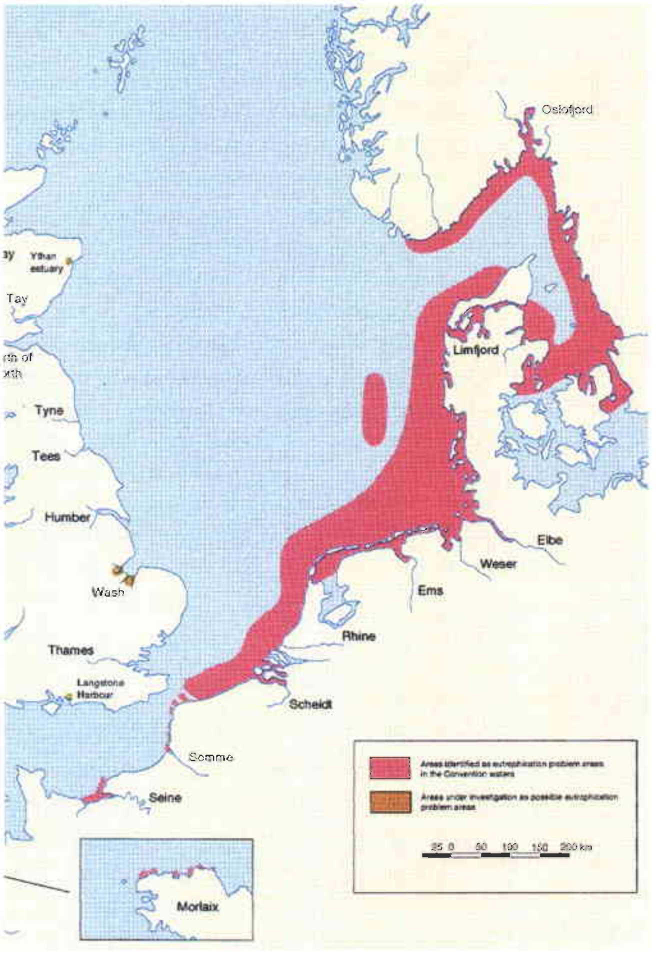




Project example 3

Product development for mapping and monitoring of land cover dynamics in tropical regions

Observation of tropical regions, where optical observation is heavily affected by almost permanent cloud cover, has proved to be one of the most promising applications of SAR. Two different product types for application in Sri Lanka are being developed in this project. One concerns the mapping of forests, the other the monitoring of rice-crop irrigation. Once the product development phase has been completed, the project envisages the transfer of the technology to a partner who will operate the system in Sri Lanka.



Project example 4

Pre-operational water and environment regional service

This project is designed to prepare the MERIS instrument, currently under development for Envisat-1, for operational use. The aim is to develop a tool to assess water quality from multispectral optical remote-sensing data. The products derived will relate to two regions: the Belgian and Dutch coastal zone and inland water bodies in the Netherlands and Switzerland. The project will initially focus on the definition of suitable user-oriented products and on the implementation of region-specific algorithms using available non-ESA ocean-colour missions such as IRS-MOS and SeaWiFS.

Table 1

No.	Project Objective	Contractor
1	Development of 3-dimensional information products relating to global mapping of aerosols	BIRA, (B)
2	Development of methods for quality assessment of SAR data for suitability for DTM production with predefined accuracy requirements; combined with associated quality indicators for the final product	CSL, (B)
3	Operationalisation and knowledge transfer to industry for service provision of SAR based products related to forestry and rice field information in tropical areas	RSL, (CH)
4	Development of 4-dimensional information products related to global mapping of aerosols, including improvements of data assimilation models	BIRA, (B)
5	Topographic mapping and merging of information into GIS for use by the Geological Survey and Mines Department, Uganda	RMCA(B) + UNESCO's GARS teams + UGSMD(Ugd)
6	Development of an information product derived from SAR extracted data for crop early monitoring systems	UCL-MILA (B)
7	Development of a forestry monitoring product for operational use in Malaysia	DHV (NL) + WAU (NL) + KEC (NL)
8	Development of GOME ozone fast delivery products at information level for the implementation of a Near Real Time user service	KNMI (NL)
9	Development of a bathymetry product for use by sand mining industry off the Belgian coasts	ARGOSS (NL) + UoG (B) + WWK (B)
10	Preparation of a pre-operational water and environment regional service for MERIS using SeaWiFS and MOS	IVM(NL) + RSL (CH) + MUMM(B) + MD(NL)
11	Development of a drought early warning product derived from scatterometer data with application and validation in Mali	NEO(NL) + TUW(A) + IER(Mali)+ ILWM(B)
12	Establishment of a flood monitoring service in Bangladesh	SYNOPTICS (NL)+ NLR(NL) + EGIS (Bangladesh)
13	Development of a propagation model product (derived from SAR DEM and vegetation from Spot) for operational mobile telephone network planning	E. BASLER & PARTNERS (CH) + RSL (CH)
14	Development of a subsidence mapping product for application in urban areas. It will be derived from differential InSAR data and validated in Northern Italy	Gamma (CH)

dates are required to submit summary proposals only. Those selected for the second round are asked to submit detailed proposals. The main selection criteria are as follows:
- in order to form the basis for an operational service, products must be at information level
- products must respond to needs expressed by public services or to market opportunities identified by the value-adding companies
- products must be amenable to a sustainable service at European level, in synergy with other sources of information.

Additional requirements regarding staffing, overall costs, data needs, implementation schedule, etc. are also taken into account. Delegates from the Participating States are involved in the final selection process.

The DUP supports interaction with the various players and other interested parties by means of the DUP Internet home page* and information meetings. Workshops are arranged to stimulate the flow of information between the parties involved in the programme (research institutes, value-adding companies, service companies, etc.)

Current activities
Fourteen activities have been started so far (see Table 1). Most of these focus on specific interaction between the know-how of value-adding companies and the market opportunities they have identified. They address areas for operational services where experience already exists (e.g. users of ERS Synthetic Aperture Radar (SAR) for interferometry, flood monitoring and bathymetry). They also represent focused efforts to establish pre-operational services in readiness for full exploitation of future missions (for example atmospheric chemistry, water-quality monitoring), in particular Envisat-1.

It is noteworthy that half of the projects are joint undertakings between value-adding companies and/or research institutes, and transcend national boundaries.

Also important is the fact that half of the activities concern Developing Countries. This reflects the Participating States' strong concern to establish operational services that are commercially viable and at the same time capable of providing solutions to problems in the Developing Countries (e.g. hazard and agricultural monitoring, infrastructure support).

The targeted customer segments are private enterprises, civil services and institutional bodies.

Conclusion
The Data User Programme is presently the only ESA programme which addresses the problems value-adding companies and service providers face when trying to gain a lasting foothold in the competitive market for Earth-observation products at information level. If they are to succeed in doing so, they must be able to take the vital step from research to commercial exploitation of data from Earth-observation satellites. This requires investment and involves risks. The DUP is a concrete way of supporting these efforts.

* http://styx.esrin.esa.it:8099/

Earth Watching: A Window on Special Events

S. D'Elia
Earth Remote Sensing Exploitation Division, Directorate of Application Programmes, ESRIN, Frascati, Italy

R. Biasutti
EO Satellite Services Division, Eurimage, Rome, Italy

Earth Watching is a joint Eurimage - ESA/ESRIN project. Its primary aim is to demonstrate the benefits of satellite remote sensing technology in emergencies: prediction, assistance or analysis. More generally, its objective is to widen awareness of the potential of remote sensing applications and to promote the use of remote sensing data. It is based on fast and preferential access to sensor planning, image generation and product distribution, and can count on dedicated, even if limited, image processing and interpretation resources. The resulting planning information, images, maps, references, text, etc. are loaded on dedicated Internet pages and can be provided in hardcopy for distribution through newspapers, magazines and television stations. This type of information has made it possible to support activities such as monitoring of threatened or ongoing floods, intervention during disasters, monitoring of pollutants in open waters, detection of ships, detection of fires, and also non-emergency, public-interest applications such as locating archaeological sites.

History

The Earth Watching project started at the end of 1993, during an emergency in Germany of extensive flooding lasting several days in the Cologne-Bonn area. This event made it evident that during natural disasters, users and government authorities need data more quickly than standard delivery times, in order to gain an immediate broad picture of the extent of the affected areas.

Earth Watching relies mainly on the remote sensing data directly managed by, or accessible through, ESA and Eurimage. Operations include sensor planning (where applicable), near real-time production, fast transmission, image processing and interpretation, text preparation, and dissemination of results.

Remote sensing data

Since satellites can cover large areas in a single pass, the resulting data from on-board instruments can quickly provide an overview of an emergency event and identify areas under threat or already affected.

Radar sensors, such as the Synthetic Aperture Radar (SAR) on board ESA's ERS-1 and ERS-2 satellites, are excellent tools for obtaining data thanks to their all-weather and day/night capability (data acquisition independent of cloud coverage or Sun illumination). This is particularly important during, for example, flooding, which is normally characterised by cloudy skies.

Optical sensors, like NOAA's AVHRR and the Russian RESURS-O1, with their wide swath and high pass repetition, can be used for detecting medium to large fires. ATSR on board ERS-1 and ERS-2 and EOSAT's Landsat-5, can provide more details on already active fires and burned areas. The optical sensors are excellent for providing multi-channel information which can be combined with radar to identify even more features.

Organisation

The Earth Watching Team activities are normally triggered by external events, e.g. media news or meteorological forecasts (Fig. 1). When starting a new activity, the team first collects as much information as possible. Sources include ESA Public Relations, various press agencies, the Internet and the Eurimage distributor network (about 40 distributors in 32 countries in Europe, North Africa and the Middle East). Data acquisition opportunities are then checked and, if necessary, a special acquisition plan is prepared for ERS-2 (and ERS-1 when active). The information on expected and planned acquisitions from all possible sensors is loaded on the Internet together with links to related news from the media.

The acquisition stations concerned are alerted. At the same time, suitable archive data over the area is searched and priority generation of related products is requested. These products are inserted into the image processing system and prepared for integration with the data being acquired. The resulting multi-temporal image will permit detection of changes.

At the time of data acquisition, the receiving stations involved are asked, depending on their location and processing capability, to either ship the raw data or to locally generate the product and send it to ESRIN by special delivery (or via telecommunication links when feasible). From the receiving station in Fucino (I), it is possible to receive a quick-look of the scene shortly after the pass, and to select and receive a subset of it in full or reduced spatial resolution.

As soon as the new images are received, they are loaded on the Internet where they are accessible through standard World Wide Web browsers. High quality prints of the images are also made available for distribution to newspapers, magazines and television stations.

Normally, quick-look (low resolution) images are available on line two or three hours after the acquisition. Within a few more hours to one day, they are followed by a higher resolution image of the affected area together with a rough interpretation text. This is updated by a multi-temporal image with refined interpretation text in approximately two more days. Finally, within one to two weeks, higher level products (e.g. subsets of the satellite image superimposed on the map) with additional text or photos collected from the Internet, newspapers, etc. are made available on line.

New attempts are continuously made to simplify image interpretation and to improve the overall service (new filters, layouts, dissemination systems, etc.). In this respect, the Earth Watching Team also cooperates with other research institutes, national entities or value-adding companies. This is also done through special projects.

During 1997, the Earth Watching team was involved in two risk management projects conducted in cooperation with European industry: one related to plains flooding and the other to earthquakes. These projects required Earth Watching to broaden its scope and procedures by incorporating the planning and production sectors of other mission operators for the use of Spot, Radarsat and Indian Remote Sensing satellite data. This increased the probability of obtaining complete data for any single event. In the case of the flooding project, two alert exercises were performed on simulated cases. The first simulated event permitted the identification of bottlenecks and the improvement of the overall system performance. Both simulations demonstrated the adequacy of the structure to provide suitable data in time and confirmed the possibility for adequate data coverage when all available missions are used. In fact, one real flood event was successfully monitored in this way by the same team, outside the project simulations.

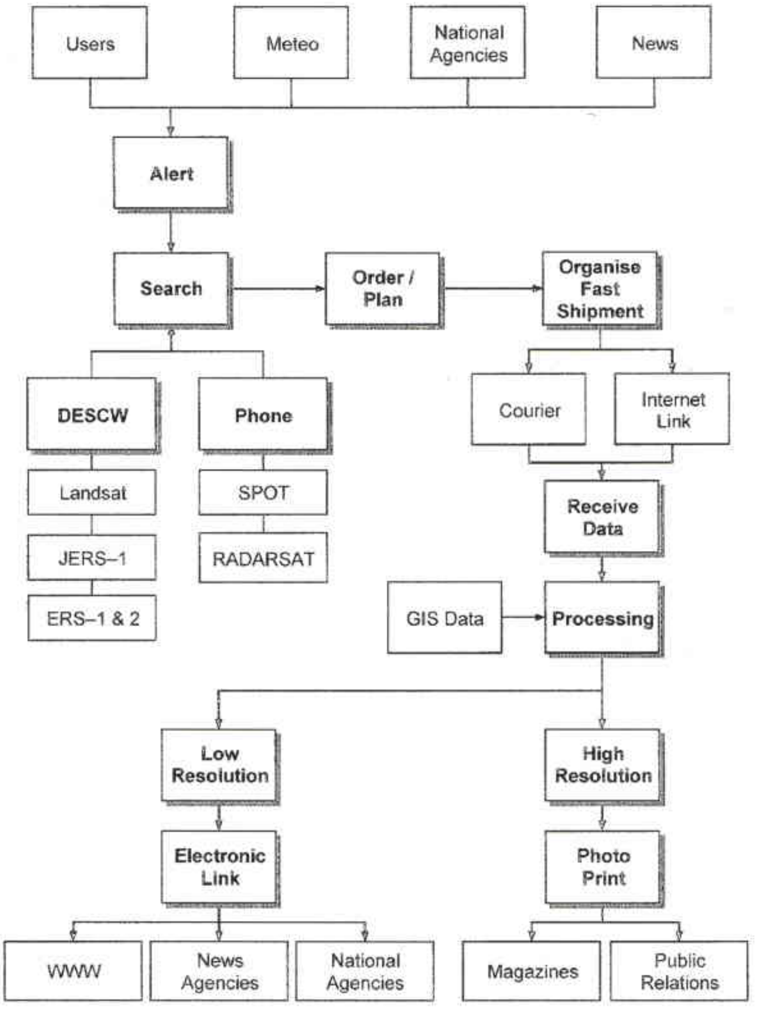


Figure 1. Data acquisition and distribution flow-chart

Conclusion

During these four years of activity, the Earth Watching project has provided support to numerous events, as demonstrated by the examples in this article. The results are available on line*.

A glossy publication, titled an "Earth Watching Anthology"** has also been prepared and distributed.

* http://earthnet.esrin.esa.it or http://www.eurimage.it

** A limited number of copies are available for distribution; please contact the ESRIN Helpdesk via e-mail: eohelp@esrin.esa.it or tel. : +39 6 941 80 777

Oil Spills, North Sea, 1996

Each year ships and industries damage the delicate coastal ecosystem in many parts of the world by releasing oil or pollutants into rivers and coastal waters. Offshore environments are also polluted by mineral oil mainly due to tanker accidents, illegal oil discharges by ships and natural seepage. After a tanker accident, the biggest difficulty is to obtain an overall view of the phenomenon, getting a clear idea of the extent of the slick and, if possible, predicting the way it will move. For both natural and man-made oil spills it is necessary to operate a regular monitoring programme.

The Synthetic Aperture Radar (SAR) instrument, which can collect data independently of weather and light conditions, is an excellent tool with which to monitor and detect oil on water surfaces. Oil slicks appear as dark patches on SAR images.

Figure 2 was acquired from ESA's ERS-2 satellite on 18 July 1996 at 11 a.m. (Greenwich time) by the Fucino ground station and by the Tromsø Satellite Station (TSS). The Earth Watching Team discovered some oil slicks in this image during data screening and asked the expert operators of TSS for an interpretation. The overall low grey level in the scene suggests that there is little wind in the area, ranging from about 1 to 7 m/s. This condition is ideal for detecting an oil film. In the image, located northwest of Bergen (Norway), there are two possible oil slicks of roughly 12 x 5 km^2 and 14 x 3 km^2. Both slicks are diffuse and it looks as if the wind has spread them. They are probably several hours old. Conditions for detecting surface dumping features are optimal, and slicks related to almost every oil platform (the very bright points) in the image can be observed. These slicks may be caused by water disposal, drilling fluids or oil. The almost completely black area in the top right of the image is due to low wind conditions.

Operators at the TSS routinely analyse all SAR data received at the station. If an oil slick is discovered, as in this case, a communication is sent to the Norwegian Pollution Control Authority (SFT) by telephone and fax. The SFT surveillance aircraft often operates near the satellite acquisitions and a direct link between the operators of TSS and the pilots is established.

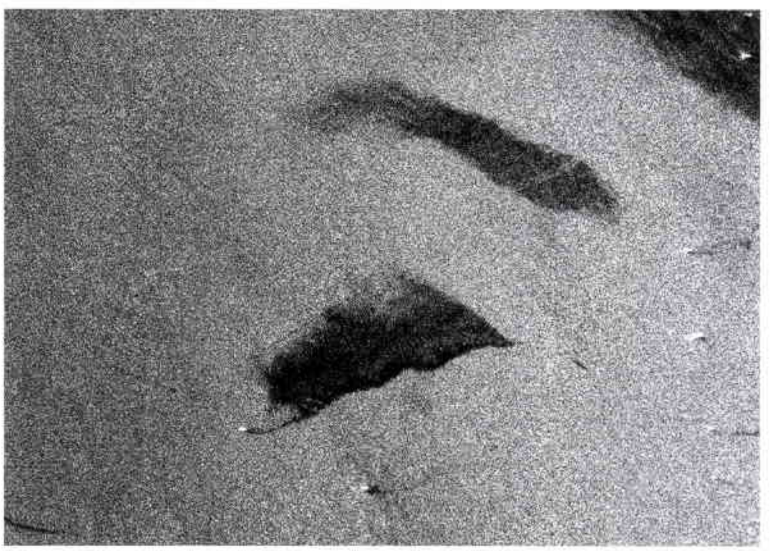


Figure 2. ERS-2 SAR scene acquired on 18 July 1996 showing oils slicks in the North Sea

Fire and Smoke in S-E Asia, 1997

Every year millions of acres of forest and savanna all over the world are destroyed, and animal and plant species disappear as a result of deforestation and fires caused by human activity, with significant effects on the delicate global ecosystem. Using data from satellites, it is possible to quickly obtain a general overview of the situation over large areas of terrain, to monitor the emergency, identify risks, detect fires and, once the fire has been controlled, assess the damage by mapping the extent of the burned areas.

In the summer of 1997, Southeast Asia suffered its worst drought in five decades and, consequently, hundreds of forest fires – many started deliberately as a method of clearing land – began to burn out of control. A cloud of smoke covering an area more than half the size of the continental United States sent air pollution in the affected area well above hazardous levels. In Sarawak, Borneo, the blanket of soot and smoke meant that every man, woman and child was inhaling the equivalent of two and a half cigarettes a day.

Images were produced at ESRIN using data from three ERS-2 sensors: SAR (Synthetic Aperture Radar), ATSR-2 (Along-Track Scanning Radiometer) and, in co-operation with the German Aerospace Research Centre (DLR), GOME (Global Ozone Monitoring Experiment). Those derived from ATSR-2 infrared data (Fig. 3) to detect hot spots were compared to pictures derived from ERS-2 GOME Level-2 products (Fig. 4), which contain the total column amount of the trace gas nitrogen dioxide. The GOME instrument can only measure during daytime; its swath consists of three ground pixels, each one measuring 40 km along-track and 320 km across-track. High values indicated in red can be correlated with the hot spots measured by the ATSR and certainly indicate biomass burning. The map (Fig. 5) shows the locations of individual fires.

The SAR image (Fig. 6) shows an area in the Tanjung Puting National Park, which with its more than 3000 km^2 of rare wildlife and flora, is the largest and most diverse protected example of the extensive coastal tropical swamp forest which used to cover much of southern Borneo. The multi-temporal image combines data from two different dates to make a colour composite image in which colours indicate changes between the two acquisitions. Green shows the healthy vegetation, while the areas appearing in magenta tones are most probably the ones affected by the deforestation caused by the fires.

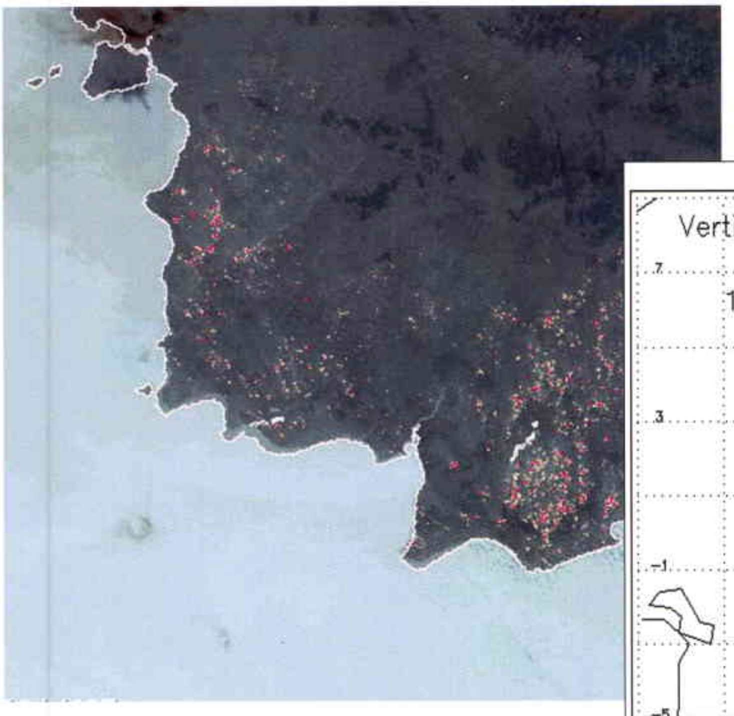


Figure 3. ATSR colour composite image, 1 km resolution, from 15 September 1997. The coastline has been added in white. All pixels indicating a temperature above 39°C have been rendered as red spots. Cold clouds appear in black and warm areas (over 32°C) in yellow

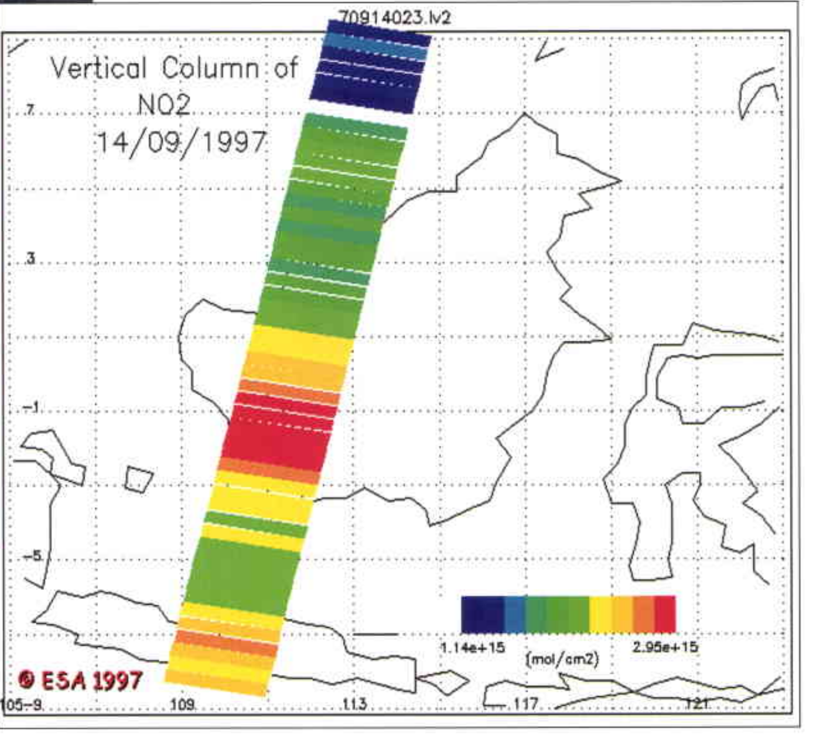


Figure 4. GOME data from 14 September 1997. More images are available on the Earth Watching WWW site

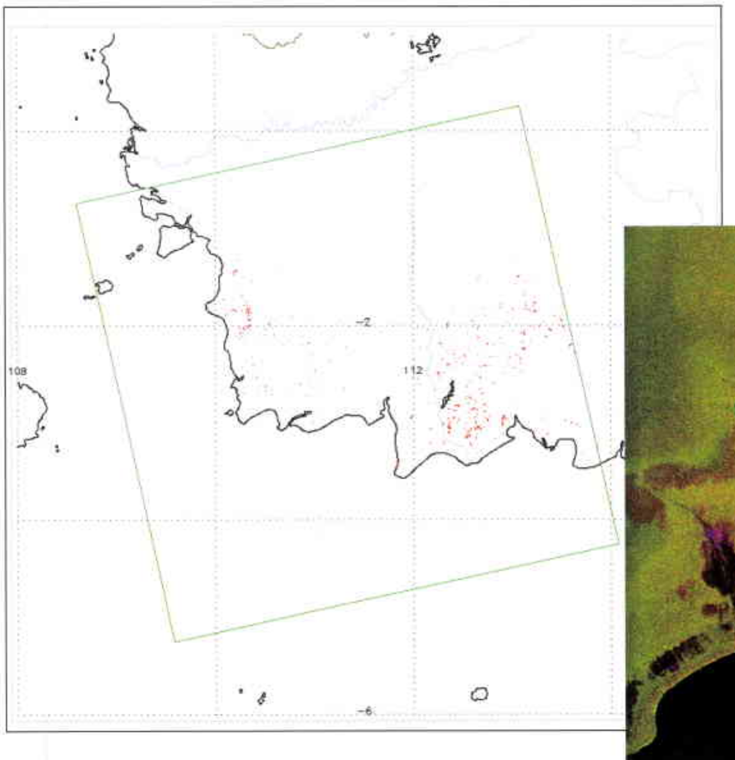


Figure 5. Map showing the locations of individual fires

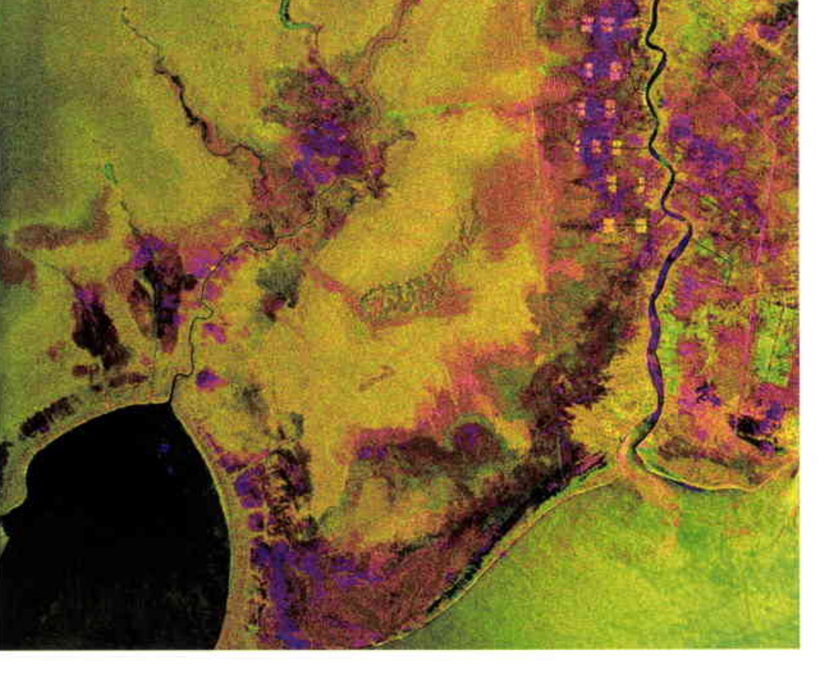


Figure 6. ERS-2 SAR multi-temporal image, combining data from 22 October 1996 and 7 October 1997

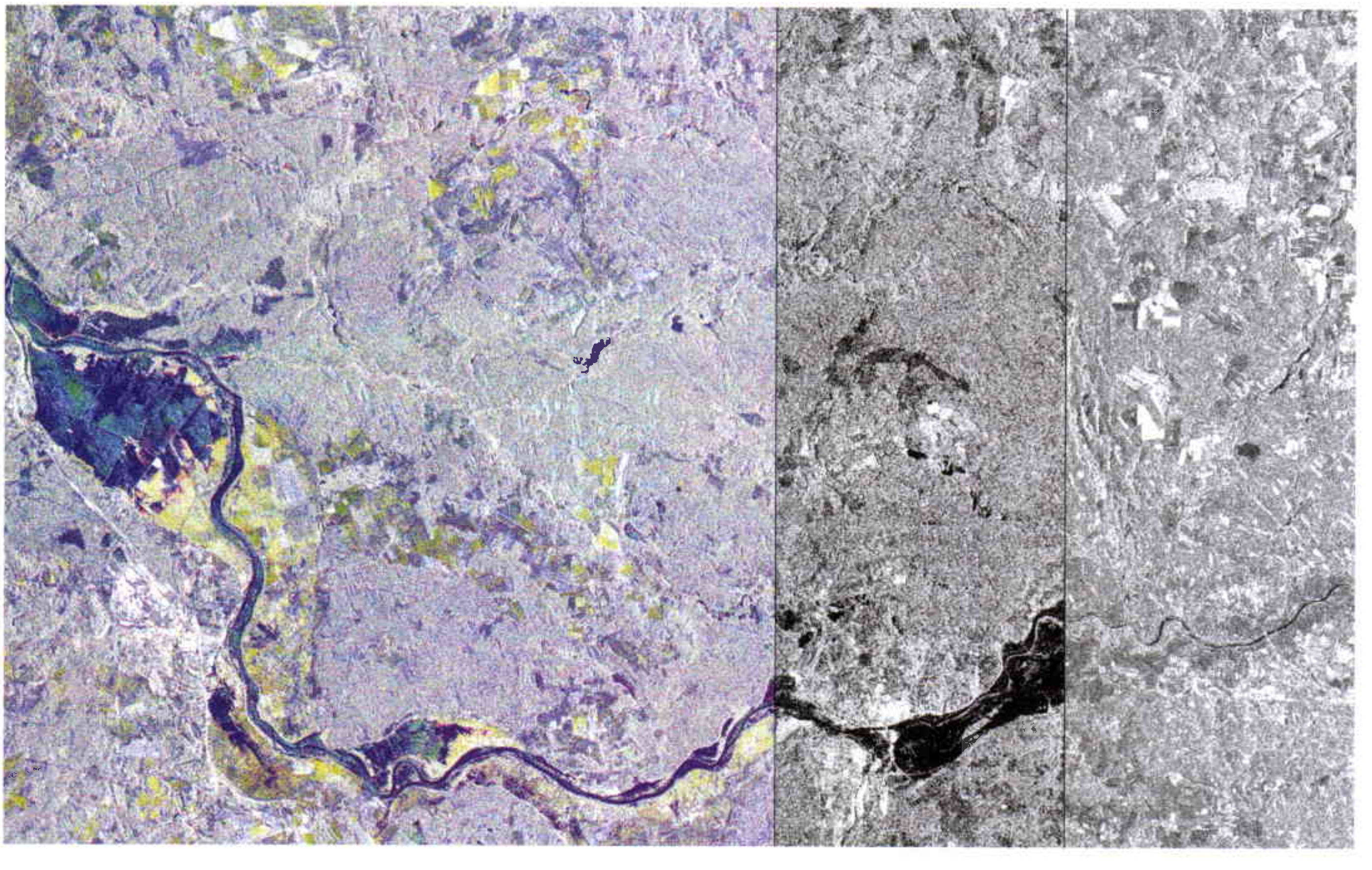
Flooding around the Oder River, Poland-Germany (1997) and in Béziers, France (1996)

One of the primary problems during flood emergencies is to obtain an overall view of the extent of the affected area and to predict likely developments. Aerial observation is often impossible due to prohibitive weather conditions and can be very time-consuming and expensive. However, the ERS-1 and ERS-2 satellites' Synthetic Aperture Radar (SAR) instruments can collect data independently of weather and light conditions. The data can provide the required assessment of the damaged area and produce detailed maps for both hazard assessment and input to hydrological models used for planning preventive measures.

To highlight the flooded areas, a multi-temporal technique is normally used. Black and white radar images of the same area are taken on different dates and assigned to the red, green and blue colour channels in a colour image. The resulting multi-temporal image clearly reveals the change in the Earth's surface through colour: the hue and intensity of the colours indicate the date and degree of change.

The technique is illustrated in Figure 7, which reveals flooding around the Oder River on 5 and 6 August 1997 at the Polish-German border. On the far right, the normal summer situation shows the narrow, shallow river presenting a weak radar reflection. Alongside is part of an image from 6 August showing the black reflection from the flood waters. The multi-temporal image brings out the changes between the two dates. Areas flooded on both dates are dark blue, while those flooded on only the 5th or 6th are magenta and green, respectively.

Figure 7. Multi-temporal ERS-1and 2 SAR image of the Oder River flooding on 5 and 6 August 1997 at the Polish-German border



On the night of 29 January 1996, a fierce flood descended on the small southern French town of Béziers. Four lives were lost and more than six hundred people evacuated. From the Loire to the Ardennes, 2700 towns and villages were devastated. The Earth Watching Team loaded the images to the Web within days of the flooding.

ERS-1 passed over at 23:00 local time on 28 January 1996, during heavy rainfall (more than 200 mm in 24 hrs); ERS-2 crossed the area at the same time a day later. In Figure 8, the bright white areas are the city of Béziers and towards the bottom left, the city of Narbonne. Due to very wet soil conditions on both dates, the prevailing colour in the coastal plain is greenish-cyan, except for the hills of Montagne de la Clape, which are covered with Mediterranean shrubs and pines. The reddish zones and spots in the lower parts of the plain were flooded during both January acquisitions. This flooding came from the River Aude, north and east of Narbonne. The worst damage occurred along the Orb River, crossing the city of Béziers. The green-yellowish area above Béziers indicates that it was flooded on the 28th from the arrival of the water that had fallen in the mountains to the north. The huge bluish-magenta area below Béziers and in other parts of the scene, as well as the reddish parts in the lowlands, reflect the situation of the flooded surface on the 29th. The large oblong area of a faint bluish colour appearing close to Narbonne still needs to be fully explained. It might indicate land hit by heavy rainfall immediately before and during the acquisition, leaving behind water-soaked terrain.

When integrated into a Geographical Information System (GIS) with other data on flooding mechanisms, this type of image is of great benefit for estimating, in 'near real-time', the extent and dynamics of the flood, as well as for the validation of hydrological models for assessing flood risks.

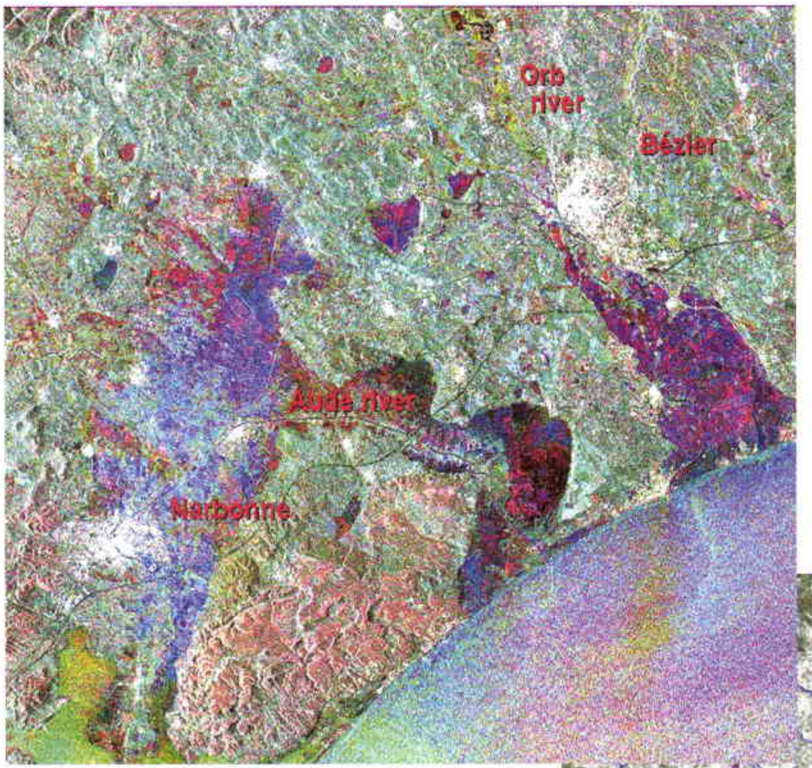


Figure 8. Red: ERS-2 SAR, 7 August 1995
Blue: ERS-1 SAR, 28 January 1996
Green: ERS-2 SAR, 29 January 1996

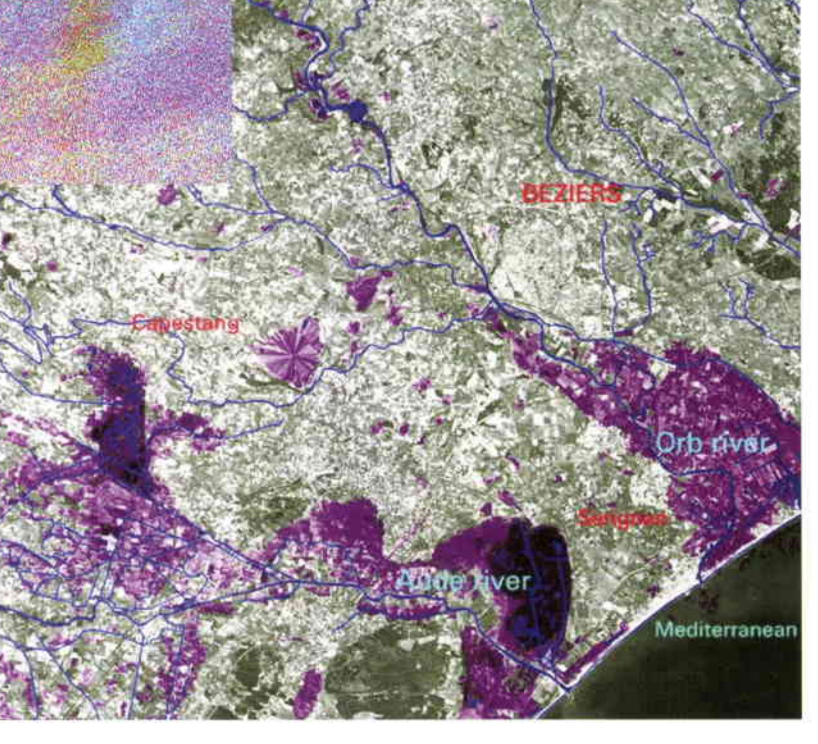


Figure 9. Here the flooded areas have been extracted from the multi-temporal SAR and superimposed on a SPOT panchromatic image (10 metre-resolution) by Laboratoire Commun de Télédétection CEMAGREF

Qualification Over Ariane's Lifetime

A. González Blázquez
Directorate of Launchers, ESA, Paris

M. Eymard
Groupe Programme CNES/Arianespace, Evry, France

In principle, the development programme for a launcher ends with the qualification phase, after which it enters operational service. In practice, however, the assessment of a launcher's reliability is a continuing process and qualification-type activities proceed, as an extension of the development programme (as is done in aeronautics), over the course of the vehicle's lifetime. Modifications to the launcher's design are made whenever anomalies that might have an adverse effect on the stringent reliability requirements are detected during testing, to pre-empt their occurrence in flight.

Introduction

The primary objectives of the qualification activities performed during the operational lifetime of a launcher are:
- to verify the qualification status of the vehicle
- to resolve any technical problems relating to subsystem operations on the ground or in flight.

Before focussing on the European family of launchers, it is perhaps informative to review just one or two of the US efforts in the area of solid and liquid propulsion in order to put the Ariane-related activities into context.

The casings of the solid-propellant boosters on the Space Shuttle, for example, are systematically recovered for technical inspection and re-utilisation. While the economics of the re-utilisation can be questioned, the technical inspections have highlighted major anomalies not previously detected in ground testing, including leakage of the rear joint, deterioration of the interior of the nozzles, abnormal erosion of the internal thermal protection, etc. All of these anomalies could have led to failures. The test programme for the Shuttle's cryogenic engine (SSME) has a testing rate higher than during the engine's development phase. During the ten years following the first flight, a test programme clocking up over 300 000 s of running time was carried out. In 1993 alone, over 37 000 s of testing was conducted.

Similarly, the RL10 engine on the Centaur stage of the Atlas launcher has been the subject of an ongoing improvement programme. About 5000 tests were performed before the first flight, and 4000 during the subsequent ten years.

On-going qualification activities of a similar nature were started for the Ariane-3 and 4 launchers in 1986, and for Ariane-5 in 1996. They can be classified into two main categories: 'regular' and 'one-off'.

Ariane-3/4 accompanying activities

Regular activities

These activities are mainly devoted to verification of the qualification status of the various launcher subsystems. They include the following work packages:
- Periodic sampling of engines: one HM7 and one Viking per year, tested to the limits of the qualification domain. As an example, from 1984 to 1994, 25 turbo pumps and HM7B engines were sampled in 240 tests, totalling 75 000 s of running time. Other equipment – such as onboard computers, guidance platforms, flight-control electronics, separation thrusters, pyrotechnic components and servo-motors – was also sampled and tested up to qualification boundary conditions.
- Detailed and systematic analysis of flight data, to reveal any possible anomalies and also to update and improve the various mathematical models representing the behaviour of the launcher (Fig. 1).
- Inspection of solid-propellant boosters recovered after flight (Fig. 2), to detect any manufacturing deviations and possible weaknesses.

One-off activities

These activities stem from the results of flight-data analysis and launcher subsystem acceptance testing. They can be as important as the new definition and qualification of a

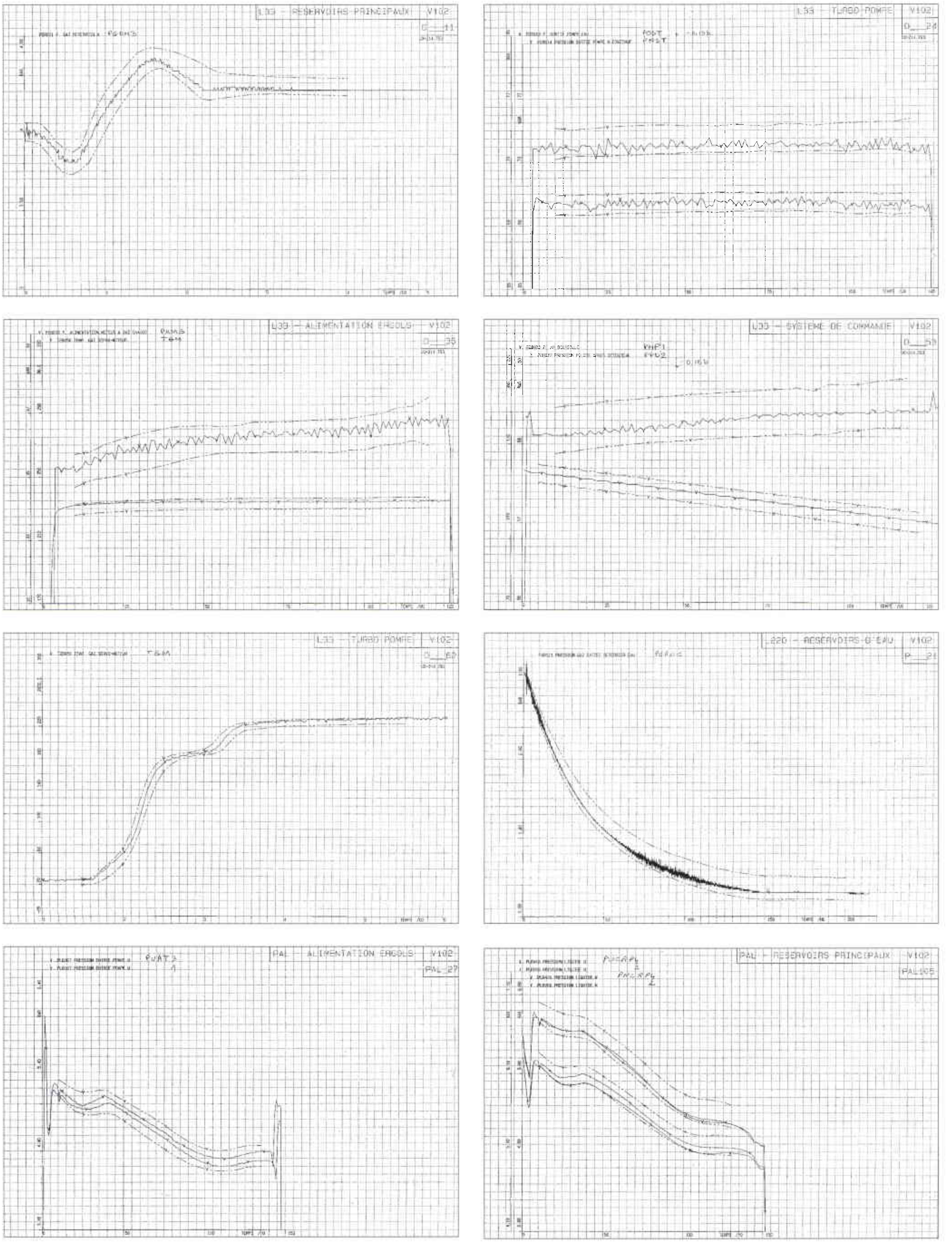


Figure 1. Between 500 and 800 parameters, depending on the Ariane launcher version, are measured, transmitted by telemetry and exploited after each flight. They constitute a valuable database that helps in detecting deviations and improving the mathematical models that simulate the launcher system's behaviour

Figure 2. Post-flight inspection of Ariane-4 solid boosters at the Guiana Space Centre provides important information that cannot be communicated by telemetry alone: behaviours of thermal protection, nozzles, fields joints, etc.
© ESA/CNES/Arianespace

pump bearing for the oxygen turbo pump on the HM7 engine, the qualification of a new nozzle throat for the Viking engine, or the qualification of new raw materials in the booster's solid propellant (Fig. 3).

In addition, cases of component obsolescence or supplier failure can arise, making it necessary to find replacements and qualify them for flight application. Problems of this nature have already been encountered and successfully dealt with in various areas, including electronics components, the Viking engine regulator, and composite structural materials.

Experience gained

These accompanying activities have highlighted several potential failure sources on the Ariane-3 and 4 launchers, allowing appropriate preventive measures to be taken:

- V22 : During long-duration tests on the Viking engine, a risk of blow-by on the regulator was detected. To eliminate it, a procedure for in-vacuo filling of the regulation circuit was established.
- V31 : To avoid damage caused by internal over-pressurising of the water tank on the L220 first stage, an extra valve was added.
- V33 : Poor liquid-propellant booster separation was observed. To correct it, the attachment fittings on the main stage were modified.
- V43 : Following the 'uncoupling' of the HM7B engine hydrogen pump, flights were suspended until a bleed valve preventing any pump cavitation had been qualified.
- V60 : Sampling tests on the separation rocket revealed a risk of a hot gas leak in the event of non-synchronised ignition sequences for the redundant pyrotechnic systems. These had to be modified to eliminate the risk.

Ariane-5 accompanying activities

Qualification of the Ariane-5 launcher is still in progress, but the production of the first set of operational launchers is already well under way. Consequently, Ariane-5 accompanying activities were started in 1996, based on the experience gained from Ariane-3 and 4 and retaining the distinction between regular and one-off activities that has proved so effective.

Regular activities

The types of recurrent activity supporting the Ariane-5 programme are similar to those for Ariane-4. There are, nevertheless, key differences stemming from two factors:

- the higher reliability target set for Ariane-5
- the development of new engines for Ariane-5.

The exceptionally high reliability requirement for Ariane-5 and the aim of reducing production and operating costs have resulted in a new launcher configuration that differs substantially from that of the previous generations. This new configuration required the development of two new liquid-propellant engines – Vulcain and Aestus – and a new solid-propellant booster.

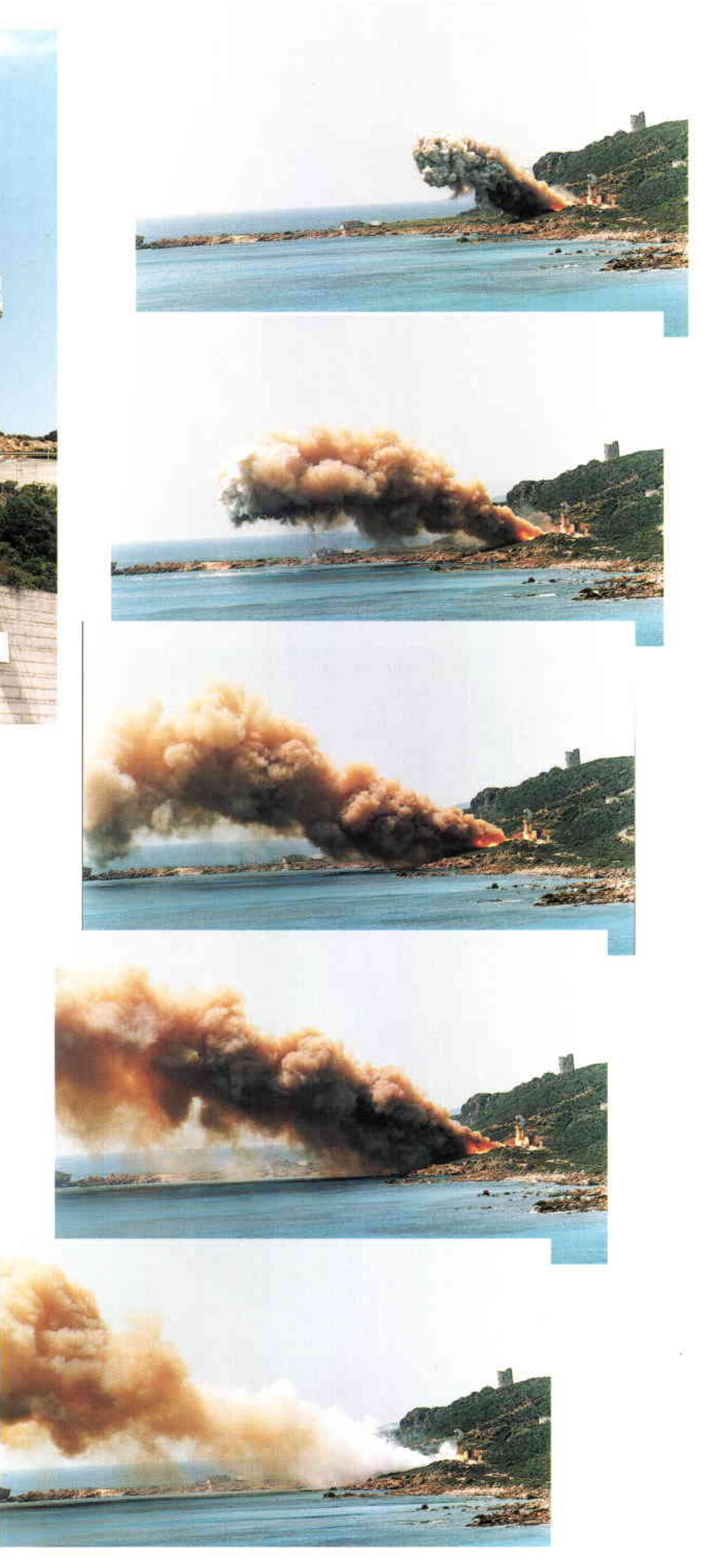
Cryogenic main stage

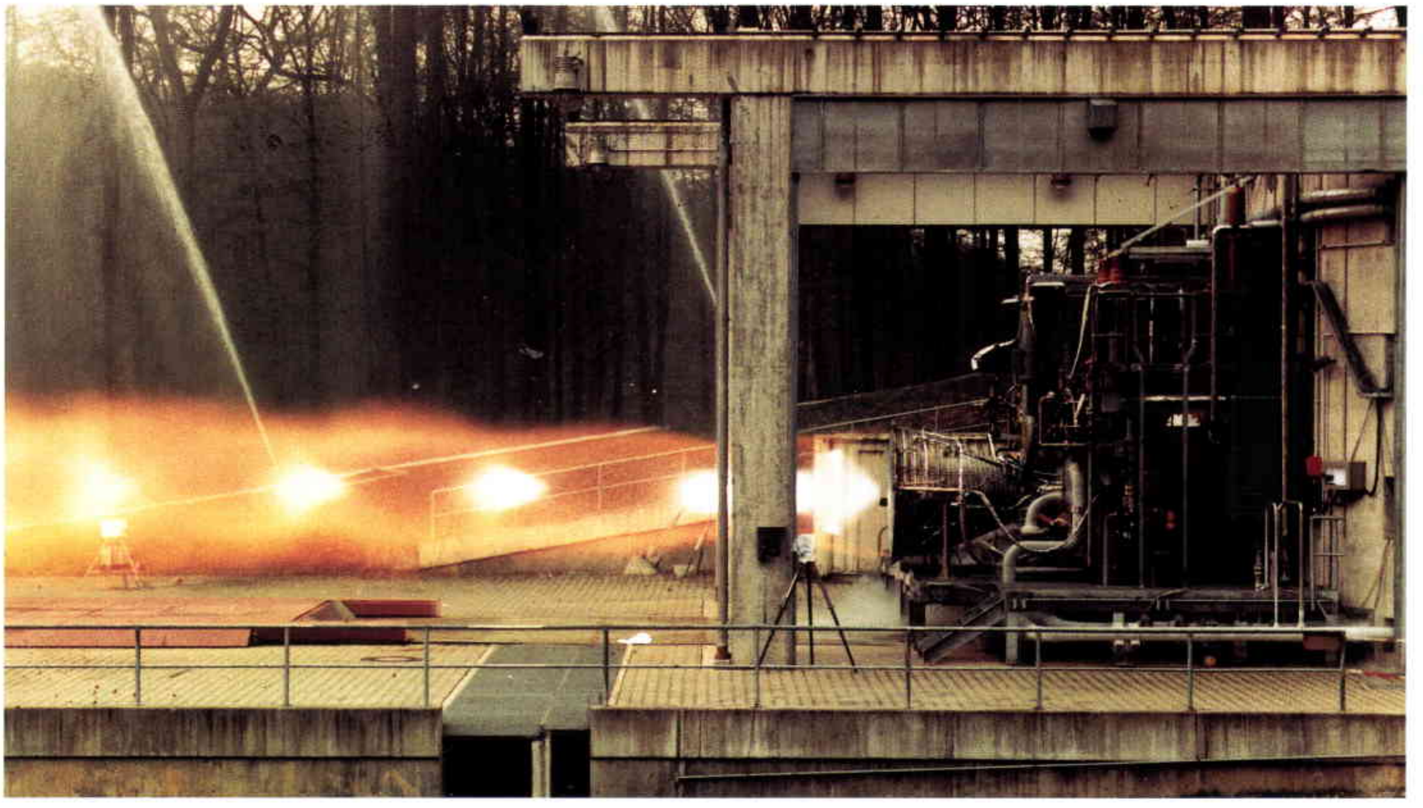
The two features mentioned above – high reliability and new development – are both highly relevant in the case of propulsion, where a clear distinction also has to be made between two cases:

- integration of various items that undergo qualification tests individually
- qualification of the engine as a whole under extreme operating conditions (Fig. 4).

To address the first case, one Vulcain engine has been revalidated and used to test engine components in a special campaign. The second case is being covered by limit tests on

Figure 3. Ariane-4 strap-on-booster test stand in Sardinia (Italy), and a full-scale firing test sequence in 1997 to qualify a new ingredient in the solid propellant's composition
© A. Constanzo for ESA/CNES/Arianespace





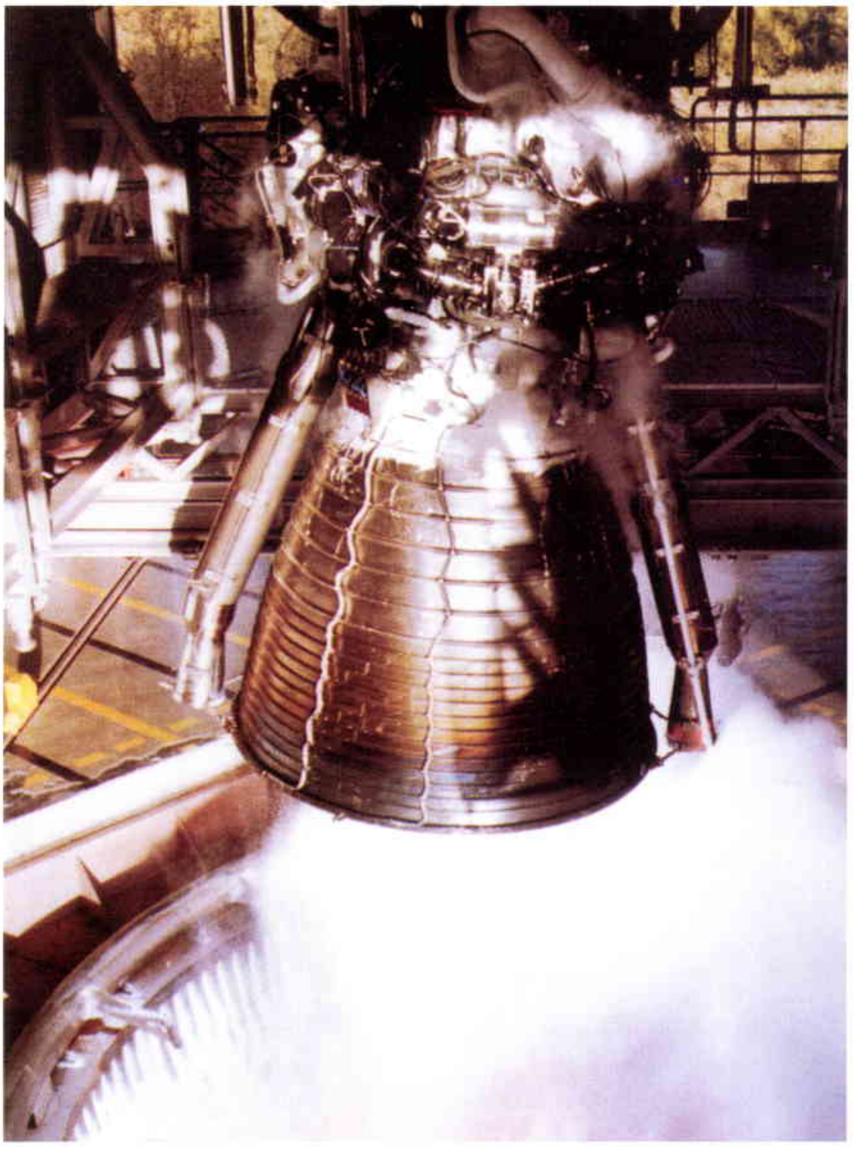


Figure 4. Test firings of the Ariane-5 cryogenic Vulcain engine in Vernon (France) and Lampoldshausen (Germany)
© SNECMA/SEP and DLR/DASA

one Vulcain engine per year. This rate of testing gives a cumulative running time over the five years of the campaign through to the year 2000 of about 30 000 s — nearly 1.8 times the estimated cumulative running time of flight engines (acceptance tests and flight).

Critical equipment for the stage and propulsion system (pressurisation/bleeding units, electro-valve units, feed valves and liquid-helium subsystem, flexible element, damper systems, etc.) will undergo dedicated qualification programmes followed by inspection.

Storable-propellant stage

The case of the Aestus engine on the storable-propellant stage is different. It is ignited in flight and operated for about 1000 s under conditions that are difficult to reproduce on the ground. The ratio of cumulative running times on the ground, with one test campaign a year, to those cumulated in flight will therefore be much lower than that given above for the Vulcain engine.

Aestus engine testing is, however, performed on a near-annual basis, with the engine undergoing nominal acceptance testing followed by short- and long-duration tests under varying operating conditions. The results of all of these tests serve to confirm the durability of the engine's performance.

The propellant tanks and high-pressure vessels will also undergo acceptance and destructive testing (fracturing) for the purposes of comparison with the qualification margins. Other items of equipment such as the pressurisation unit and electrical servo-motor will be subjected to their own qualification programmes periodically.

Solid-booster stage

As far as the solid-booster propulsion system is concerned, the initial development testing serves primarily to freeze the definition of the boosters and above all the casting production procedures and hardware acceptance criteria. The limited number of ground tests – five development and two qualification – is insufficient for accurate definition of the available margins, especially since the internal ballistics are different in flight and during ground testing. Recovery of flight specimens for inspection is therefore extremely important, as these provide the data needed for accurate definition of the actual margins for the features considered most critical (thickness of thermal protection, nozzle parts, field joints), which cannot be determined by in-flight measurements alone. Moreover, despite the fact that the booster definition is frozen on qualification, procedures and raw materials are bound to evolve over time, without it being possible to assess the impact of this on available margins.

The boosters from at least two Ariane-5 launches per year will therefore be recovered for inspection and at least one full-scale booster firing will be performed on the test stand at the Guiana Space Centre.

Other launcher systems

Other launcher systems will be sample-tested on a regular basis, including:

- electrical systems: onboard computer, inertial reference unit, flight control electronics, etc.

- attitude control system: thrusters, tanks with membrane, hydrazine feed valves, etc.

- pyrotechnic systems

- nozzle actuator units for the solid-propellant boosters and the cryogenic main stage.

Sampling will proceed on the basis of how critical a given item is. Items will undergo qualification testing followed by inspections. Limit tests will be conducted on the electronics components, together with a destruct inspection.

One-off activities

These can be divided into two groups:
- actions to address observed anomalies
- actions in cases of component or material obsolescence.

In the case of performance deviations being observed in flight (or during sampling tests), the prime aim is to arrive at a thorough understanding of the problem and thence define the most effective solution.

Experience gained under earlier Ariane launcher programmes has demonstrated the importance of taking prompt action to deal with cases of material obsolescence, particularly:
- the procurement of materials, ingredients, semi-finished products and units
- electronic components.

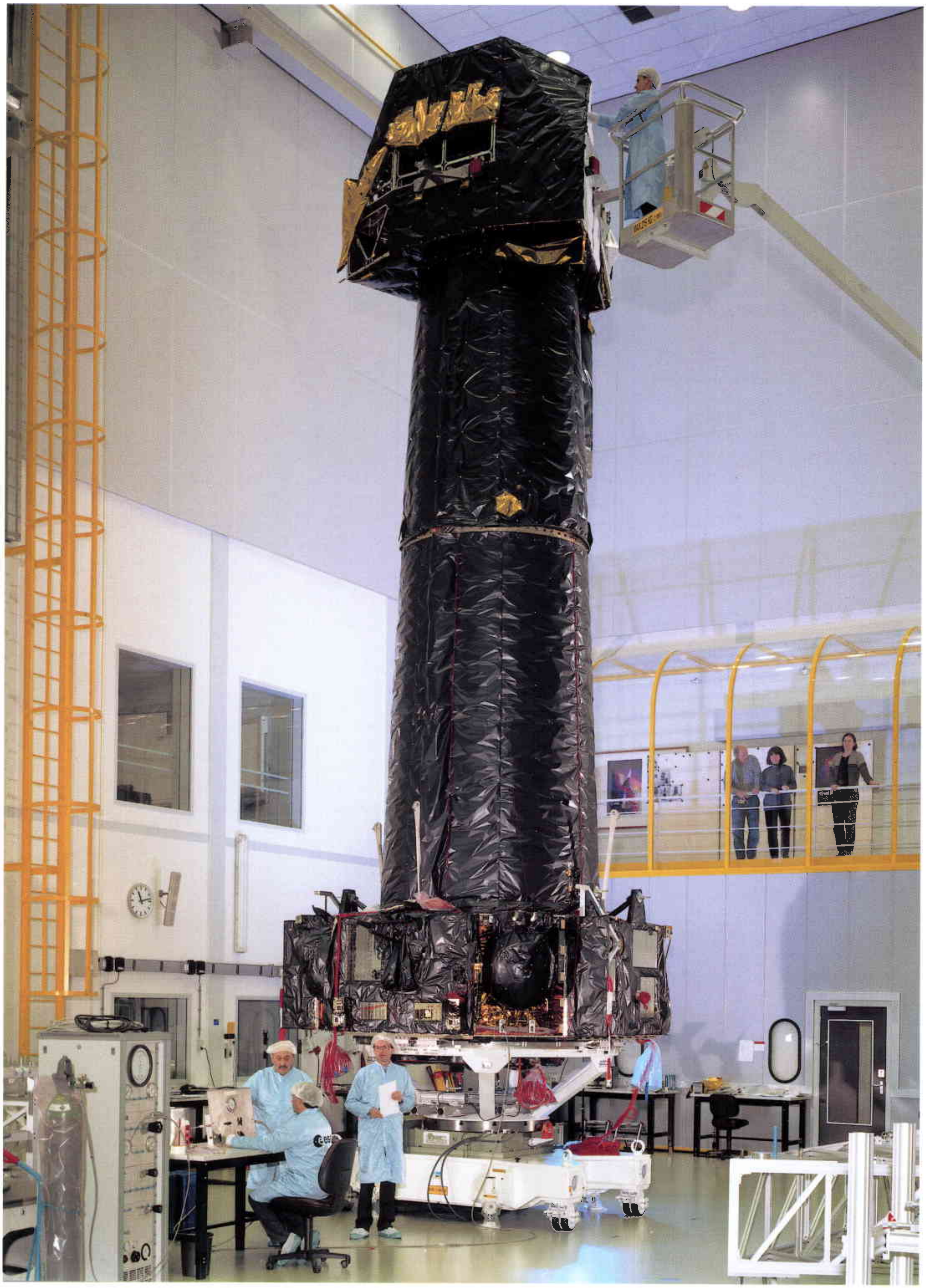
Hardware obsolescence or the withdrawal from the market of the relevant supplier can affect items in either category. Moreover, the risk of such obsolescence problems occurring is increasing as a result of industrial restructuring on an international basis and the nature of the launcher components themselves. Electronic equipment is particularly prone to such problems. Such changes will inevitably lead to the need for the period substitution of certain items, the replacements for which will also require the necessary re-qualification.

Conclusion

The considerable experience acquired in the development and operation of the Ariane-1 to 4 series of launchers has demonstrated that flight failures can be prevented by conducting the accompanying activities that have been described here. With more than one hundred flights to Ariane's credit, Ariane-4 currently enjoys the highest reliability record in the market: 0.966 according to the AMSAA model. These accompanying activities are set to continue throughout the lifetime of Ariane-5, with the systematic analysis of flight data combined with the sample-testing of critical items from the production line. The goal is to ensure that Ariane-5 has an even higher reliability throughout its lifetime than its predecessor.

Acknowledgements

The author wishes to thank André Constanzo of Arianespace for providing the photographs that accompany this article.



Testing of the XMM Structural and Thermal Model at ESTEC

P. Kletzkine, T. van der Laan, R. Lainé & D. Stramaccioni
XMM Project, ESA Directorate for Scientific Programmes,
ESTEC, Noordwijk, The Netherlands

The XMM (X-ray Multi-Mirror) spacecraft, a space-borne X-ray observatory to be launched by Ariane-5 in 1999, stands 10 m-high and measures over 4 m in diameter in launch configuration, for a launch mass of just under 4 tonnes. Such a tall spacecraft challenges the capabilities of existing European environmental testing facilities. The spacecraft design does allow for a relatively straightforward splitting into modules. The Structural and Thermal Model (STM) of the XMM spacecraft has successfully undergone mechanical environmental testing at the European Space Research & Technology Centre (ESTEC). This article briefly introduces the XMM project, presents an overview of the XMM configuration constraints, explains the spacecraft-level model philosophy and mechanical test flow, and summarises the present status of the tests performed.

The XMM Project*

The XMM (X-ray Multi-Mirror) spacecraft is a space-borne observatory covering the soft X-ray portion of the electromagnetic spectrum. XMM is to be launched by Ariane-5 in 1999. By virtue of its large telescope collecting area and its highly eccentric orbit, it will permit long observations of X-ray sources and achieve an unprecedented sensitivity. The on-board scientific experiments are conceived and built by scientific institutes in ESA's member countries as well as in the USA. Once XMM is in orbit and checked out, time will be made available to the scientific community applying for observing periods on a competitive basis. The heart of the mission is the X-ray telescope. It consists of three large mirror modules and associated focal plane instruments held together by the telescope central tube. The scientific instruments are the European Photon Imaging Camera (EPIC), Reflection Grating Spectrometer (RGS) and Optical Monitor (OM).

* More information on the XMM project is available via the Internet at http://www.estec.esa.nl/spdwww/xmm/index.html

Configuration constraints

The satellite mass at launch is about 3900 kg. XMM is configured in a modular way and consists of:
- the Focal Plane Assembly (FPA) mounted on a platform carrying the EPIC and RGS detectors, as well as the units ensuring the data handling and power distribution
- the Telescope Tube (TT) maintaining the relative positions of the FPA and MSP
- the Mirror Support Platform (MSP) carrying the three Mirror Modules with their various baffles and the two RGS grating boxes, the Optical Monitor and the star trackers
- the Service Module (SVM) which carries the spacecraft subsystems and provides resources.

The Service Module consists of a closed-box structure with a central cone surrounded by side panels and equipped with a deployable Telescope Sun Shield. Most Service Module electronic units are mounted on the inside of the side panels. Foldout solar arrays, two antennas and one of the two batteries are mounted on the outside of the box structure. The four propellant tanks and four thruster pairs are located at its corners. The Mirror Support Platform mounted on the box is supported by the central cone.

It is readily apparent that splitting the satellite into a Service Module and a Payload Module does not solve the problem of size limitations in environmental testing facilities since the payload is distributed throughout the length of the spacecraft. Furthermore, analysis determined that mechanical qualification of the Service Module alone was unrealistic because the mechanical behaviour of the lower part of the spacecraft is largely determined by the presence of the three Mirror Modules which together with the two Reflection Grating Assemblies (RGA) account for more than 1300 kg of mass mounted into the Mirror Support Platform. Proper load introduction into the Service Module from the Mirror Support Platform fully equipped with Mirror Modules is indispensable.

For environmental test purposes, the spacecraft was therefore split at roughly mid-height. This resulted in a configuration which lent itself to accommodation in the largest existing European test facilities, namely those at ESTEC:
- ESTEC's Large Space Simulator with its 6m-diameter solar beam for thermal testing

- ESTEC's 280 kN electro-dynamic shaker for vibration testing
- ESTEC's mass-properties measurement machine with its recent L-4600 arm
- ESTEC's Large European Acoustic Facility for acoustic, modal survey and clampband release testing of the complete spacecraft.

Spacecraft-level model philosophy

The *Structural and Thermal Model* (STM) was used to qualify the complete spacecraft primary structure and thermal design. The STM can be separated into a Lower Module and an Upper Module as described above; the structural and thermal designs take into account that the two are tested separately. The STM was also used to prove the Lower Module-to-Upper Module mating/de-mating procedures, verify the behaviour of the Lower Module-to-Upper Module interface, verify alignment and light tightness design and test procedures, verify compatibility with the shock inputs, and exercise assembly and handling procedures and the Mechanical Ground Support Equipment.

The *Electrical Model* (EM) was used to verify the electrical design, internal interfaces, software, check-out procedures and the Electrical Ground Support Equipment. Tests will be performed on the Electrical Model to verify Electro-Magnetic Compatibility (EMC) and Electro-Static Discharge (ESD) behaviour, both radiated and conducted.

The *Proto-Flight Model* (PFM) is the actual satellite to be flown. Its structural qualification has been achieved on the STM, the 'Proto' part of the name concerning only limited electrical aspects and minor configuration changes.

Additionally, there is a *RF Suitcase Model* that will be used to test radio-frequency compatibility between the spacecraft and the ground stations.

Mechanical test flow

The test flow of the *Structural and Thermal Model* is optimised by making use of the modular split of the spacecraft: parallel testing is conducted whenever the two modules are not mated. Integrations of the Upper Module and Lower Module also took place separately. Subsequently, the two modules were mated, aligned, submitted to a thermal distortion test and alignment check, de-mated, and shipped to ESTEC for environmental testing. Each module underwent, in turn, mass-properties measurement, thermal balance and sine vibration. The remaining tests could be carried out on the complete spacecraft, and therefore the Upper Module and Lower Module were mated and the assembled STM spacecraft underwent a modal survey, acoustic testing, a clampband shock test and functional tests of mechanisms. At regular intervals between tests throughout the gruelling qualification environment, checks verified the spacecraft's ability to maintain full integrity, alignment and light tightness – all crucial to the scientific mission.

Thermal testing

The purpose of the thermal balance test campaign with the XMM spacecraft Modules was to verify the performance of the thermal control subsystem and to validate the thermal mathematical models used by the thermal engineers to establish the design. The tests were performed in the Large Space Simulator (LSS) at ESTEC, the largest solar simulator facility in Europe. The test programme was conceived to demonstrate that payloads and spacecraft equipment are always kept within specified temperature limits under simulated orbital conditions that are the extremes of the expected mission envelope. While the Upper Module was mounted inside the chamber in its upright position (as it will stand on top of the Ariane-5 launcher), the Lower Module was 'upside-down', with the 2700 kg mass of the Service Module and Mirror Modules on top of the lower half of an extremely light-weight Telescope Tube. This rather surprising set-up offered the possibility of realistically simulating the thermal environment of the bottom part of the spacecraft where the Mirror Module apertures had an unobstructed view to cold space. The correct simulation of the heat fluxes lost into space was of paramount importance for the verification of the temperatures and gradients of the Mirror Modules and the Mirror Support Platform. This would not have been possible if a more conventional mounting of the spacecraft by means of its launcher interface flange had been selected.

Once the last entry door of the Large Space Simulator was sealed, the pump-down sequence started to bring the pressure level inside the chamber down from one atmosphere to less than the $5x10E^{-6}$ mbar required to suppress any convective heat transfer and simulate the high vacuum conditions of outer space. Soon after, the black shrouds that cover the inner walls of the Large Space Simulator were flushed with liquid nitrogen to bring their surface temperature down to -180°C in order to reproduce the cold black sink provided by space. The 6m-diameter solar beam of the Large Space Simulator was then switched on to complete the orbital simulation. The solar flux provided by the Large Space Simulator reproduces the spectrum of solar light, the parallelism of its rays and its intensity, which was made to vary during the test to reproduce the various seasonal conditions (from 1320 to 1420 W/m^2). Albedo and Earth radiation did not need to be simulated because of their negligible contribution along the very-high-altitude orbit of XMM.

Due to the peculiar architecture of XMM, it was rather simple to simulate the thermal interface provided by the missing part of the spacecraft. In fact, because of the low thermal conductance of the long thin-walled Telescope Tube that is entirely made out of carbon-fibre composite, the two Modules cannot exchange heat by conduction. The flux exchanged by radiation (less than 25 W flowing from the Lower Module to the Upper Module) was simulated by controlling the temperature of a plate placed inside the test adapter that held the two Modules. It is worth mentioning that an optical aperture stop (one of the two installed inside the Telescope Tube) is mounted near the interface plane where the Telescope Tube is split, and provides a physical separation between the upper and lower tube cavities.

The two Modules were mounted by means of the same test adapter on the Large Space Simulator gimbal stand that also provided the possibility of changing the attitude of the spacecraft with respect to the solar beam direction, as was required by the simulation of the various orbital phases.

Because of the stringent cleanliness requirements imposed by the optics of the telescope system, a pure nitrogen purge line was located inside the test adapter and used to directly vent the interior of the Telescope Tube during the repressurisation phases. The cryo-panels inside the facility were used to trap contaminants. The thermal balance test also had to verify the effectiveness of the cleanliness measures and procedures adopted. They are aimed at providing the cleanliness level required for the thermal vacuum test of the flight spacecraft as it will be performed with the same set-up and the same mechanical equipment.

The STMs of the two Modules were equipped with dummy units; heat dissipation was simulated by means of heaters inside the units. The dissipated power totalled 450 W for the Lower Module and 300 W for the Upper Module. For the thermal control of the Mirror Modules and the Mirror Support Platform 400 W were used, and 90 W were used for the thermal control of equipment. In addition, test heater lines were used to control the test adapter, the solar array simulators, as well as the guard heaters which balanced the heat losses through the cabling. 21 power supplies provided the power for the Upper Module test and 74 power supplies for the Lower Module. In order to have a detailed temperature mapping of the various parts, 370 temperature sensors were installed on the Upper Module and 600 sensors on the Lower Module. To connect heaters and sensors, about 8 km of electrical wiring had to be routed for the Upper Module test and 15 km for the Lower Module.

The spacecraft was equipped with 3 STM Mirror Modules with 58 mirror shells of non-flight-standard optical quality. The Mirror Modules and Mirror Support Platform were finely instrumented in order to verify that the stringent requirements on their temperature uniformity were actually met. (They have to be kept at 20°C with deviations of less than 2°C.) The Service Module was equipped with thermal simulators of the solar arrays that reproduced the correct heat rejection capability of the lateral radiators. The thermal blankets* and radiator coatings had a flight-standard quality.

Lower Module test phases

The Lower Module's thermal-balance test lasted 11 consecutive days (Figs. 1 and 2). During this test, the unit heat dissipations were increased or decreased from their nominal values to force ranges of temperatures as wide as possible and provide clearer cases to be compared with the mathematical model results.

Two hot steady-state cases with nominal attitude (pitch 0, roll 0), maximum solar flux (1420 W/m^2) and with two different unit power dissipations were performed to verify the sizing of the radiators and to measure the spacecraft sensitivity to unit dissipations. Under the simulated sunlight, the thermal blankets showed very good performance in insulating the Telescope Tube and the spacecraft. Across the few-millimetre-thick blanket, the temperature dropped from 130°C on the illuminated skin to the 16°C average of the Telescope Tube. The temperature difference between the illuminated side of the Telescope Tube structure and the shadow side was only 3°C (or less). The temperature of the external skin on the shadow side dropped to -150°C.

Three cold steady-state cases with minimum solar flux (1320 W/m^2) and various combinations of pitch and roll angles and unit power dissipations followed, with the purpose of checking the heater system, the minimum temperature levels, the Mirror Modules' temperature control system and to characterise the thermal stability of the telescope elements with respect to changes of attitude. The Mirror

* The external skin of XMM's thermal blankets is made of carbon-filled kapton and displays a semi-gloss black finish. This material was selected because its thermo-optical properties do not change under solar irradiation. This will help to keep the temperature of the telescope stable throughout its expected 10-year lifetime. In addition, with this material being electrically conductive, the build-up of electrostatic charges under solar irradiation is avoided.

Figure 1. XMM Lower Module inside the Large Space Simulator thermal-vacuum test chamber, with deployed thermal simulators of the solar arrays

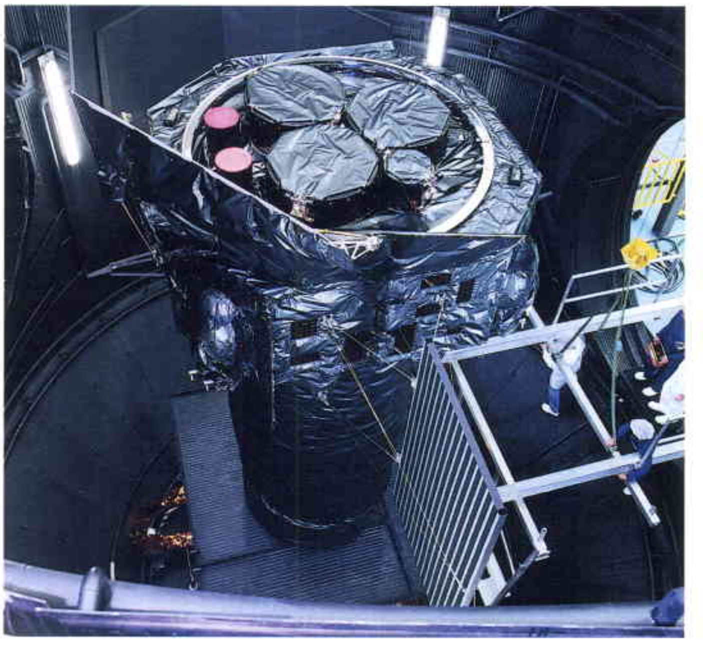


Figure 2. XMM Lower Module inside the Large Space Simulator thermal-vacuum test chamber. The three Mirror Module doors and the Optical Monitor door (all closed) and the two Star Tracker baffles are clearly visible

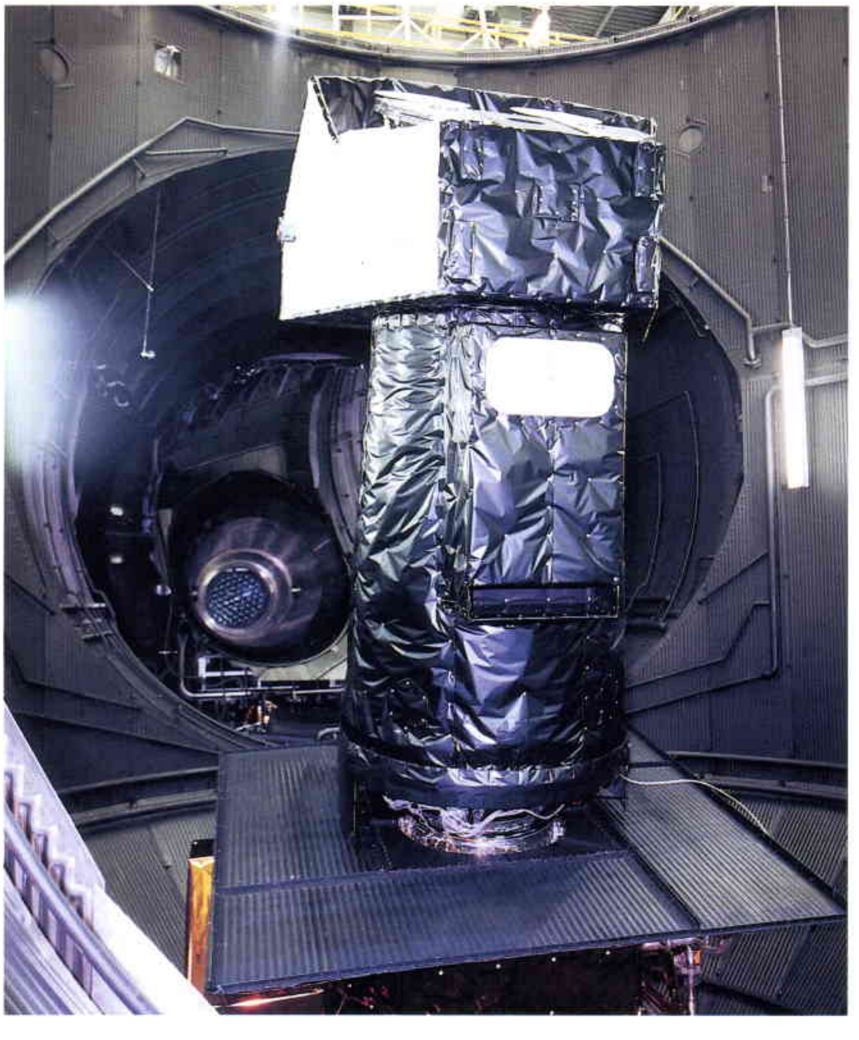


Figure 3. XMM Upper Module inside the Large Space Simulator thermal-vacuum test chamber. The Module has been turned to attitude +20deg roll, +20 deg pitch. The five camera radiators are visible on top of the spacecraft

Modules were controlled by their pulse-modulated heater system without inducing temperature oscillations that would have perturbed the stability of the optical system.

Finally, a 1.8-h eclipse with the subsequent recovery phase was simulated. The Mirror Modules were boost-heated before eclipse, then their heaters were switched off during eclipse and eventually brought back to their operational temperature during the recovery phase. In general, the temperature drops were in line with, or less than, the predicted ones so that the time needed to resume scientific observations is minimised (observations can only be made when temperatures and gradients are within the thermal stability requirements).

The thermal balance test was also very successful in detecting areas where the thermal design had to be improved and corrected on the flight model, such as the larger-than-predicted cooling effect of the large Telescope Sun-Shield on the Service Module.

Upper Module test phases

The Upper Module thermal-balance test lasted 9 consecutive days (Fig. 3). Two hot steady-state cases with maximum solar constant and increased unit heat dissipation were performed with nominal and slewed attitudes. The radiator sizing was verified and the sensitivity of the platform to gradients when the attitude was changed was confirmed to be small. In any case, the camera radiators managed to cool the CCDs (Charge Coupled Devices) down to the desired -130°C. Two cold cases followed with minimum solar constant combined with nominal and slewed attitudes and nominal unit dissipation, allowing the worst cold-case condition to be reached.

Finally, a long eclipse was simulated, with cool-down of experiments and units during a 1.8 h eclipse when switched off. This was followed by an eclipse recovery, which simulated a failure of the electrical power sub-system in switching on the unit substitution heaters after the eclipse. In this case, it was verified that the spacecraft could be rescued by the low temperature guard thermostats which would automatically switch the heaters on.

The test configuration with the test adapter used for the STM programme will also be used for the PFM tests. The objective of the thermal vacuum tests is to verify that the spacecraft performs correctly in all operational modes at the extreme temperatures that can be withstood by its equipment. In addition, some thermal balance test phases will be inserted in the thermal vacuum programme in order to verify the thermal control performances after the modifications introduced between the STM design and the final Flight Model design. For cleanliness reasons, the test will be carried out with the STM Mirror Modules installed in the PFM of the spacecraft Lower Module instead of the Flight Model Mirror Modules.

Structural testing

Shaker tests

The test objectives were:

- Proof of correspondence between hardware-dynamic characteristics and mathematical models at modular level. This is necessary to validate the launcher-XMM coupled analysis.
- Proof of strength for those parts that did not see strength verification beforehand such as:
  - Focal Plane Platform and Service Module equipment panels and their interfaces to the equipment
  - Focal Plane Assembly secondary structure
  - Service Module shear walls
  - Service Module secondary structures such as thruster brackets and Telescope Sun-Shield (TSS).

In each of the three orthogonal axes, each module was sine-vibration tested following the classical sequence: low-level, intermediate-level to define notch profiles, qualification-level followed by low-level again in order to check that modal characteristics have not been affected by the tests.

Shaker input levels for the Upper Module could not be taken directly from the Ariane-5 user's manual because of the transfer characteristics of the Lower Module.

A system-level response analysis was run to determine these transfer characteristics, and the resulting inputs from the Lower Module into the Upper Module at the interface between the Lower Telescope Tube and the Upper Telescope Tube. These levels were used as input for the Upper-Module testing (Figs. 4 and 5).

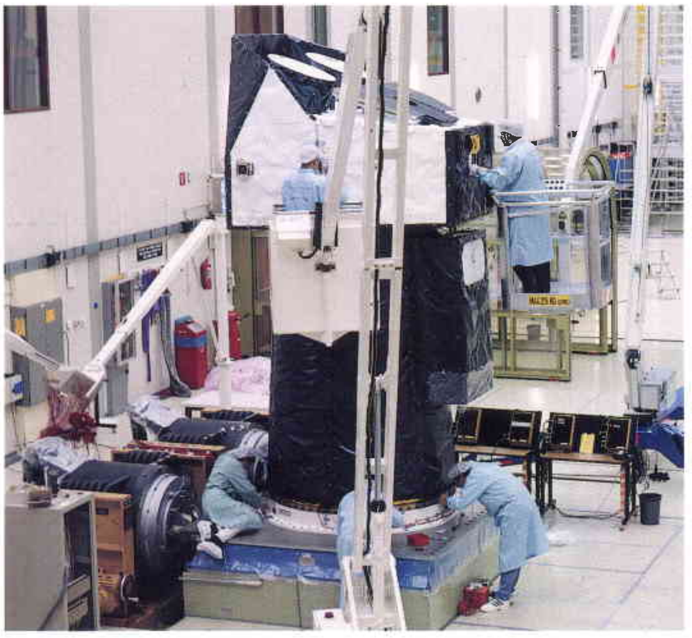


Figure 4. XMM Upper Module being prepared for the lateral sine vibration test, on the slip table of the 280 kN shaker

Figure 5. XMM Upper Module ready for the axial sine vibration test, on the dual head expander of the 280 kN shaker

Figure 6. XMM Lower Module ready for the axial sine vibration test, on the dual head expander of the 280 kN shaker. One of the solar array dummies and the Telescope Sun-Shield are clearly visible

Figure 7. XMM Lower Module being prepared for the lateral sine vibration test, on the slip table of the 280 kN shaker

Figure 8. Mating of the XMM Upper Module and Lower Module to form the assembled spacecraft

For the Lower-Module testing, the input levels found in the Ariane-5 users' manual were used (Figs. 6 and 7). In spite of the absence of the Upper Module, the Lower Module has many modes corresponding to the complete system dynamics so that a system-level notch profile could be established. This notch profile has been found to be acceptable (also to launch authorities).

The testing of both Modules demonstrated that the desired response levels were reached at the foreseen resonances.

Modal survey

After the tests on the shaker, the Upper and Lower Modules were mated (Fig. 8) and alignment measurements were performed (Fig. 9). This opened the way for modal-survey testing on the complete spacecraft to confirm system-level modes.

The modal-survey testing, performed by a team from the Deutsches Zentrum für Luft- und Raumfahrt (DLR) - Göttingen, has shown that the overall lateral mode corresponds well with computer predictions (11.7 Hz measured against 11.8 Hz calculated) and has confirmed the recurrence, on the complete spacecraft, of local Service Module modes as found in the Lower-Module test.

The objective of identifying below 100 Hz all modes with an effective mass above 5% of the total mass, has been met.

Figure 9. Alignment operations on the assembled XMM spacecraft

Figure 10. Modal survey testing of the assembled XMM spacecraft in the Large European Acoustic Facility. The sound horns used for the acoustic test are visible on the left side

This test was rounded off with a so-called 'boosted' run in which high lateral inputs were given to the Focal Plane Platform such that response levels reached flight levels times a qualification factor. This dwell test at 11.7 Hz demonstrated the load capacity of the fully built-up central core in both lateral directions, as well as the stability of the first lateral resonance under increased loading.

For reasons of practicality, the modal-survey testing took place in the Large European Acoustic Facility (LEAF) (Fig. 10) where acoustic testing was to be performed next.

Acoustic testing
Thanks to the impressive dimensions of the available acoustic facility, acoustic testing could be performed on the complete spacecraft. It particularly involved the structures with low mass per area such as the Telescope Sun-Shield, the Service Module upper and lower platforms, the Telescope Tube, and the Focal Plane Assembly secondary structures. Dummies represented solar arrays; flight solar panels were submitted to separate acoustic tests.

Although the Telescope Sun-Shield went through an acoustic verification at unit level earlier in the programme, this test was of particular interest since the Sun-Shield was now mounted on the Service Module edge, which modifies the lower resonances.

The specified launch environment (plus 4 dB qualification margin) determined the qualification test levels and tolerances (Table 1). Responses at the level of the Service Module units were recorded in order to be compared to the unit level specifications. After qualification, further test runs provided supplementary information as to the margins available.

Table 1

Octave centre frequency (Hz)	Qualification level (dB)	Tolerances (dB)
31.5	132	-2 / +4
63	134	-1 / +3
125	139	-1 / +3
250	143	-1 / +3
500	138	-1 / +3
1000	132	-1 / +3
2000	128	-1 / +3
Overall level	146	-1 / +3
Duration	2 minutes	

Figure 11. XMM Lower Module undergoing axial mass properties measurement, on the WM 50/6 machine

This spacecraft-level acoustic test series was successful in demonstrating qualification of the structure and also in identifying those units for which further unit-level qualification data had to be acquired.

Clampband release

An Arianespace team performed this test with the complete spacecraft clamped to its launch vehicle adapter. After a fit-check with the adapter, it involved the release of the ϕ2624 clampband. The objectives were:

- to prove correct fit to the adapter including accessories (e.g. clampband, clampband extractors and catchers, umbilical connectors, purge ports, release springs, and separation switches)
- to demonstrate feasibility of mating the Telescope Sun-Shield to the spacecraft after clampband installation
- to show proper clampband release without interference with any part of the spacecraft including the Telescope Sun-Shield
- to measure shock levels induced by the clampband pyrotechnic release on both sides of the separation plane and at selected equipment levels.

Subsequently, a release of the Telescope Sun-Shield was performed to verify that its deployment mechanism functioned properly, even after clampband-release shock and under adverse thermal gradients.

This series of tests was fully successful in as far as the results gave rise to no particular concern.

Mass properties

The objectives of this test were to measure the mass, Centre of Gravity (CoG) and Moments of Inertia (MoI), along all three axes of the XMM Upper and Lower Modules.

To measure the CoG and MoI of space items, the ESTEC combined centre of gravity and moment of inertia machine WM 50/6 was used (Fig. 11). The measurements along the specimen horizontal axes were performed on the same machine by means of an L-shaped adapter identified as L-4600 (for a specimen diameter of up to 4600 mm) (Figs. 12 and 13). The characteristics of the WM 50/6 machine are not compatible with the whole XMM spacecraft in terms of maximum admissible mass and maximum admissible overturning moment, especially in horizontal configuration. Therefore, the measurements of CoG and MoI were performed at module level. The mass of each module was measured with a Schenk bridge-weighing machine, with an accuracy of ± 200 g.

Figure 12. XMM Lower Module undergoing lateral mass properties measurement, with the L-4600 adapter arm on the WM 50/6 machine

Figure 13. XMM Upper Module undergoing lateral mass properties measurement, with the L-4600 adapter arm on the WM 50/6 machine

The measurement results confirmed the predictions made on the basis of calculations.

Conclusion

The Structural and Thermal Models of XMM have been successfully tested to flight qualification at the ESTEC Test Centre within seven months, from September 1997 to March 1998.

Large spacecraft such as XMM stretch or surpass the capabilities of current operational environmental test facilities in Europe. The XMM environmental test programme combines testing on the complete spacecraft wherever possible with modular testing when unavoidable. The resulting satisfactory qualification and acceptance is possible thanks to a split into modules that was taken into account during the design stage.

Acknowledgements

The authors thank the teams from the XMM Prime Contractor Dornier, the ESTEC Test Division and the Comet consortium, as well as from DLR, Arianespace, and other supplier companies whose products and services made the tests possible and whose work forms the basis for this article.

The Hipparcos and Tycho Catalogues

The Mission Products

The principal parts of the Hipparcos Catalogue are provided in both printed and machine-readable form. Tycho Catalogue results are provided in machine-readable form only. The printed volumes include a description of the Hipparcos and Tycho Catalogues and associated annexes, a description of the satellite operational phase, a description of the corresponding data analysis tasks, and the final data.

Machine-readable versions of the catalogues are provided in two forms: the definitive mission products are released as a set of ASCII files on a series of CD-ROMs, which contain all of the printed catalogue information as well as some additional data. Auxiliary files containing results from intermediate stages of the data processing, of relevance for the more-specialised user, are also included.

A distinct single CD-ROM product, Celestia 2000, contains the principal astrometric and photometric data, in compressed form, along with specific interrogation software developed for specific platforms.

The Hipparcos Mission

The Hipparcos space astrometry mission was accepted within the European Space Agency's scientific programme in 1980. The Hipparcos satellite was designed and constructed under ESA responsibility by a European industrial consortium led by Matra Marconi Space (France) and Alenia Spazio (Italy), and launched by Ariane-4 on 8 August 1989. High-quality scientific data were acquired between November 1989 and March 1993. The scientific aspects of the mission were undertaken by nationally-funded scientific institutes. All of the scientific goals motivating the mission's adoption in 1980 were surpassed, in terms of astrometric accuracy, photometry, and numbers of stars.

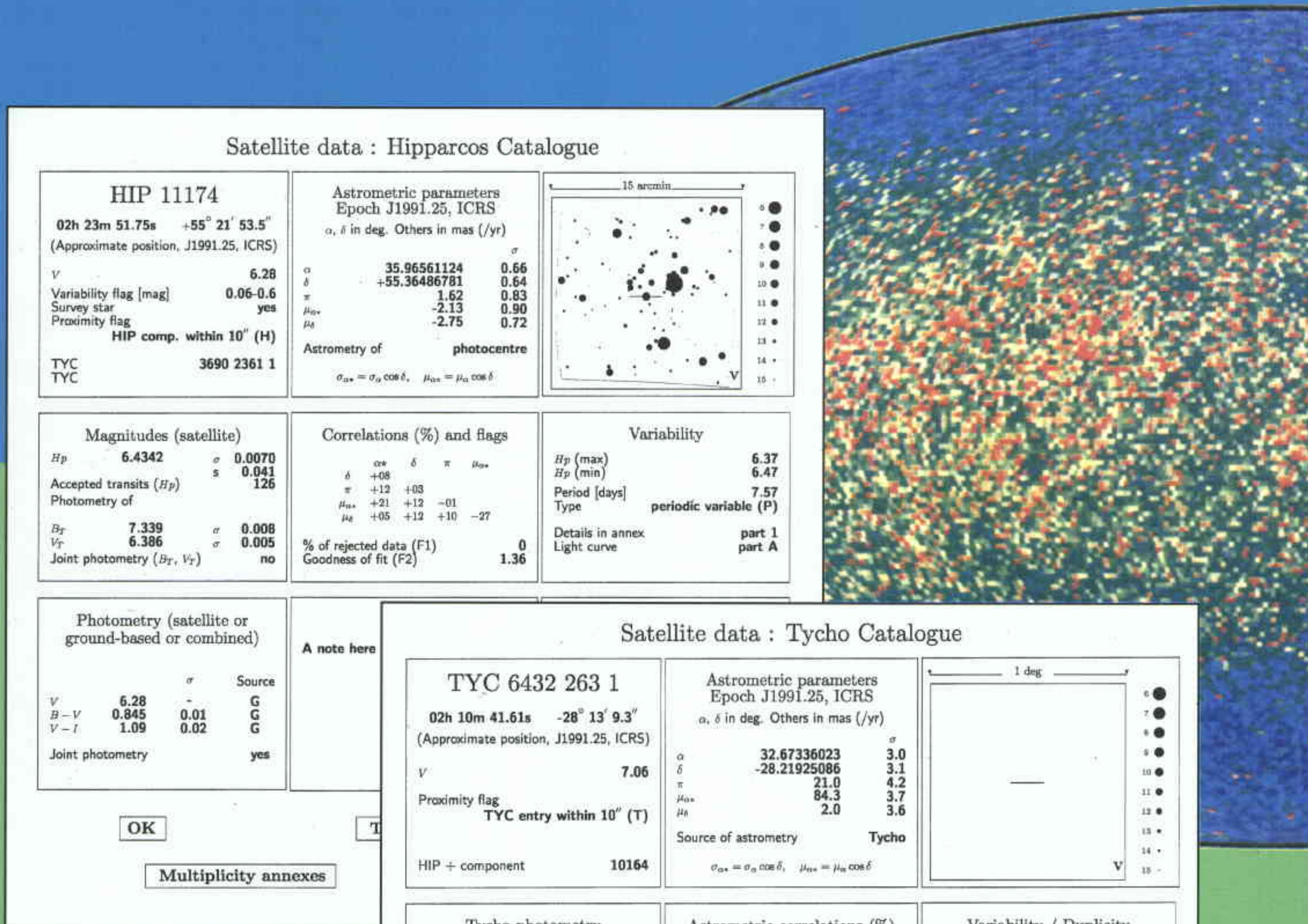
The global data analysis tasks, proceeding from nearly 1000 Gbit of satellite data to the final catalogues, were undertaken by three scientific consortia: the NDAC and FAST Consortia, together responsible for the production of the Hipparcos Catalogue; and the Tycho Consortium, responsible for the production of the Tycho Catalogue. A fourth scientific consortium, the INCA Consortium, was responsible for the construction of the Hipparcos observing programme. The production of the Hipparcos and Tycho Catalogues marks the formal end of the involvement in the mission by ESA and the four scientific consortia.

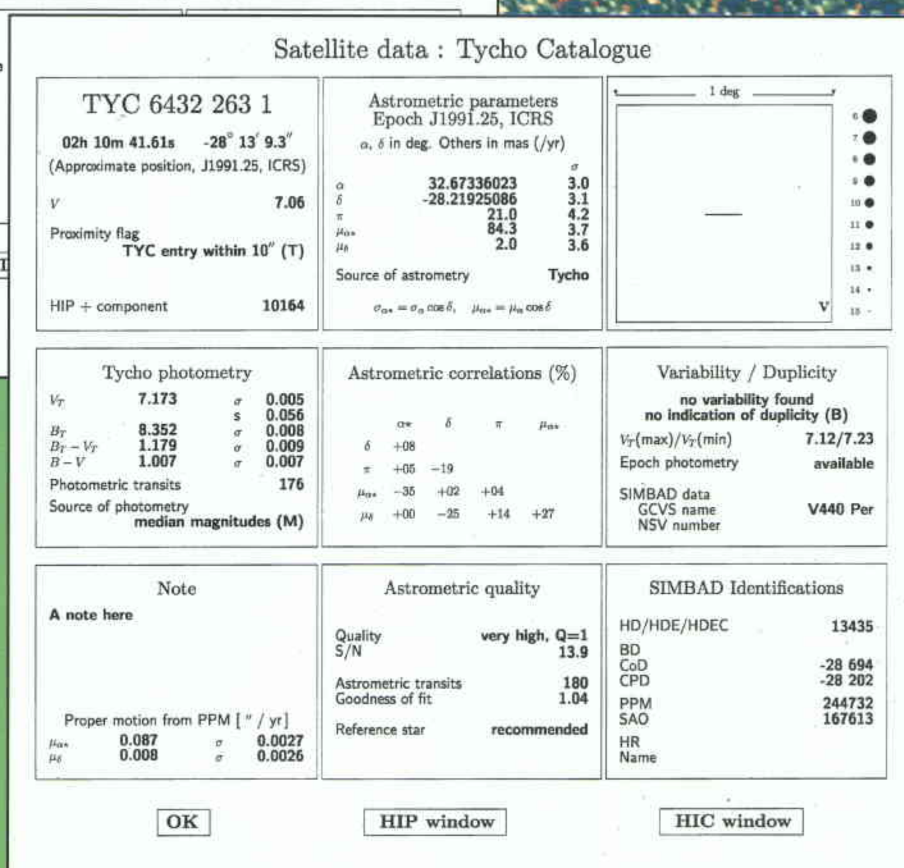
The Hipparcos and Tycho Catalogues

The final products of the European Space Agency's Hipparcos mission are two major stellar catalogues, the Hipparcos Catalogue and the Tycho Catalogue.

Each catalogue includes a large quantity of very high quality astrometric and photometric data. The astrometric data in the Hipparcos Catalogue is of unprecedented accuracy: positions at the catalogue epoch (J1991.25), annual proper motions, and trigonometric parallaxes, have a median accuracy of approximately 1 milliarcsec. The Hipparcos Catalogue includes annexes featuring variability and double/multiple star data for many thousands of stars discovered or measured by the satellite. The Hipparcos and Tycho Catalogues will remain the definitive astrometric stellar catalogues for many years.

Celestia 2000





Celestia 2000

Celestia 2000 is a CD-ROM package containing the Hipparcos and Tycho catalogues, plus related annexes, in compressed binary format, along with dedicated software permitting interrogation, sample construction and information display.

It has been designed and constructed with both the professional and amateur astronomer in mind.

The package is designed for IBM PC and compatibles running under Windows 3.1, Windows 95, or Windows NT.

Order Form

Final results from the ESA Hipparcos space astrometry mission are available in three formats:

— A 16–volume hard-bound printed catalogue, containing descriptions of the data reduction techniques, along with the Hipparcos Catalogue and related annexes, plus an ASCII version of the Hipparcos and Tycho Catalogues and annexes in a set of 6 CD-ROMs.

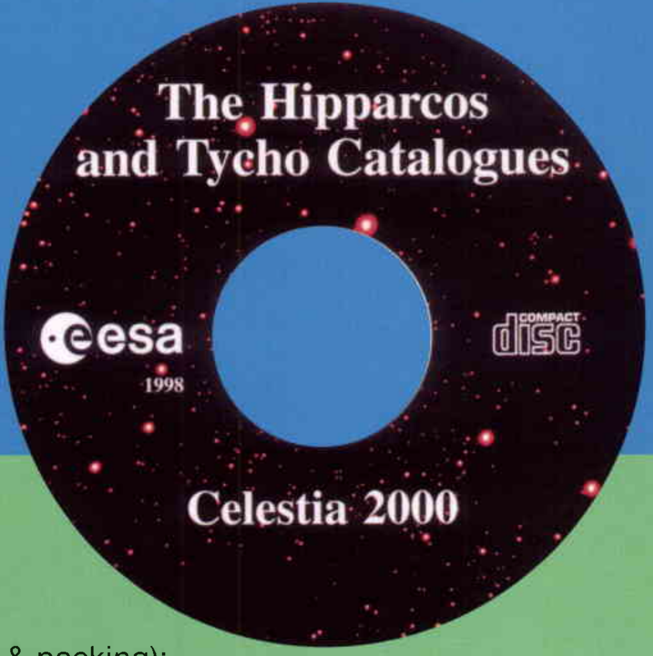
—A subset of the above consisting of Volume 1 (Introduction and Guide to the Data) and the ASCII CD-ROM set.

—Celestia 2000: a CD-ROM package containing the Hipparcos and Tycho Catalogues and annexes along with interrogation software.

Return the Order Form to:

ESA Publications Division
ESTEC
P.O. Box 299
2200 AG Noordwijk
The Netherlands

Fax: + 31 71 565 5433



Order Form

Please reserve for me the following (prices include post & packing):

..... set(s) of the 16-volume printed catalogue (with ASCII CD-ROMs) @ 650 Dfl ($400) per set

..... subset(s) of Introduction & Guide to the Data only, with ASCII CD-ROM set @ 165 Dfl ($100) per set

..... set(s) of Celestia 2000 @ 80Dfl ($50) per set

Name: ....

Address: ....

....

Signature: Date:

An invoice will be sent and on receipt of payment your requested product(s) will be delivered to the address filled in above.

Towards a Common Check-out and Control System for Rosetta

P. Ferri & E.M. Soerensen
Mission Operations Department, ESA Directorate for Technical and Operational Support, ESOC, Darmstadt, Germany

M. Nesbit & J. Noyes
Scientific Projects Department, ESA Directorate for Scientific Programmes, ESTEC, Noordwijk, The Netherlands

Definition of the Rosetta ground segment began in 1996 and it soon became clear that a common checkout and mission-control system would be very beneficial for the mission. The chosen approach for achieving this goal was to develop building blocks for the Central Checkout System that can be re-utilised later in the development of the Flight Control System. The Rosetta prime contractor and AIV contractor fully endorsed this approach and the complete system is currently under development. The first delivery of the database system should take place in November 1998, followed by that of the first Central Checkout System in 1999.

Introduction

The International Rosetta mission will be launched in 2003. After journeying through space for almost 10 years, the spacecraft will approach comet P-Wirtanen and orbit it for about one and a half years, performing scientific investigations of the cometary environment from just a few kilometres above the nucleus' surface. Rosetta will also release a probe that will land on the surface of the nucleus to make in-situ investigations.

During its long journey to the comet, the spacecraft will spend most of its time in semi-hibernation (low activity status), although periodic check-outs of the functioning of all subsystems and the payload will be carried out. The application software and the on-ground and on-board control procedures required for the scientific phase around the comet will not be fully developed and tested before launch, since the long duration of the mission would probably make them obsolete before they are first used. Consequently, Rosetta's on-board data-handling system must be developed as an open system to allow those procedures to be up-linked to the spacecraft at a later date, after their final testing and validation on the ground. This means that the check-out phase, which for a normal spacecraft is completed before launch, will continue well into the mission for Rosetta.

The computer systems and the software used for the check-out phase and for the mission operations phase are normally developed separately and used by different groups of engineers and technicians. On the other hand, many of the functions they are required to perform are identical and a common core system can in principle be defined that can be used in both environments. The less distinct border between check-out and flight operations for the Rosetta mission make it particularly suitable for a first attempt to integrate these two activities, starting with the development of common systems and support tools.

The ESOC Mission Operations Department, together with the Rosetta Project Office at ESTEC, has defined an approach that takes into account the development schedule for this mission and in particular the fixed launch date of January 2003. The concept chosen leads to the development of building blocks for the Central Checkout System that can be re-utilised later in the development of the Flight Control System. This common core, known as the Rosetta Common Checkout and Control System (RCCCS), will form the basis for this new approach, which will be followed by other ESA science missions in the future.

Spacecraft checkout and mission operations

The activities associated with the Assembly, Integration and Validation (AIV) programme for the space segment of a major ESA mission like Rosetta typically start about two to three years before launch. During this phase, the different parts of the spacecraft are put together to form first the subsystems and payload instruments, and then the spacecraft itself. The process is validated at all levels through a series of check-out and test activities, which permeate the assembly and integration work throughout, culminating with the system-level validation tests, which also involve the ground segment. Finally, the spacecraft is shipped to the launch site, where the last preparatory activities for the flight take place and confidence and final validation tests are carried out.

The equipment used to support this long and crucial phase in the mission's preparation can be described as a set of mechanical and electrical support equipment that is mostly spacecraft-specific. The Electrical Ground Support Equipment (EGSE) includes Special Check-Out Equipment (SCOE) to, for example, provide signals to the optical sensors of the spacecraft's attitude control subsystem so as to simulate the real conditions they will encounter in space. Other SCOE provides electrical power to the spacecraft, simulating the outputs of the solar arrays and batteries, or allows the measurement of electrical signals from selected power or data lines on the spacecraft.

The core of the EGSE is the Central Checkout System (CCS), a computer system that controls all of the activities of the other EGSE equipment. It enables one to construct and send telecommands to the spacecraft and receive and interpret telemetry data from it, via a special interface that utilises either a direct-video or a radio-frequency link. The CCS can be operated manually by an operator who can type an instruction via a command-line interface and visualise the status of the spacecraft or of the EGSE equipment on a display. Owing to the importance of repeatability of the test activities, however, the normal mode of operation for the CCS is via a pre-defined list of control instructions and telecommands, called the 'test script' or 'control file', which can be executed automatically by the CCS. The system also has facilities to identify potentially dangerous situations and signal them to the test operator via alarm messages or by automatically interrupting the test sequence and taking measures to put the spacecraft and the equipment into a safe configuration. The CCS archives all data collected during the entire AIV phase, and these data can be accessed on-line or retrieved later for investigation purposes by the AIV team, or even remotely by the subsystems and payload developers and by the scientific community.

The operations phase of a mission starts shortly after separation of the spacecraft from the launcher, typically 20 to 30 minutes after lift-off. The equipment necessary to support this phase is partially located in the ground stations around the World, with the task of maintaining the radio-frequency (RF) link with the spacecraft. Remaining parts are vested in the Operations Control Centre (OCC), in charge of the monitoring and control of all the spacecraft and ground-segment functions.

The core of the OCC is the Flight Control System (FCS), a computer system and its software that interfaces with the ground stations to receive telemetry and tracking data from the spacecraft, and to transmit telecommands to it. The FCS monitors the incoming telemetry and raises alarms to an operator, the spacecraft controller. It handles manual real-time and time-tagged commanding, as well as background commanding in the form of automatic command queues. Mission operations are normally scheduled by combining inputs from the users (for a science mission typically collected by a Science Operations Centre) and from the operations team into a schedule of telecommands, which is periodically sent to the spacecraft. The FCS can also generate schedules for the simultaneous operation of the relevant ground stations. All data received are archived for on-line and offline retrieval and analysis by the operations team, or remotely by the scientific community.

As can be seen from the above, many of the activities carried out in the AIV phase are identical to those of the mission-operations phase, but the objectives and context are different:
- The AIV objectives are to test the behaviour and performance of the spacecraft and its components and to prove that the required functionality and performance are according to specification. The mission-operations objectives are to maximise the mission's return in terms of quality and quantity of the products during the spacecraft's in-orbit lifetime.
- The AIV context is the ground testing of all spacecraft modes (both prime and backup), in some cases deliberately causing anomalies, with a quick access/recovery capability together with interruptible operation periods. Corrective maintenance is also possible without the need for operating other functions. The mission-operations context is a spacecraft in orbit with limited and less-reliable access. Operations and corrective maintenance are more complex.

Due to the above differences, there have traditionally been differences in the computer systems used in the two areas, particularly where system functionality is concerned. For a mission-control system, the emphasis is on safety, reliability, maximisation of productivity and minimisation of risk. For AIV, the emphasis is on test repeatability, and thus the automation of test sequences.

CCS and FCS commonality
Despite the different objectives and contexts for checkout and mission operations, they have major functions in common. As pointed out above, during most of its life cycle a space project requires facilities that allow monitoring and control of the spacecraft's functions. A single system could in principle be used for the following phases of that life cycle:
- integration and testing of the subsystems at system level
- integration and testing of the payload at system level
- testing of the fully integrated spacecraft as a complete mission system
- launch pad operations, and
- mission operations.

In all of these phases it is necessary to monitor and control the activities throughout the cycle of assembling, integrating, testing, and operating. When assembling, integrating, and testing a subsystem, for example, there is a user, the subsystem tester, controlling subsystem activities through signals and/or commands and monitoring subsystem activities by interpreting signals and/or telemetry. For subsystems with computing capabilities, the tester may be loading software, tables of parameters, procedures (sequences of commands) and commands to invoke software programs and procedures. The subsystem may report health status and performance summaries via telemetry. The subsystem may also perform some level of self-calibration and diagnostics and report the results to the tester.

Integration of the spacecraft and its payload onto a launch vehicle is conducted at the launch site. During this phase, both the launcher and the spacecraft/payload continue to be tested as systems, and the combined launcher and spacecraft/payload takes part in a countdown rehearsal. Spacecraft/payload test activities are monitored and controlled by testers at the launch site and the mission control and operations centre. The monitoring and control techniques used in this phase are similar to those used in the spacecraft integration and test phase.

Finally, mission operations begin after the spacecraft has separated from the launch vehicle. The mission operations centre monitors and controls both the spacecraft and the ground stations used to track and

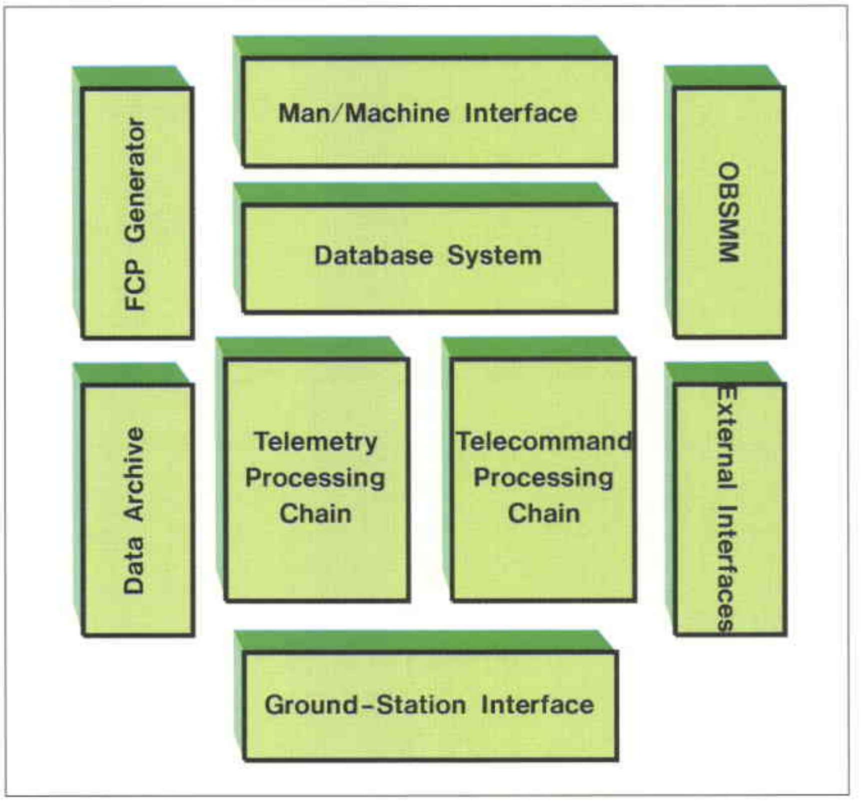
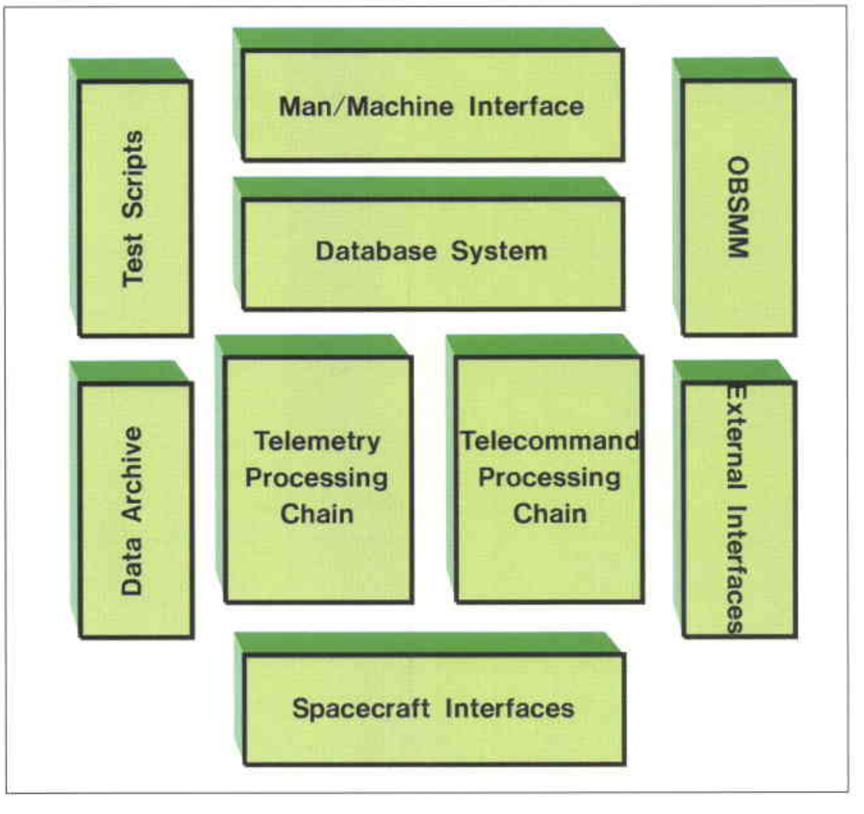


Figure 1. Functional building blocks for a generic Flight Control System (FCS)

Figure 2. Functional building blocks for a generic Central Check-out System (CCS)



communicate with it. The monitoring and control techniques used in this phase may include all of those used in the previous phases.

Identification of the FCS and CCS components can be defined as 'common' is based on the functional breakdowns of the two systems, shown in Figures 1 and 2, respectively. These building blocks are briefly described and compared in Table 1, which shows that there is indeed a large degree of commonality.

Figure 3 shows the functionality for a common checkout and mission control system that provides a central core of identical functional blocks for both the CCS and FCS. This type of exercise also highlights functional blocks

Table 1. Description of functional building blocks for an FCS and a CCS

Flight Control System (FCS)	**Central Checkout System (CCS)**
Man/Machine Interfaces Provides the operator with interfaces to the monitoring and control system, including the database system.	*Man/Machine Interfaces* Function identical to the one described for the FCS.
Database System Allows the definition and handling of all the mission parameters required to drive the control system.	*Database System* Identical to the one described for the FCS.
Telemetry Processing Chain Performs the processing of the data received from the spacecraft and the ground systems, including parameter extraction, interpretation.	*Telemetry Processing Chain* Identical to the one described for the FCS.
Telecommand Processing Chain Constructs and sends the telecommands to the spacecraft and the instructions to the ground equipment. It also interfaces with the telemetry function to verify correct execution.	*Telecommand Processing Chain* Identical to the one described for the FCS.
Ground Station Interfaces Handles the interfaces to the ground stations for transfer of telemetry, telecommand, tracking and station control data.	*Spacecraft Interfaces* Allows the CCE to interface directly with the spacecraft.
External Interfaces Handles the interfaces to mission-operations-specific functional blocks such as the Flight Dynamics System, the Mission Planning System, and the Science Operations Centres.	*External Interfaces* Handles the interfaces to the special checkout equipment and the payload checkout systems.
Flight Operations Procedures Generator Produces all the procedures and timelines necessary to carry out the flight operations.	*Test Scripts Generator* Produces the computerised procedures used to automatically drive the test sessions.
Data Archiving Supports the long-term archiving and the on-line and off-line (retrieval) data distribution to a variety of external users of the FCS, in particular to the scientific community, industry and project engineers.	*Data Archiving* Supports the long-term archiving and on-line and off-line (retrieval) data distribution to a variety of external users of the CCE, in particular to the payload instrument test equipment and to industry and project engineers.
On-Board Software Maintenance Management Used to maintain the on-board software via telecommands during flight.	*On-Board Software Maintenance Management* Used to maintain the on-board software during AIV via telecommands or direct access to the spacecraft.

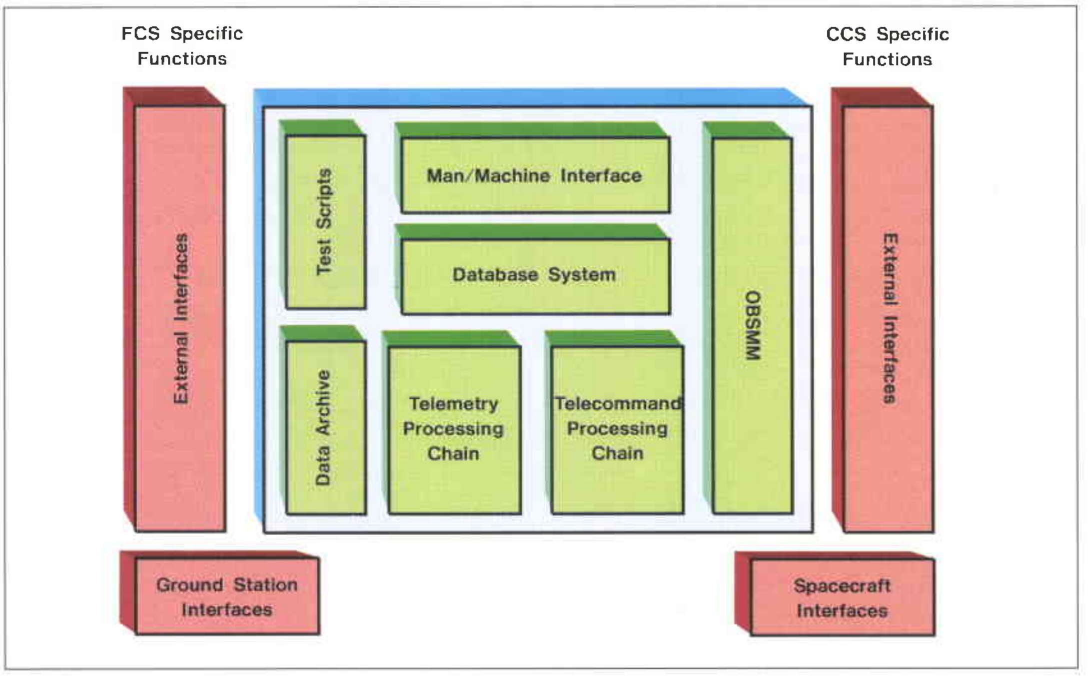


Figure 3. Implementation concept for a generic Central Check-out and Control System (CCCS)

specific to the CCS environment (e.g. direct interfaces to the spacecraft, SCOE functions) or the FCS environment (e.g. flight dynamics, mission planning, ground-station interfaces). Nevertheless, a Common Check-out and Control System can be defined reasonably easily if the interfaces to the environment-specific blocks are separately defined and linked to the central core in the same way.

The Rosetta approach

In general, then, all major elements of a CCS and FCS could be shared, but the implementation of a fully common system calls for a completely new development effort, due to the deeply-embedded differences in the systems currently available for checkout and mission operations. To avoid introducing unnecessary risk with respect to cost and schedule, the Rosetta project has elected to choose only a subset of the theoretically common functional blocks for system development. The selection was based on a trade-off of the need for new developments against the savings in effort on the users' side, the type and number of interfaces to other elements, and the schedule and cost impacts. Blocks that anyway needed mission-specific development have of course been included. The result is shown in Figure 4, where the

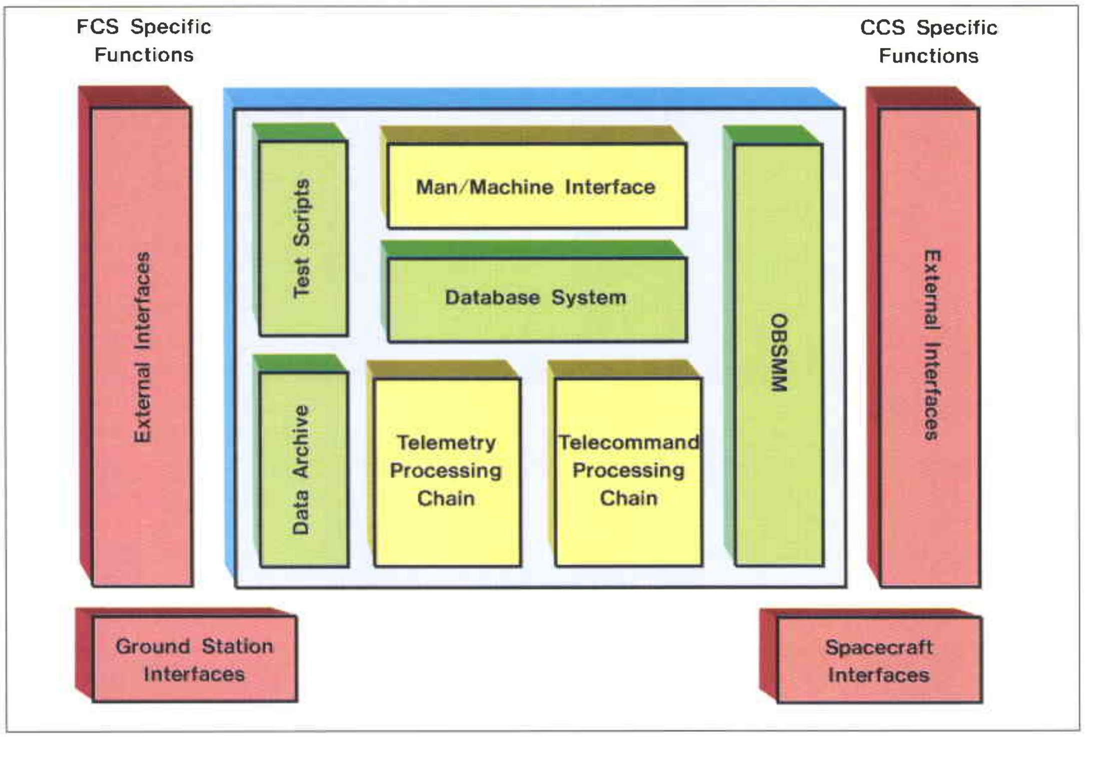


Figure 4. Implementation approach for the Rosetta Common Check-out and Control System (RCCCS)

colour coding indicates the amount of commonality achieved. Green means the block will be developed as fully common between the two systems ('plug and play' systems); yellow means that the FCS block will be developed separately, but will re-use software modules from the corresponding CCE block whenever practical ('pick and choose' systems); and orange indicates that different blocks will be developed for the two systems.

This low-risk approach is expected to require more effort when reviewing the design specifications, but cost savings are expected in the overall development of the common functional blocks. Additional benefits are also expected in other areas of the overall mission-preparation activities, such as preparation and validation of the mission database and flight operations procedures, which are normally extremely labour-intensive activities.

The first utilisation of the RCCCS will be for Rosetta integration and testing activities, followed by the preparation of the mission control scenario. Some of the FCS-specific functions, in particular those related to Rosetta's near-comet activities, will only be needed long after launch.

Table 2. Implementation schedule for the RCCCS

Year	Phase	Objective
1998/1999	CCS and common elements of the FCS developed	CCS and common FCS elements development phase monitored by ESTEC, ESOC and contractors. Identification of further common packages of code during the review cycles
Mid-1999	EQM AIV preparation starts with database contents definition	Database system available for population. ESTEC and ESOC review contents
3rd quarter 1999	EQM AIV preparation continues with OBCP definition and preparation	OBCP definition and preparation system available for system level AIV on EQM
Beginning 2000	EQM AIV starts	
Mid-2000	Mission operations preparation	Use of FCS starts with acceptance testing of first delivery, followed by spacecraft-related tests (Listen-In Tests, System Validation Tests) and mission simulations
3rd quarter 1999	Flight-model AIV starts	
Jan. 2003	Rosetta launch	
2005	Asteroid fly-by	FCS modules for optical navigation are required
2009	Near-comet operations preparation	FCS modules for mission planning are required
2012/2013	Near-comet operations	
Mid-2013	Comet perihelion passage	Rosetta end-of-mission

Major milestones have already been completed with the definition of the high-level functional requirements, the contract award for the development of the CCS part, and the definition of the detailed requirements for two of the common functional blocks, namely the Database System and the Data Archive. Table 2 indicates the remaining milestones until the end of the mission.

Future applications

The main drivers for the approach adopted to a common check-out and mission control system for Rosetta are the nature of the mission itself and development constraints in terms of schedule and the re-use of existing systems. The same approach has already been selected for another major ESA science mission, First/Planck. As this mission is due to be launched a few years after Rosetta, it can build on the Rosetta approach and take advantage of the experience gained therein. The possibilities for re-using tools and modules already developed for Rosetta will also be examined. It is also expected that First/Planck will have more fully common CCS and FCS blocks, cost and schedule constraints permitting. It can also take maximum advantage of new technologies, thereby providing a further substantial step towards a European infrastructure for common checkout and control systems.

Other possible candidates for the utilisation of this approach, and eventually of the tools being developed, will be the scientific missions in the 'Smart' and 'Flexi' series. The short development schedules and tight budgetary constraints for these missions make them ideal candidates for the exploitation of the CCS/FCS commonality concept, particularly if it has already been proven by other major scientific missions.

The Space Station Cooperation Framework

A. Farand
Legal Affairs, ESA, Paris

International cooperation on Space Station started as a result of an invitation to friends and allies of the United States, formulated in January 1984 by President Ronald Reagan, to participate in the development and use of a permanently manned Space Station. This cooperation was formalised by the signing of a first series of international agreements on 29 September 1988. The cooperative framework established by those agreements required major restructuring because of a significant redesign of the US Space Station programme ordered by President Bill Clinton on his arrival at the White House at the beginning of 1993, and the subsequent invitation made to Russia by the original Partners to become a major player in the project.

Introduction

On 29 January 1998 in Washington, the representatives of fifteen States - the United States, Russia, Japan, Canada and eleven ESA Member States - signed an Inter-Governmental Agreement (referred to as the IGA) concerning cooperation on the civil International Space Station. This Agreement not only formalised Russia's integration into the partnership, but also confirmed major changes in the Partners' contributions and a dramatic evolution of the rules put in place for this cooperation. On the same occasion, the head of NASA and the heads of the Russian Space Agency (RSA), ESA and the Canadian Space Agency signed Memoranda of Understanding (MOUs) containing detailed provisions for the implementation of Space Station cooperation.

Whilst it was originally envisaged that a fourth similarly worded MOU with the Japanese cooperating Agency would be signed only after ratification of the new IGA by the Japanese Diete, NASA and the Japanese Government, representing a series of Japanese agencies charged with different aspects of the cooperation, changed their approach and signed their MOU on 24 February 1998, thus enabling the Diete to examine this MOU together with the IGA.

The signature ceremony of 29 January 1998, which was the result of more than four years of hard-pressed bilateral and multilateral negotiations, could be characterised as a major milestone in the international partnership. In addition to a fairly broad legal regime developed in the IGA itself for the conduct of Space Station cooperation, very innovative rules have been drafted to govern such things as the development and utilisation of the Space Station, and the management and financing of the Partners' programmes and of the international programme made up by the Partners' combined contributions.

The Space Station Agreements

The most important influence in the shaping of all aspects of Space Station cooperation is the strong leading role of the United States in the programme from the outset. The Space Station started out as a US programme to be executed by NASA at the end of the 1970s. It acquired an international dimension for the first time with the conclusion in 1985 of three MOUs for the conducting of parallel detailed definition and preliminary design studies on the Space Station. These MOUs, dealing with what are commonly referred to as 'Phase-B' activities, were concluded between NASA and ESA, NASA and the Japanese Government, and NASA and the Canadian Ministry of State for Science and Technology (MOSST).

One year later, negotiations started on the legal framework that would apply for the full development (Phase-C/D) and exploitation (Phase-E, combining operation and utilisation) of the Space Station. Because of the expected 30-year duration (later revised to 15 years) of this project and the corresponding multi-billion-dollar envelope, it was decided not to limit the legal instruments to Agency-level MOUs, but to involve those States wishing to participate in such a project through the conclusion of an international agreement - the Space Station Inter-Governmental Agreement (IGA) - setting out the general principles for carrying out this cooperation, including those governing the parties' conduct in outer space. The IGA establishes 'a long-term international co-operative framework among the Partners, on the basis of genuine partnership, for the detailed design, development, operation, and utilisation of a permanently inhabited civil International Space Station for peaceful purposes, in accordance with international law'. The IGA makes a distinction between Partner States and Partners that is quite innovative in terms of international law, and which is of particular importance for Europe: there were twelve original Partner States, but they represented only four Partners in the project, the nine (now eleven) European States being grouped, for the purposes of conducting this cooperation, under the umbrella designation of the 'European Partner'.

An Arrangement for the application of the IGA pending its entry into force was also signed on 29 September 1988 (and again on 29 January 1998) by the IGA signatories. The text of the Arrangement merely expressed the intention of the States concerned to abide by the applicable provisions of the IGA until the time of its entry into force, provided that such provisions were compatible with their domestic legal systems. In practical terms, this Arrangement would almost exclusively concern the application of provisions pertaining to liability, the exchange of data and goods, the issuance of appropriate documentation to liaison personnel, and customs matters, i.e. those matters that could be implemented on Earth.

In September 1993, shortly after the conclusion of the redesign process that confirmed the passage from the original Space Station 'Freedom' to a slimmer Space Station 'Alpha', the United States decided to involve Russia in the programme. This decision was taken for a number of reasons, ranging from the desire to benefit from Russia's wealth of experience in human space flight to foreign-policy objectives. Since the IGA and the MOUs do not contain specific clauses that would allow an expansion of the partnership through a simple accession of new States to the Space Station Agreements, there was a need for the Partners to agree on an acceptable procedure to provide for the inclusion of Russia in the partnership. The absence of an accession clause from which States other than Partner States (i.e. signatories of the IGA) could benefit is easily explainable, since Space Station cooperation is a closed partnership in which each Partner's contribution has to be integrated coherently into the Space Station itself. After consultations among the Parties to the IGA, the Partners invited Russia on 6 December 1993 to join the partnership and initiate negotiations within the framework established by the Space Station Agreements. Russia accepted the invitation on 17 December 1993 and negotiations started in April 1994

Figure 1. The International Space Station (artist's impression by D. Ducros)

after the Partners and Russia had discussed a number of basic rules for facilitating the conduct of these negotiations.

It should be stressed that Article 26 of the 1988 IGA provided that 'this Agreement may be amended by written agreement of the Partner States for which this Agreement has entered into force'. This would have limited the negotiations for amending the IGA to the United States and Japan, since the 1988 IGA was in force for those two Partner States only. For obvious reasons, this limitation imposed by Article 26 did not prevent the start of negotiations between the four original Partners and Russia, in April 1994, and it took a dozen one-week rounds of negotiations over a period of two and a half years to reach an understanding among all the interested Parties on the text of a new IGA. The negotiations started on the basis that the 1988 IGA should be amended through a Protocol, adopting a minimalist approach under which only those changes strictly necessary to accommodate Russia's arrival in the partnership would be made, so as to ensure a certain continuity in the legal instruments. However, halfway through the negotiations, in view of the scope of the amendments being considered, the negotiating teams recommended that the original IGA be replaced by a new one, the Protocol route being judged impracticable.

From mid-1994 to mid-1997, NASA and the RSA also drew up an MOU, similar in structure to those concluded by the other Cooperating Agencies in 1988, which were amended in parallel to take into account all of the new characteristics of the programme. Although the original concept of an integrated Space Station has been preserved in this negotiation process, many features of the cooperation have been modified, generally for the sake of underlining the genuine partnership concept, or have evolved considerably from what was envisaged at the outset.

The original Partners could justify their acceptance of a number of IGA and MOU provisions confirming the lead role of the United States in the international programme not only because of the overwhelming importance of its contribution to the programme, but mainly because of the need to provide for a clear line of command and control in this endeavour. Throughout the negotiation process, on the strength of its long experience of long-duration human space flight, Russia pressed for recognition in the Space Station Agreements of a role that would reflect both the qualitative and quantitative importance of its contributions to the programme. In the re-negotiation of the IGA, this overarching Russian requirement was a factor as important as the US leadership had been during the original IGA negotiations of 1986-1988 in establishing a particular balance between the Partners, this being accomplished without prejudice to the genuine partnership concept. As a result of the most recent negotiations, the lead role of the United States, and almost all of its original responsibilities in the programme's overall management and coordination, have been confirmed in the IGA. However, a large number of changes were made to reflect the new technical reality brought about primarily by Russia's contributions, but also by Europe's redesign of its original contributions to the project and its insistence that specific activities, including the periodical correction of the orbit of the Station using the ESA-developed Automated Transfer Vehicle (ATV) in conjunction with Ariane-5, be recognised.

The new IGA is still consistent with the closed partnership approach. Any expansion of the partnership to include new Partner States, or any significant evolution of the international programme to involve the Partners in new missions, will require fresh negotiations among the Partners, a process that has proved to be time-consuming in the past.

The multilateral Inter-Governmental Agreement

Because of its lead role in the project, the United States decided that the State-level commitments related to Space Station cooperation had to be registered through a series of bilateral instruments to which it would be a party. It was only halfway into the original IGA negotiations, in the summer of 1987, that the United States agreed with the other States involved in the negotiations that the IGA should be a multilateral instrument.

Furthermore, in view of the relative urgency of the matter dictated by programmatic imperatives, the US negotiators also decided that the IGA would be an 'Executive Agreement' which, under US constitutional practice, does not require ratification by the Senate (the IGA still requiring each Partner State to deposit its instruments of ratification), thus being a more expeditious process. Following the Executive Agreement route should not in itself affect the nature of the commitment made by the US Government to the other Parties to the IGA. This IGA still generated rights and obligations for its signatories under international law, as would any other type of international agreement. However, this course of action somewhat limited the room for manoeuvre available to the US negotiators, as they had to make sure that commitments entered into through the IGA were always consistent with the relevant provisions of US law, or that there was a possibility for the United States to apply its law when discharging a number of its obligations. In other words, the US negotiators were not in a position to agree with language that would require changes to US laws. The requirement spelt out in Article 15 of the IGA that financial obligations are subject to a Partner's funding procedures and the availability of appropriated funds, which is a rarity in international law, was also imposed as a result of the application of US laws making such a requirement mandatory in certain circumstances. Because of the need to exercise caution in the drafting of the IGA, one would assume that the IGA would also be consistent with the current applicable laws and regulations of all the Partner States. However, this may not always be the case and this makes it worthwhile to look briefly into the matter of ratification.

Ratification of the IGA

The 1988 IGA provided that the Agreement would enter into force following its ratification by the United States and another Partner. Japan was the first Partner to deposit its instrument of ratification, in 1989, and the IGA entered into force in January 1992 upon ratification by the United States. Although seven European Partner States ratified the IGA between 1989 and 1992, the Agreement never entered into force for the European Partner as a whole - nor for the European States individually for that matter - because the specific condition expressed in the IGA for this purpose (that the aggregate of the contributions of the States having ratified should represent 80% of the ESA Columbus Programme's financial envelope) was never fulfilled. Canada did not deposit its instrument of ratification of the 1988 IGA essentially because of delays encountered in the preparation and presentation to Parliament of the required legislation. With the new Agreement signed on 29 January 1998, the ratification process has to be restarted on the basis of new conditions: this IGA will enter into force once the instruments of ratification of the United States, Russia and Japan are deposited, at which time it will replace the 1988 IGA. Thereafter, the IGA will enter into force for the European Partner as a whole after its ratification by four European Partner States and following receipt by the Depository of a formal notification to this effect by the Chairman of the ESA Council.

Before depositing its instrument of ratification, a State must follow an internal procedure, as dictated by its own constitutional practice, to make sure that the international obligations outlined in the Agreement are transposed into domestic law, or at least are not incompatible with domestic law. For example, Germany has incorporated the whole text of the 1988 IGA into its national laws and, as a consequence, any provision in existing German laws that was not compatible with the IGA would be deemed inapplicable for the purpose of Space Station cooperation. At the other extreme, the United Kingdom deposited its instrument of ratification without any prior regulatory or legislative action. It was envisaged that the Department of Industry would be responsible for drafting the necessary amendments to existing laws and regulations before the European pressurised laboratory was launched. These amendments will not be all encompassing, but will target only those provisions that are incompatible with Space Station cooperation.

The Memoranda of Understanding

As a second layer of international instruments, four bilateral MOUs concluded between NASA and the Cooperating Agencies of the European Partner and Canada respectively, on 29 January 1998, and NASA and the Japanese Government on 24 February 1998 will enter into force only after the Parties notify each other that their internal procedures required for this purpose have been completed. The four new MOUs concern the detailed design, development and operation of a manned civil Space Station. An MOU is generally not considered to be an agreement generating rights and obligations in international law for its signatories, although this does not exclude the possibility of remedies provided for under a Partner State's legal system being applicable on the basis of such an MOU if, for example, a party to it failed to discharge its obligations appropriately. The MOU is considered to be a type of arrangement that registers a political and moral commitment on the part of an international organisation, a Government, or a constituent part of the latter, to conduct itself in a certain way. Because of their close links with the IGA, it would appear that the Space Station MOUs will have acquired the status of international agreements, as an exception to the general practice in this field.

It is interesting to note that the multilateral bodies to be established for the management of the Space Station, such as the Multilateral Coordination Board (MCB), the top-level body in charge of coordinating the activities of all Cooperating Agencies related to the Station's operation and utilisation, are provided for in the MOUs, which are bilateral instruments between NASA and each of the other Cooperating Agencies. The pattern of cooperation put in place through the MOUs has been referred to as the 'hub and spoke' approach, similar to the pattern adopted for air transport in a number of countries. In this particular instance, NASA is the hub and all of the other cooperating agencies are 'spokes': the consequence of such a pattern is, for example, that a commitment made in a given MOU by a Cooperating Agency in favour of others has to be reflected in the other relevant MOUs, with this commitment 'transiting', so to speak, through NASA, which is party to all of the MOUs.

Mention should be made of the third layer of international instruments represented by the 'implementing arrangements' referred to in Article 4 of the IGA. These arrangements are subject to the MOUs and thus NASA should always be a party to an implementing arrangement. The IGA and the four recently-signed MOUs contain numerous provisions calling for the conclusion of implementing arrangements, and in that sense the IGA and MOUs constitute only the tip of the iceberg of the legal instruments that need to be put in place by the Partner States and the Cooperating Agencies. Article 4.2 of the IGA which establishes this hierarchy between Space Station Agreements (IGA, MOUs and implementing arrangements) is silent on the other arrangements and agreements that can be concluded among Partners for the purpose of furthering Space Station cooperation. One example of other agreements is the MOU concluded in 1990 (and amended in 1997) between NASA and the Italian Space Agency (ASI) for the development by ASI of the Mini Pressurised Logistics Module (MPLM), which under the MOU is a NASA-provided element to the Space Station. Another example of an arrangement not provided for in Article 4.2 of the 1988 IGA, which is related to Russia's arrival in the partnership as described below, is an arrangement signed in 1996 between ESA and the RSA for the delivery by ESA of a European Robotic Arm (ERA) to be used on the Russian segment of the Space Station.

Legal regime governing Space Station cooperation

A number of Articles in the IGA have been designated as constituting the legal regime of the cooperation. The IGA and the other instruments signed on 29 January 1998 establish the basic rules for operation of the 'genuine partnership' and provide a list of each Partner's contributions.The IGA states that this cooperation should be carried out in accordance with international law, a reference encompassing not only the rules elaborated in the various conventions listed in the IGA preamble, but also the rules generated by all other recognised sources of international law.

It should be stressed that the drafters of the IGA have not outlined a set of homogeneous rules that would apply only in or on the Space Station, but rather, in dealing with a number of specific legal issues, they have tried to establish

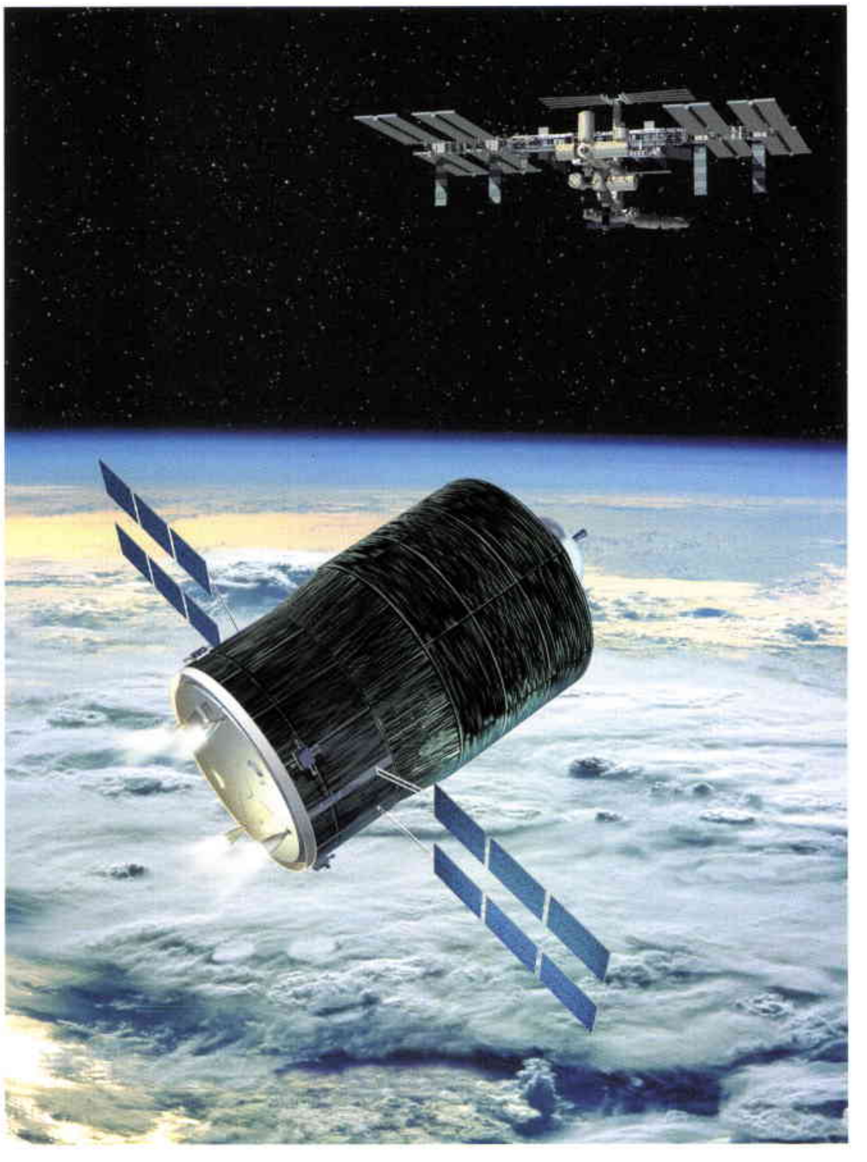


Figure 2. The Automated Transfer Vehicle (ATV) (artist's impression by D. Ducros)

the necessary links between: (a) the different parts of the Station, these being the flight elements provided by each of the Partners, and the personnel, and (b) the jurisdiction exercised by the Partners on their own territory. In other words, the set of rules constituting the legal regime is aimed generally at recognising the jurisdiction of the Partner States' courts and consequently allowing for the application of substantive national law in such areas as criminal matters, civil matters, including liability issues, and administrative matters, which cover among other things the protection of intellectual property rights and the exchange of data and goods. It goes without saying that such an approach may generate conflicts of jurisdiction in particular instances, but the IGA's drafters were confident that they would be resolved through the application of existing rules and procedures developed for other types of human activity.

At the heart of the legal regime set up for Space Station cooperation, Article-5 establishes that 'each Partner shall retain jurisdiction and control over the elements it registers in accordance with paragraph 1 above and over personnel in or on the Space Station who are its nationals'. It was essential for the drafters of the IGA to establish such a basis for jurisdiction because a number of States participating in this project which adopt a very restrictive attitude to the extraterritorial application of their laws, notably Canada, needed to invoke the specific provisions of an international agreement to justify the extension of their national jurisdiction to the flight elements they would be providing. At the other end of the spectrum, the United States felt that this jurisdictional basis would be needed in order to make room for certain exceptions - those resulting from negotiations with the other Partner States - to the blanket application of United States' jurisdiction over the Space Station.

A potential problem raised by the current wording of Article 5, for which no solution is being offered at this point, but which is likely to be considered further by the Partners concerned through appropriate legal means if and when it materialises, is the exercising of jurisdiction over personnel provided by one of the Partners who are not nationals of the corresponding Partner State or who are nationals of more than one Partner. Also relevant in this context is the distinction between members of the Space Station crew complement and other astronauts visiting the Station for a limited time, for example in a capsule docked with the Station during a crew rotation, when they will be subject to the exercise of jurisdiction provided for in Article 5. Past experience suggests that these visitors will quite often not be nationals of the Partner States that send them to the Space Station.

The utilisation of the Space Station

The basic principles for utilisation of the Station are laid down in Article 9.1 of the IGA:

'Utilisation rights are derived from Partner provision of user elements, infrastructure elements, or both. Any Partner that provides a Space Station user element shall retain use of those elements, except as otherwise provided for in this paragraph. Partners which provide resources to operate and use the Space Station, which are derived from their Space Station infrastructure elements, shall receive in exchange a fixed share of the use of certain user elements'.

The share of the use of user accommodations, such as pressurised laboratories, to be retained by the Partner providing these accommodations is expressed in fixed percentages in the MOUs. To be more precise, ESA will retain 51% of the user accommodations on its European pressurised laboratory, and Japan's Cooperating Agency will retain the use of 51% of the user accommodations on its Japanese Experiments Module (JEM). The remaining 49% shares of user accommodation in the COF and the JEM are attributed to those Partners providing infrastructure resources to ESA and Japan's Cooperating Agency (referred to in the MOUs as 'the GOJ'), essentially NASA but also CSA which is providing the Remote Manipulator System (RMS) as an infrastructure element.

A second step in the understanding of the principles applicable to the Station's utilisation is an examination of the approach taken in the allocation of Space Station resources. Firstly, an agreement has been reached between the original Partners and Russia based on the premise that Russia on the one hand and the other Partners on the other retain utilisation of their own contributions to the Station, and seek to offset only those items that cross the interface. This, of course, has many implications with regard to the sharing of Station resources and the treatment of common operations costs involving exchanges between the Russian segment and the Alpha segment composed of elements provided by the other four Partners. The Partners have nevertheless laid strong emphasis on the need for the closest possible adherence to the philosophy of an integrated International Space Station and the rules underpinning that philosophy in the Space Station Agreements.

By way of illustration, it was decided that for the purposes of sharing utilisation the Russian Partner would keep 100% of utilisation of its own modules, thereby recognising that the infrastructure element supplied to the Station by Russia for its own benefit and that of the other Partners would enable it to accumulate up to 100% of the utilisation rights in its own modules. This calculation has the advantage of avoiding a debate on the relative value of the utilisation and infrastructure elements supplied by Russia as a portion of the Space Station as a whole. This means that the percentage agreed, on the basis of 100% within the Alpha segment, between the founding Partners could be retained for the purpose of sharing available resources. The MOUs will provide for the precise percentage of resources to be allocated to each Cooperating Agency: for example, ESA's share has been fixed at 8.3% of the resources available for sharing on board the Alpha segment.

Establishing a direct link between the allocation of resources and the financial responsibilities of the Cooperating Agencies, Article 9.3(a) of the ESA/NASA MOU provides that:

'NASA, ESA and the other Partners will equitably share responsibilities for the common system operations costs or activities, that is the costs or activities attributed to the operation of the Space Station as a whole.... RSA will be responsible for the share of the common system operations costs or activities corresponding to the operation of the elements it provides. NASA, ESA, the GOJ and CSA collectively will be responsible for the share of common system operations costs or activities corresponding to the support of the operation of elements they collectively provide using the following approach: each will be responsible for a percentage of common system operations costs or activities equal to the percentage of Space Station utilisation resources allocated to it ...'

In addition to the above-mentioned common system operations cost responsibilities, each Partner will also be financially responsible for costs or activities attributed to operating and sustaining the functional performance of the flight and ground elements it provides and the use of its user accommodations. To give an idea of the magnitude of the costs to be borne by each Partner, it should be recalled that ESA estimated at the end of 1995, on the understanding that such an estimate would not prejudge the actual amount to be spent, that the total exploitation costs over a period of 10.5 years would be of the same order of magnitude as the total development costs of its contributions, three quarters of that sum being devoted to discharging common system operations responsibilities. This explains the efforts put by the European Partner into persuading its Partners of the need to lay down transparent financial rules for the cooperation.

On the question of crews, an understanding has been reached whereby the crew complement for the Station as a whole would be raised to seven at the beginning of the exploitation phase, which would require the development by NASA of a rescue vehicle (ACRV) able to accommodate four people, in addition to the Russian Soyuz capability for returning three people to Earth. Of the seven crew members, Russia would be able to claim three to carry out all maintenance and utilisation operations required in and on the Russian segment, while the other Partners would share the other four places.

Financial rules applicable to the cooperation and their impact on the mixed fleet of launchers

A significant interest of the European Partner in the IGA and MOU negotiation process, which extended from mid-1994 until the end of 1996, was of a financial nature and resulted from directives and guidelines given by the

Figure 3. Lift-off the second Ariane-5 test flight (502)

participants in the ESA Council Meeting at Ministerial Level held in Granada (E) in November 1992. The European Partner therefore proposed to amend Article 15 of the IGA on Funding with a view to formalising two concepts: (a) the offset concept, according to which a Partner would be able to meet its share of the Station's common system operations costs by supplying goods and services produced by itself, and (b) the concept of the 'not-to exceed figure', which would involve the establishment of procedures administered by the management bodies for containing the common system operations costs within predetermined and agreed levels, thus imposing a ceiling on these costs. This would enable a Partner to know the full extent of its commitment sufficiently in advance and to plan its expenditure accordingly.

These two concepts are linked to agreement among all the Partners on the setting-up of a fleet of spacecraft supplied by four of the five Partners to meet all of the Station's transport requirements.This change, which was unavoidable with Russia's arrival in the partnership, represents a significant departure from the situation outlined in the IGA signed in 1988, where the US Space Shuttle was the only space transportation system to be used for the cooperation. With Ariane-5 operating in conjunction with the ATV, the European Partner is in a position to discharge its share of common costs in a worthwhile manner, given that space transportation is going to account for some 80% of the Station's common operations costs. Much of the discussion between the European negotiators and their counterparts has centred on the type of assurance that the European Partner could be given at this stage by the United States and the other Partners to the effect that Ariane-5/ATV, deployed for Station-orbit reboost missions for instance, and other European services would indeed be used to offset the whole of Europe's share of common system operations responsibilities, so that cooperation could be established on the basis of no exchange of funds between the European Partner and its Partners.

Conclusion

The rules established for Space Station cooperation will undoubtedly contribute to a certain emancipation - from a legal standpoint and compared with the current situation in which only the United States and Russia have the technical means and expertise to send a human being into outer space - of the Cooperating Agencies of Europe, Japan and Canada in their manned space activities. This emancipation will have a beneficial impact on all aspects of these activities, such as the selection of their astronauts, their training, their assignment to specific flight crew and missions, and the performance of the missions themselves, all of which is to be done in accordance with criteria, rules and standards that they themselves will set and apply to their own personnel, which should obviously meet or exceed Space Station requirements.

As with almost all aspects of Space Station cooperation, more work lies ahead for the Cooperating Agencies after the signing of the new Space Station Agreements. A reader of the IGA and the MOUs might be surprised at the number and scope of the implementing arrangements that remain to be negotiated, concluded and implemented. The Code of Conduct for the astronauts, which is not technically an implementing arrangement but could be seen as having a legal status somewhat similar to that of the IGA and the MOUs, is the most urgently needed document, and also a very complex one, yet to be developed by the Partners pursuant to Article 11 of the IGA. The first elements of the Space Station are scheduled to be launched mid-1998 and the Code should be in place between NASA and the RKA before a first Space Station crew is sent up at the beginning of 1999.

The development of Space Station rules will be a challenging task for the European Partner States. It calls for an effort of harmonisation between their national laws and regulations applicable to one aspect or another of Space Station cooperation. This effort will doubtless be pursued in parallel with the development of the implementing arrangements. esa

Operations Planning for the International Space Station

R. Leuttgens & J. Volpp
ESA Directorate for Technical and Operational Support, ESOC, Darmstadt, Germany

The planning process for the decade-long operation of the International Space Station (ISS) has to take into account the unique characteristics of this endeavour with its five International Partners: the USA (NASA), Russia (RSA), Japan (NASDA), Canada (CSA) and Europe (ESA). Each Partner is providing at least one space-segment element and will operate it quite independently within an agreed resource envelope. Each Partner, apart from Canada, will also provide an Earth-to-orbit vehicle for Space Station re-supply and logistics operations. The major European contributions are the Columbus Orbital Facility (COF) and the Automated Transfer Vehicle (ATV) launched by Ariane-5.

Introduction

As a consequence of the ISS's long operational lifetime, the mission planning process is being performed in several distinct steps - Strategic, Tactical and Execution Planning - with distinct planning products covering different time intervals ranging from several years to just a few days. It has to take into account lead-time constraints imposed by the launch vehicles and the time scales needed to develop new equipment, which may begin several years before the in-orbit operations are performed although detailed schedules may not be developed until just a few days before the equipment is operated. The relatively high degree of independence of each of the International Partners means that the planning process has a strongly decentralised component which drives the implementation.

ESA's own ISS operations planning activities are performed in two distinctly different modes. During both the Strategic and Tactical Planning process, they are generally subservient to those of the various multilateral teams - cadres of personnel from each of the International Partners - who develop high-level annual and increment details and plans from information supplied by the Partners. During the Increment Planning (also referred to as Execution Planning) process and the Operations Evaluation process, however, ESA's activities are far more independent and result in the development of ESA-specific plans and products, though the multilateral teams still control the way in which some of them are developed and integrated.

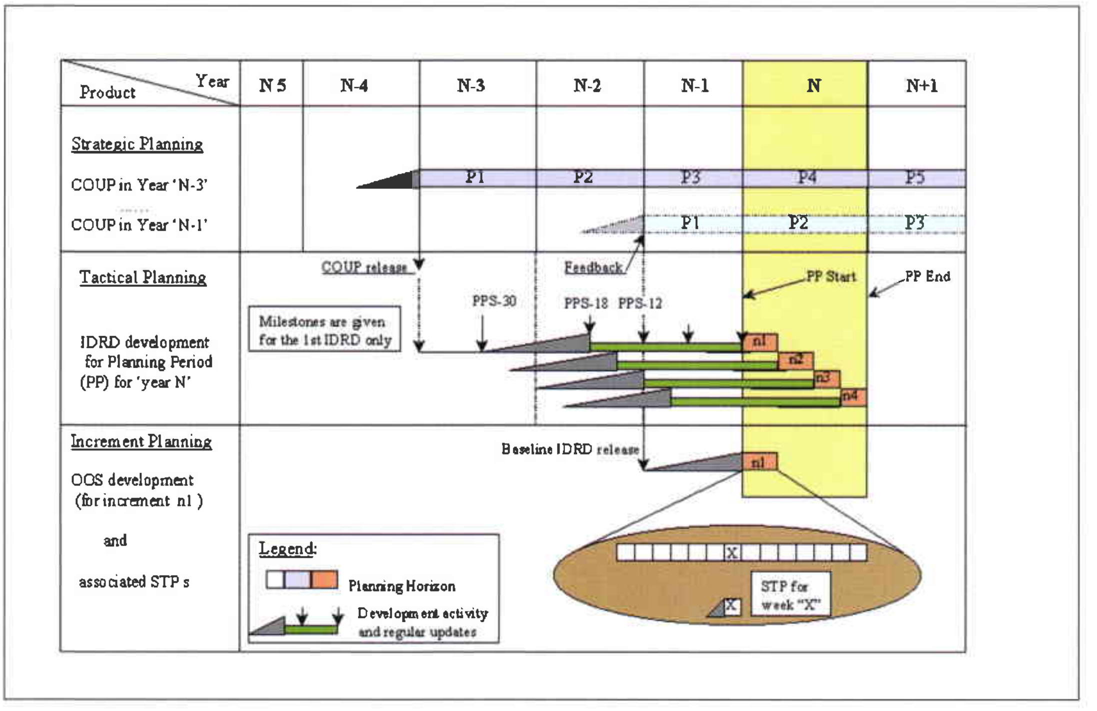
To avoid unnecessary complexity, this article focuses on the planning processes after the completion of ISS assembly.

Multi-Increment and Strategic Planning

The Multi-Increment and Strategic Planning covers a five-year period. The Multi-Increment Planning Integrated Product Team (MIP IPT) and the Utilisation Operations Panel in which ESA will have direct representation, develop the Operations Summary and its Addendum, which provide the system-related projections of the ISS resources and flight manifests for the coming 5 years. This document serves as an input for two parallel processes with ESA participation: (a) development of the Composite Operations Plan (COP), which covers the ISS system and servicing aspects; and (b) development of the various Partner's utilisation plans, which will then be consolidated by the Utilisation Operations Panel into the Composite Utilisation Plan (CUP). The COP and CUP will provide the Utilisation Operations Panel with the necessary input for the development of the Consolidated Operations and Utilisation Plan (COUP), which constitutes the end-product of the annual strategic planning cycle. It provides the annually-based data upon resources and their share for each Partner, payload list and accommodation, non-routine operations and maintenance, support services, and direction/guidance for the execution.

Each year the new period 'P5' will be added and the period of the previous year 'P1' will be removed. Details for years 'P4' and 'P3' details will be refined, while the data for 'P2' and 'P1', which are the years closest to execution, merely reflect information provided by the tactical planners who provide the strategic planners with visibility and feedback on their implementation of the COUP (Fig. 1). The

Figure 1. Generic template for the planning products and milestones in preparation of operations during 'year N'



COUP is the key input document for the Tactical Planning.

Tactical Planning

Tactical Planning (TP) covers a period of approximately one year, generally from the first manned launch in the calendar year until the first launch of the next calendar year. This planning period will generally encompass four increments, each of which is defined as the time between two launches with crew exchanges. Unmanned launch vehicles are covered within the increment.

Integrated Tactical Planning is performed by the Tactical Planning Integrated Product Team (IPT). The formal planning activities start 30 months before the planning period start (PPS-30), which is 6 months after the annual COUP release.

It is on the basis of these COUP requirements that the appropriate International Partner entities provide their proposals according to their flight-element and user needs. The breakdown of the annual resources into resource allocations per increment and per individual payload has to be performed. Based on the Partners' inputs, the Tactical Planning IPT will then develop the main planning product, the Increment Definition and Requirements Documents (IDRD). The latter is baselined in two iterations, the Preliminary Planning Period IDRD released at PPS-24 months and, after review by the International Partners, the first release of the Baseline Planning Period IDRD at PPS-18 months (Fig. 1).

Each IDRD serves two purposes:

(a) As input to the Increment Planning, it defines for its specific increment mission operations and utilisation objectives, the top-level cargo manifest (up-/down-loads), payload complement, accommodation and resource allocations, crew rotation and training plan and in-orbit maintenance.

(b) In addition, a set of summary documents is provided which are used to inform the strategic-level planners about what has been planned for Years 1 and 2 of the upcoming COUP, and the degree to which these IDRDs have met the previous COUP's requirements.

For ESA these activities are primarily performed by the tactical planners of the Mission Management Team, with support from the COF and ATV engineering organisations, the Payload Integration, Payload Operations and the Utilisation teams. During the period PPS-30 months to PPS-24 months, the Mission Management Team has the task of breaking down the annual resources allocated to ESA into resource allocations per increment and payload. To perform this efficiently, a Resource Assignment tool (RAS) has been integrated into the Mission Management Support Tools (MMST). Two other MMST integrated tools, the Tactical Parameter Data Collection System (TPDCS) and the Engineering and Logistic Data Collection System (ELDCS), serve to collect from the various European operations teams the following data sets for each increment of this planning period:

(a) projected COF accommodations, resources and services for each increment

(b) utilisation requirements such as payload objectives, manifesting requirements, on board placement requirements, campaign requirements, high-level operations and resource requirements
(c) COF logistics and maintenance requirements
(d) COF system corrective and preventive maintenance requirements.

Data set (a) is provided to the Tactical Planning IPT early in this period since it is needed to generate the initial increment resource and accommodation allocations to Partners. In addition, the TP IPT generates the initial service allocation per Partner, in particular re-supply/return allocations.

Based on these initial allocations, the tactical planners of the Mission Management Team select from data sets (b), (c) and (d) a compatible set of system and utilisation requirements for each increment in the planning period and submit these data to the TP IPT. The data exchange between the ESA MMST and the NASA Tactical Planning System (TPS in Fig. 7) is performed electronically.

Having received these data from each Partner, the TP IPT develops the Preliminary Planning Period IDRD and releases this for review by the Partners via TPS. The Mission Management Team coordinates the ESA review, which involves each of the teams mentioned above. Discrepancies are negotiated and resolved between the ESA Mission Management Team and the TP IPT, which then develops the Baseline Planning Period IDRD, which will be updated every 6 months if required. As the tactical planning period covers several increments, the maturity of the data for later increments in the period will usually increase with the release of later updates to the IDRD. Besides the already-mentioned feedback to the strategic-level planners, this IDRD provides the basic input for the Increment Planning as described below.

Increment Planning

The purpose of Increment Planning is to develop increment-specific operations products and the associated information necessary to prepare and conduct real-time operations. The information generated through this process is exploited by users, International Partners, sponsors, flight crews, ground controllers, ground processing, training, and management to plan the preparation and execution of an increment and to help make management decisions. Ground rules and constraints define the boundaries of the planning process. They include rules for crew scheduling, resource distribution and management, Extra-Vehicular Activity (EVA) planning, trajectory planning, robotics operations planning, and integrated Earth-to-Orbit Vehicle (ETOV) joint operations.

Planning as defined for the International Space Station, and in particular for the Columbus Orbital Facility (COF), is based on a distributed hierarchical concept with participants such as the Space Station Control Centre, the Payload Operations Integration Centre and other Partner centres. Each Partner in the Space Station Programme is considered a single planning entity, distributed geographically, tasked to integrate and plan their respective Partner element activities and resource utilisation. A so-called international Increment Execute Planning Team (IEPT) is formed to perform these tasks in a geographically distributed manner. The planning concept reflects a bottom-up integration of plans (Fig. 2). Finally, all plans are integrated into a Space-Station-wide set of products reflecting the operations activities carried out during an increment. Planning for the COF has to consider and reflect the sharing of resources within the COF between US and European payloads, and therefore the role of a planning entity changes.

Planning is divided into two major planning phases: the pre-increment planning phase and planning during the increment. The former develops an overview of all activities carried out during the increment and considers resource utilisation for the most critical resources on-board. Planning during the increment details portions of the increment further, usually one or two weeks, and therefore develops more detailed plans and schedules. The main products that characterise the outputs of these phases are the On-Orbit Operations Plan (OOS) and the Short-Term Plans (STP). The OOS gives a listing of activities being performed on a weekly basis, and where necessary on a daily basis. The STP details one week of the OOS and gives a more detailed view of the activities to be carried out during this week. The activities reflected in the STP are categorised into those to be carried out within the week, those to be carried out on a particular day of the week, and those that are scheduled to start at a particular time of the week. The short-term planning therefore combines operational flexibility and traditional timelining of operations activities into one single plan.

During the pre-increment planning phase, only a small subset of the Space Station's total resources are considered. The international Increment Execute Planning Team (IEPT) is responsible for determining which resources

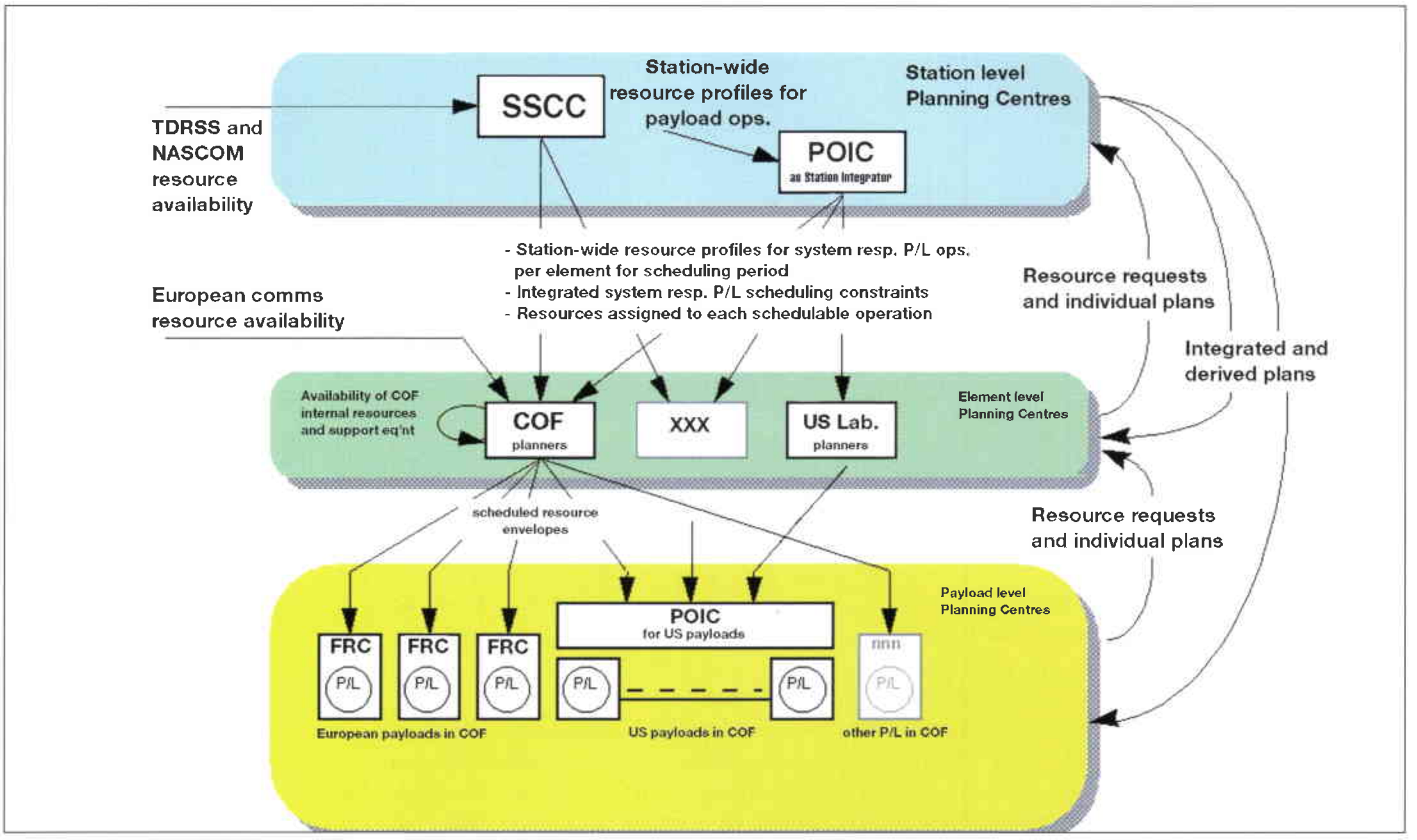


Figure 2. Execution Planning

are considered during this planning process, namely those resources whose availability can be predicted in the pre-increment time frame. Prior research has shown that crew time, power and communications are the major resources that are predictable, as they depend primarily on vehicle configuration (number of crew onboard, number of operational solar arrays, etc.). Another reason for limiting the number of resources considered pre-increment is that only a few resources truly constrain the planning and scheduling of onboard activities. For example, crew time is a very limited resource that is needed for many onboard activities.

Inputs to the Increment Planning Process

Increment planning begins with the increment- and flight-specific requirements, guidelines, and resource allocations documented in the Increment Definition and Requirements Document (IDRD), Mission Integration Plans (MIPs), and Generic Planning Groundrules and Constraints Document, Station Programme Implementation Plan, Programme Planning and Manifesting, and operations requirements specifications. These planning data inputs are needed to develop the various operations planning products. An example of resource allocations as reflected in the IDRD is shown in Figure 3.

Outputs of the Increment Planning Process

The major end-products of the Increment Planning process are the Joint Operations Plans for visiting vehicles (ETOV), the On-orbit Operations Summary (OOS) and the Short-Term Plans (STP). OOSs are high-level plans that provide a summary of system and payload activities information for the entire increment. The ETOV Joint Operations Plans provide the detailed definition of operations for the period of joint operations described at a high-level in the OOS. Generic Ground Rules and Constraints, Increment and ETOV specific planning rules include specific resource distribution decisions determined in accordance with the resource allocations in the IDRD.

On-orbit Operations Summary (OOS) development

Prior to the development of the Plans identified above, the available resources have to be analysed and considered together with the general and specific rules and constraints. Usually, so-called resource profiles (Fig. 4) are developed which define the boundaries of plan development. These resource profiles define the possible limits for each resource over a defined period of time, which can be the increment itself or a lower granularity similar to the one that the increment plans cover, weeks or days. It is the result of a preliminary plan which covers the whole increment. This plan reflects the sum of resources being consumed by the system and payload activities and might include margins to cover changes and uncertainties. Such a breakdown of resources as defined in the IDRD is shown below, covering an increment of four weeks' duration, taking the share of US payloads into account.

Once the initial plan has been developed, the process of developing the OOS begins. This planning process differs between the Basic and Final OOS development cycles. The Basic cycle is a complete end-to-end generation of data and products. The Final cycle process updates the data and products generated during the Basic cycle. It is less perturbing to planning organisations to simply assimilate updates to planned operations than it is to receive new products which may be completely different from those generated in the previous planning cycle.

For example, the Basic OOS may show that certain systems/payloads operate during certain weeks of the increment. A Final OOS that is an update would likely keep many of those operations planned as they were during the Basic OOS. A Final OOS that is regenerated may show those operations planned at completely different times. This update philosophy allows planners to minimise the number of changes made from the Basic OOS to the Final OOS, which reduces the impact on users/facilities and operations personnel. An example of an OOS is shown in Figure 5.

Short-Term Plan (STP) development
This process consists of two phases: short-term planning and re-planning. Short-term planning is the process through which the detailed schedule of systems and payload operations activities is developed and the long-range plan of activities throughout the rest of the increment is updated. Plan updating is the process by which the schedule is updated

CATEGORY/ AGENCY	Accommodations Rack Locations ISPR #	Energy Energy (kWh)	Crew Crew Hours (hrs)	Data TDRSS Ku-Band (hrs)
ISS Capability	20	45158	1246	336
RSA Allocation	0	0	534	0
System Total	0	15805	249	118
Utilization Total	20	29353	463	218
NASA Allocation	0	22484	355	167
STA Allocation	10	3757	59	28
CSA Allocation	0	676	11	5
ESA Allocation	10	2436	38	18
% of Capability				
RSA Allocation	0%	0%	42.9%	0%
System Total	0%	35%	35%	35%
Utilization Total	100%	65%	65%	65%
% of Utilization				
NASA	0%	76.6%	76.6%	76.6%
STA	50%	12.8%	12.8%	12.8%
CSA	0%	2.3%	2.3%	2.3%
ESA	50%	8.3%	8.3%	8.3%

Figure 3. Resource allocations as reflected in the IDRD

Resources	STP-1	STP-2	STP-3	STP-4	Increment
COF System Energy (kwh)	756.32	756.32	756.32	756.32	3025.28
COF System Crew (hours)	12.50	0.00	3.08	0.00	15.58
COF System ku-band (IDRD units)	0.16	0.06	0.06	0.06	0.35
COF P/L Total Energy (kwh)	443.25	937.52	949.24	835.46	3165.47
COF P/L Total Crew (hours)	29.37	37.79	39.49	22.48	129.13
COF P/L Total ku-band (IDRD units)	7.50	14.21	13.93	11.27	46.91
COF Total Energy (kwh)	1199.57	1693.84	1705.56	1591.78	6190.75
COF Total Crew (hours)	41.87	34.71	41.57	19.40	137.55
COF Total ku-band (IDRD units)	7.66	13.77	13.99	10.83	46.25

Figure 4. Resource profiles

PLANNING REQUEST	mG	STP-1	STP-2	STP-3	STP-4	Increment
SYSTEM						
VDPU Exchange	D	S1				
Video for CHXFA filter exch		S1				
CSWA Dry-out		S1	S1	S1	S1	
Inventory Check		S1		S1		
Energy (kwh)		756.32	756.32	756.32	756.32	3025.28
Crew (hours)		12.50	0.00	3.08	0.00	15.58
Ku-band(IDRD units)		0.16	0.06	0.06	0.06	0.35
ESA BIOLAB						
Expt Ops 1	R		S1	C		
Video Downlink 1	R		S28			
Spectro Op 1	R		S14			
BGB EPU Ops			S1			
BGB Cell Obs1	R			S1		
Energy (kwh)		67.33	145.54	146.46	123.10	482.43
Crew (hours)		2.00	3.92	2.76	0.16	8.83
Ku-band(IDRD units)		0.02	1.24	0.82	0.64	2.72
NASA ZCG						
ZCG Set-up			S1	S1	S1	
ZCG Install Crystals			S1	S1	S1	
ZCG Stow Crystals			S1	S1	S1	
ZCG Growth Run 1	R		S1			
ZCG Growth w/Data			S7	S7	S7	
ZCG Monitor Crystals			S5	S5	S5	
Energy(kwh)		0.00	46.90	46.90	46.90	140.70
Crew(hours)		0.00	7.33	7.33	7.33	22.00
ku-band(IDRD units)		0.00	0.00	0.00	0.00	0.00
NASA OSMP+AG						
Antigravity			S1		S1	
Dositometers				S1		
Energy(kwh)		0.00	0.00	0.00	0.00	0.00
Crew(hours)		0.00	3.09	1.00	3.09	7.17
ku-band(IDRD units)		0.00	0.50	0.00	0.50	1.00
COF Tot Energy (kwh)		1199.57	1693.84	1705.56	1591.78	6190.75
COF Tot Crew (hours)		41.87	34.71	41.57	19.40	137.55
COF Tot ku-band (IDRD units)		7.66	13.77	13.99	10.83	46.25

Figure 5. Example of COF On-orbit Operations Summary (OOS)

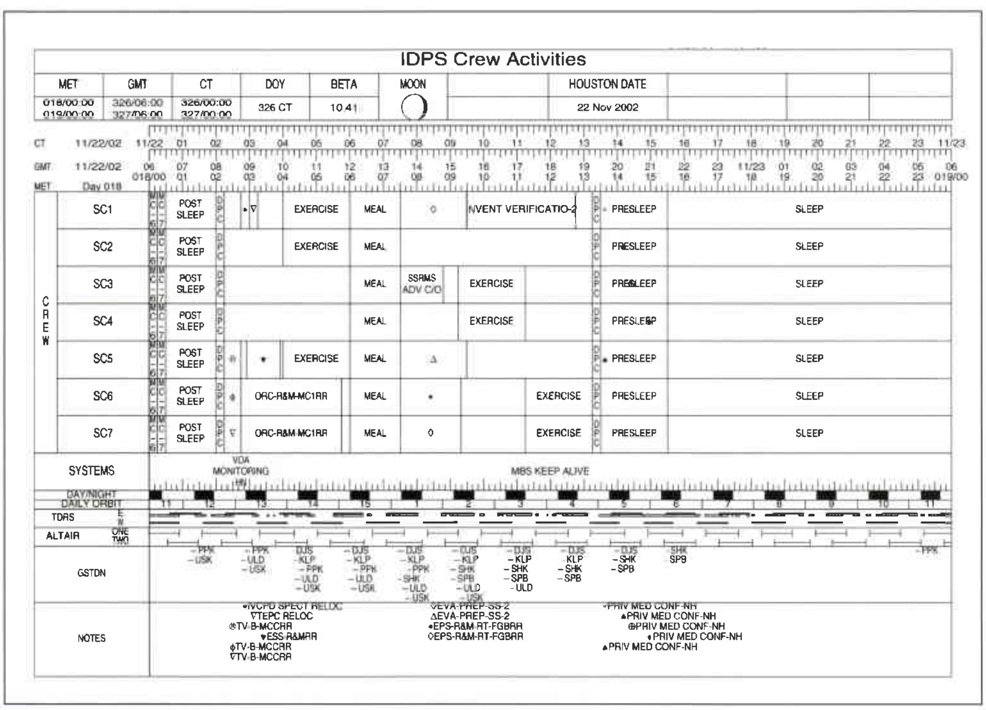


Figure 6. Example of a Short Term Plan (STP)

during operations to reflect desired or required changes to systems or payload operations.

Short-term planning is performed by an international team of systems and payload planners. The detailed schedule developed during this process is used by the ISS crew and the ground controllers to perform the activities defined for the planning period. The long-range plan is used as the basis for generating future detailed plans, and covers the time-frame from the end of the next detailed schedule through to the end of the increment.

Re-planning is performed by the on-console teams in the SSCC, POIC, and Partner Control Centres. The detailed schedule developed during short-term planning is updated by the re-planning process in response to required or desired changes. Updates to the schedule will be performed to maintain a safe and functional ISS, or in response to desired payload operations changes. An example of a Short-Term Plan (STP) is shown in Figure 6.

Implementation

On the Tactical Planning level, the overall configuration of the tools reflects the relative independence of each Partner's domain and, especially in Europe, also the geographically decentralised set-up. As an example, Figure 7 shows the basic principle of the tactical-parameter data collection at NASA and ESA, and the single-channel data exchange across their common interface.

NASA and the Tactical Planning IPT use the Tactical Planning System (TPS) for data collection on NASA's side, for data exchange with the International Partners, and for the dissemination of planning products (IDRDs) to all International Partners. The ESA Mission Management Support Tools (MMST) are the European counterpart to the TPS. With their World Wide Web based user interfaces, the various tools, TPDCS and ELDCS are used to

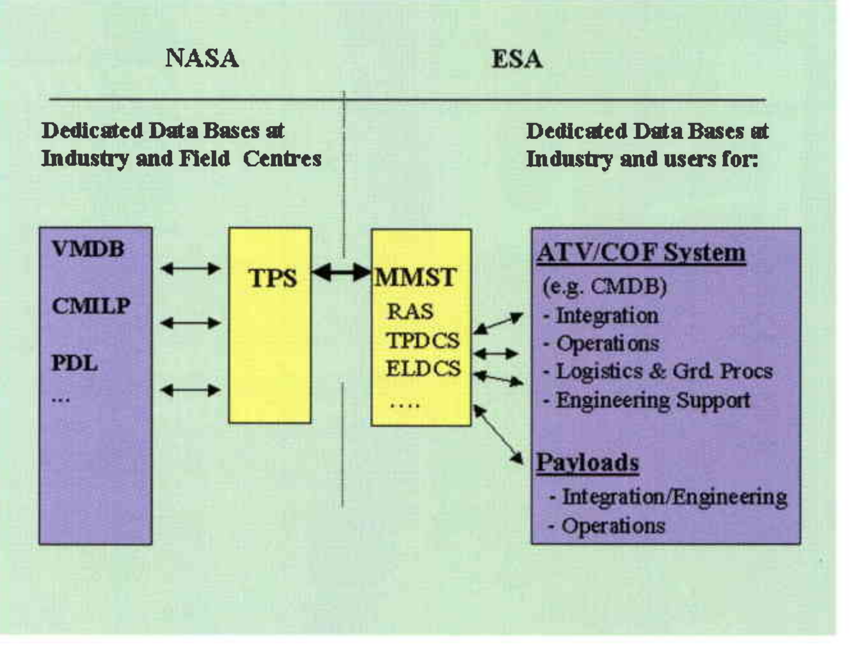


Figure 7. Tactical parameter data collection and exchange between ESA and NASA

collect the necessary data from the various European teams. The single interface between the MMST and the TPS facilitates the exchange of a consistent data set.

The Station-wide plans are developed in an integrated manner by geographically distributed participants using modern communications technologies and tools. The implementation in support of the distributed planning process and the cooperative concept requires a Ground Segment infrastructure utilising the most advanced and mòdern techniques for information distribution and exchange, to ensure a consistent and coherent information flow between all participants and planning layers. This type of information distribution is based on the principle of 'information casting': all planning participants receive information about their resource requests, such as the relative state with respect to the planning processes, conflicts with other resource requests, indications for conflict resolution and overall resource consumption and usage.

esa

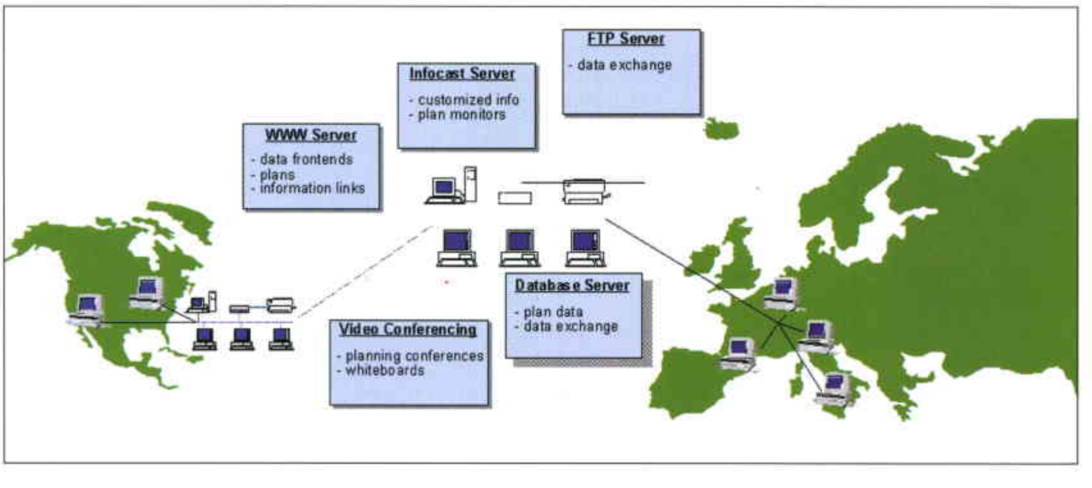


Figure 8. Distributed Planning Environment

A Space Tribology Handbook

E. Wyn Roberts
ESTL, AEA Technology, Warrington, UK

M. Eiden
Mechanical Systems Division, ESA Directorate for Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

The production of a Space Tribology Handbook forms part of an overall strategy, initiated by ESTEC's Mechanisms Section, to improve the quality of space mechanisms through the establishment of a set of globally applicable space mechanisms standards and guidelines for mechanism design. The standardisation activities are being performed under the European Cooperation for Space Standardisation (ECSS); the space mechanism engineering requirements have been established in an ESA/Industry collaborative effort in 1997. The Space Tribology Handbook provides the essential guideline for tribology aspects of mechanism engineering, useable in the day-to-day work of mechanism engineers. This strategy should promote a more standardised approach to mechanism design and testing and achieve reduced schedules, cost-effective developments and high-quality mechanisms.

The need for a Space Tribology Handbook
Tribology (from the Greek 'tribos' meaning 'to rub') is the study of friction, wear and lubrication. Friction and wear are generated at the interface of contacting bodies in relative motion and therefore occur in components such as bearings, gears, screws and slip-rings. If the friction (or adhesion) forces are high, a component may prove difficult to drive or, even worse, may seize; if high wear occurs, a component will lose its precision and, ultimately, its ability to operate at all. Tribology is, therefore, an important issue, especially in mechanisms intended for use on spacecraft – for if spacecraft mechanisms fail, there is (usually) no means to repair the damage or to apply fresh lubrication. Furthermore, if the mechanism in question is critical to the spacecraft's operation (as would be the case with solar array drives, antenna pointing mechanisms and deployment devices), then loss of the mission could result.

To avoid such anomalies and to ensure that mechanisms operate to their prescribed specification, effective designs are required which incorporate good tribological practice so that friction, adhesion and wear are minimised. In Europe, the importance of tribology in space was quickly recognised by the Agency and led, in 1972, to the establishment of ESTL (European Space Tribology Laboratory), which is now part of AEA Technology. Since then, ESTL has generated a considerable amount of tribological data, advised on tribological design issues, and tested tribo-components and mechanisms under space simulated conditions. As a consequence, a wealth of knowledge has been generated and much of this has been disseminated to the space community by way of publications and courses on space tribology. These activities have undoubtedly raised awareness of tribology and encouraged mechanism engineers to give due consideration to tribological issues in their designs. However, there was no handbook available detailing the tribological performance of materials and providing guidelines on their use in mechanisms design. It was for this reason that the Space Tribology Handbook was produced. With its publication, the space community now has a unique document which provides a source of information consolidated by test validation.

The Handbook has been written with the aim of assisting designers and engineers in the implementation of sound tribological practices and to help them determine how best to treat and lubricate components for a given application. Specifically, the Handbook:
- provides a definitive reference manual on space tribology
- provides useful data on typical systems where tribology is important either to performance or reliability
- specifies guidelines for the selection, use and limitations of tribo-materials (encompassing lubricants, surface treatments and substrate materials)
- aids the designer in the selection of tribo-components
- provides guidance on the ground testing of tribo-components and mechanisms.

Figure 1 shows the completed Handbook's cover with example sheets illustrating the format and style.

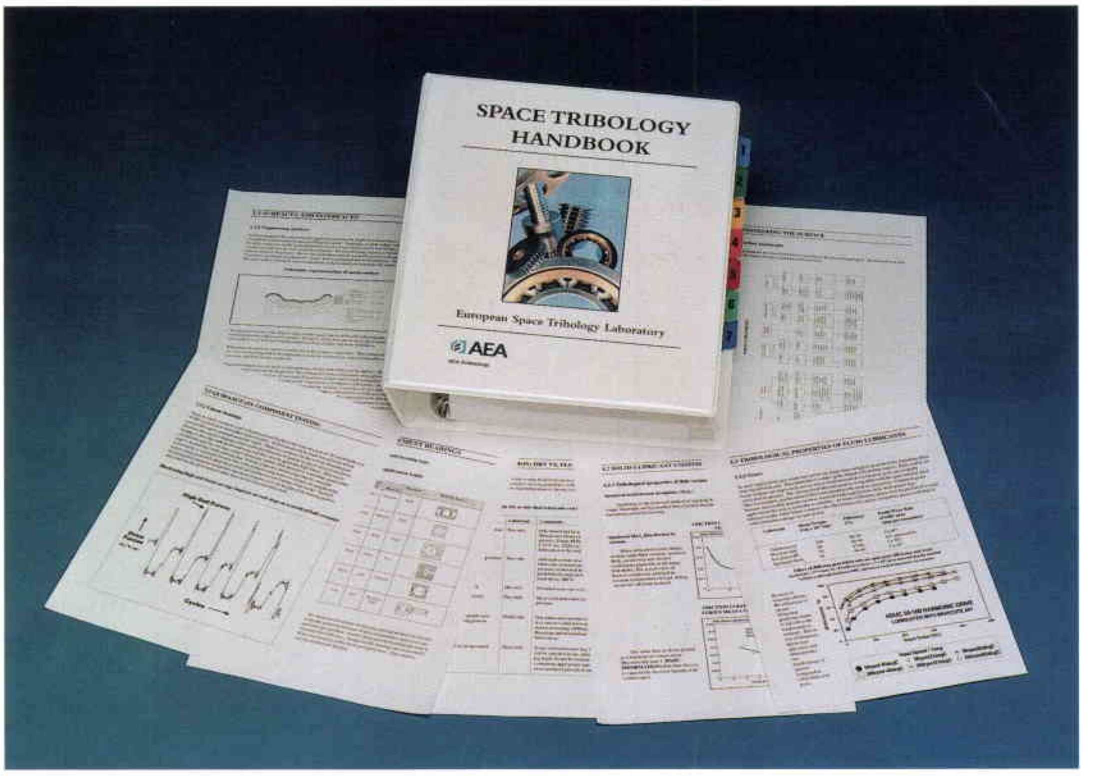


Figure 1. The Space Tribology Handbook showing examples of contents

The scope and structure of the Handbook

The handbook is arranged in seven chapters, the titles of which are listed in Figure 2. The first chapter serves as an introduction to tribology, its purpose being to familiarise readers who are new to the subject with the fundamental concepts of tribology. The remaining chapters form the Handbook's guidelines and span the progression from the initial selection of a tribological component, through its lubrication and, finally, to its testing at component and mechanism level.

A flow chart detailing how the various stages of component selection, lubrication and testing are presented and cross-referenced is illustrated in Figure 3.

Contents of Handbook

The following outlines the contents of the individual chapters of the Handbook.

Basic Tribology

Engineers involved in the design of mechanisms need to have an understanding of the basic concepts of tribology so that they can recognise the issues which are critical to the success, or failure, of their mechanism. Fundamental to this understanding is a knowledge of how engineering surfaces interact when brought into contact under load and how this interaction changes when there is relative motion (which may be separation, sliding or rolling) between the contacting bodies.

This chapter, therefore, looks at what happens when real surfaces come into contact and explains how contact areas in reality are small and contact stresses high. The manner in which surfaces deform is discussed and the conditions under which these deformations become permanent (plastic deformation) are

1. Basic Tribology
2. Tribo-component Selection, Design and Performance
3. Selection of Lubricant Type
4. Solid Lubricants
5. Fluid Lubricants
6. Materials for Tribological Components and Surfaces
7. Component and Mechanism Testing

Figure 2. Contents of the Space Tribology Handbook

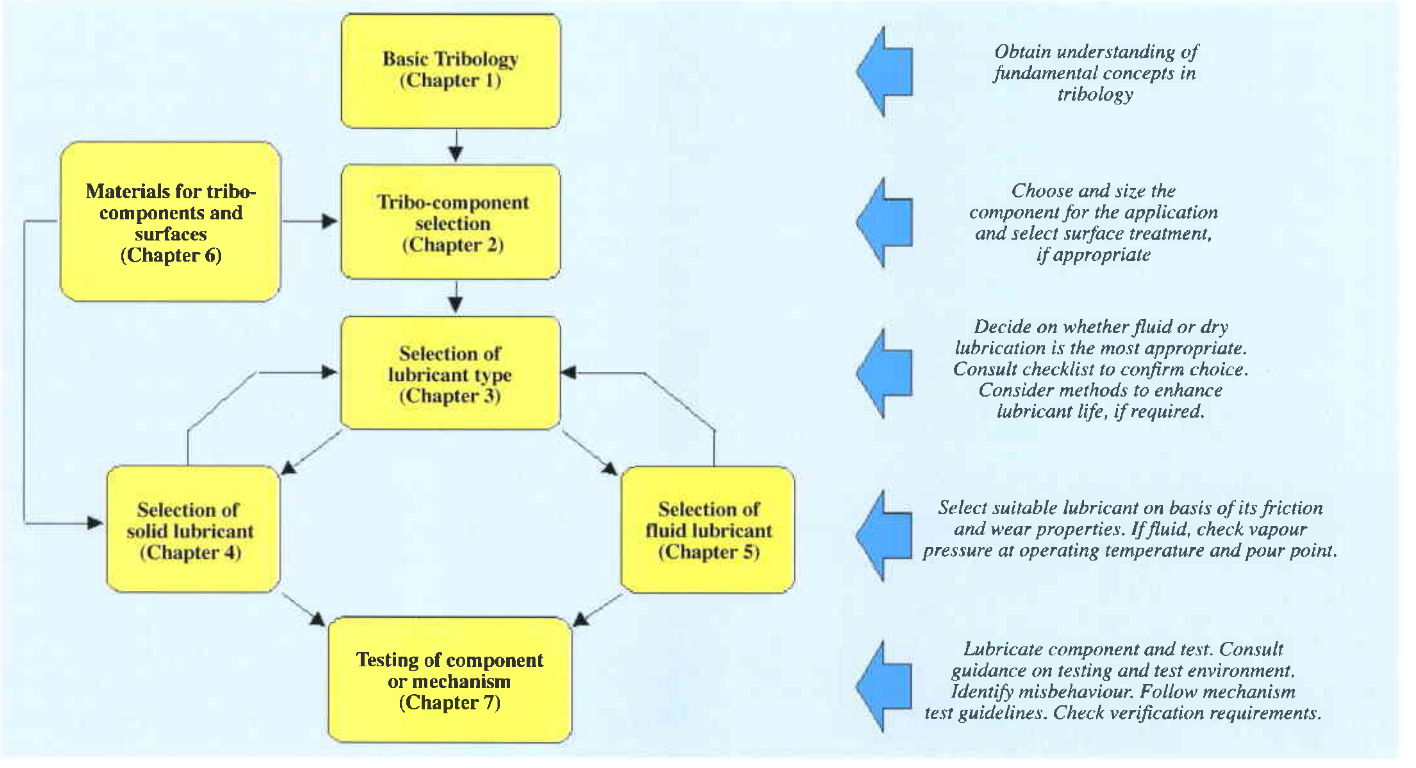


Figure 3. Flow-chart showing the Handbook's structure and logic

identified. The various phenomena, which give rise to friction and wear, are described and the manner by which these may be reduced (through lubrication) is explained. Finally the unique environment in which space mechanisms have to operate is defined and the impact such an environment has on tribological systems is outlined.

Tribo-component selection, design and performance

This chapter is intended to assist the designer in the selection of tribological components – that is, on how to choose the most suitable component for a given application (Fig. 4). The areas covered are:

- selection of rotary, rolling-element bearings
- selection of plain, spherical and rod-end bearings
- selection of ball, roller and plain screws
- selection of linear bearings
- selection of gears
- sliding electrical contacts
- other tribo-components: separation surfaces, end stops, cams, threaded fasteners, brakes, seals
- safety factor for tribo-components.

For each generic component, advice is given on which type of component is best suited to an application on the basis of parameters such as load capacity, stiffness and precision. The materials, and their relevant properties, from which the components are manufactured are specified. Examples are given of where specific components have been used successfully and what software is available to assist in design and prediction of performance.

Selection of lubricant type

Having identified the component to be employed, the next step to address is whether to use fluid or dry lubrication (Fig. 5). This chapter defines the criteria by which this decision should be made and also offers guidelines on selection for those cases where, in principle, both fluid and dry lubricants are applicable. Checklists are provided to help select a specific lubricant once the choice has been made between fluid and dry. In addition, suggestions are made on how to extend the life of space lubricants. The chapter features the following topics:

Figure 4. Effective mechanism design requires an informed approach to selection, sizing and lubrication of tribological components. The Handbook provides guidelines in these areas and helps to ensure that the most appropriate component and lubrication are chosen for a given application. The photograph shows a type of bearing (angular-contact) which is commonly used in space mechanisms. The races are lubricated with a thin film of molybdenum disulphide

Guide to selection; dry versus fluid lubrication:
- applications where only dry or fluid lubricants can be used
- choosing between fluid and dry lubrication when both are applicable
- checklist when choosing solid lubrication
- checklist when choosing fluid lubrication
- labyrinth seal leak-rate calculation.

Enhancing lubricant performance:
- extending life of perfluorinated lubricants
- extending life of solid lubricant coatings
- running-in of solid-lubricated components.

Solid lubricant coatings:
- coating types and methods of application
- guide to selection of solid lubricant coatings
- tribological properties of thin films
- lubricant coatings for temperature extremes
- effect of environment
- coatings to prevent static adhesion and fretting damage
- storage and handling of coated components.

Bulk solid lubricants:
- polymers and polymer composites
- non-polymeric composites.

Figure 5. The choice of lubricant is critical to the successful operation of a space mechanism. The Handbook provides guidelines for selecting both fluid and dry lubricants. Specialised lubricant processes may be required such as the plasma-assisted deposition system, shown here, for the production of thin layers of lead films

Solid lubricants
Solid lubrication of a bearing may be brought about in one of two ways. It can be provided as bulk material for a moving surface, transferred by rubbing from a solid made from, or containing, the dry lubricant as, for example, with self-lubricating cages. Alternatively it can be applied to one (or both) counterface(s) in the form of a film, as with techniques such as sputter deposition. Information on both forms of solid lubricant is included in this chapter. The areas covered are:

Selection of solid lubricants:
- when to use solid lubricants
- advantages and disadvantages of solid lubrication
- types of solid lubricant.

The section on coatings describes the various methods of application and the corresponding thickness ranges. This is followed by a general guide to selection based on the coatings' tribological properties in air and vacuum, their range of operating temperatures, their suitability for precision components, and the type of application and duty for which they are best suited. More detailed information on the tribological properties of specific coatings follows with examples of their performance when applied to ball bearings and gears.

The section on bulk solid lubricants deals with self-lubricating polymers and composites. The latter are composites containing solid lubricants, which may be reinforced with fillers in the form of particulates or fibres. The types covered are polymer composites (for bearing cages and gears), thin-layer polymeric composites (for journal and spherical bearings), metal/MoS_2 composites (for motor and slip-ring brushes) and leaded bronzes (for bearing cages). In each case the mechanical and material properties are specified and the friction and wear characteristics are listed.

Fluid lubricants
The following aspects are addressed:
- selection of a fluid lubricant
- fluid lubricant database
- tribological properties of fluid lubricants
- fluid loss, retention and replenishment
- handling, cleaning and lubrication procedure.

The section dealing with selection describes the types of fluid lubricant available and gives the relevant properties (vapour pressure and pour point) of some commonly used space oils and greases. More extensive data is provided by the fluid lubricant database which lists the known physicochemical and tribological properties of over 100 fluid lubricants that have been used, or are candidates, for space applications. The tribological properties of oils and greases are described and their measured performance in components such as bearings, gears and screws is presented.

Materials for tribological components and surfaces
This chapter surveys the properties of materials that have been used, or may be suitable for use, in tribological components in space mechanisms. Its purpose is to act as a reference source of basic material properties and as a supplementary source of information to that provided in other chapters. Additionally, a guide is given on the selection of base materials and appropriate surface treatments for commonly used tribological components. Specific topics covered are:

- the compatibility of materials with vacuum environments (vapour pressure and outgassing characteristics)
- physical and mechanical properties of bulk tribo-component materials (including hardness, elastic modulus, tensile strength, maximum operating temperatures and density)
- listings, descriptions and suitability of surface treatments
- a materials selection guide for bearings, gears, screws, fasteners and separating surfaces.

Component and mechanism testing
Here, guidance is given on the testing of tribo-components and mechanisms for space satellite applications. It identifies and defines the various test environments and provides guidelines on how to achieve them. Examples are given of thermal-vacuum test set-ups for component and mechanism testing together with notes on the testing of specific tribo-components (Fig. 6). The rationale for mechanism testing is explained and verification requirements, based on current ESA guidelines, are presented.

Future updates
In line with the evolution of space tribology, it is our intention to update the Handbook on a regular basis. This will be achieved by incorporating newly generated data and responding to the suggestions and reactions of users. In this way, the Handbook will remain a contemporary, up-to-date and, above all, relevant document which meets the needs of space mechanism designers and engineers.

Figure 6. Thorough testing of components and mechanisms is essential in order to prove that all functional and lifetime requirements are met. The Handbook provides guidelines on all aspects of ground testing and details ESA's current mechanism verification requirements. The photograph shows the installation of an antenna-pointing mechanism in a test chamber where it will be subjected to a thermal-vacuum test

To obtain a copy of the Space Tribology Handbook, you can request an order form by writing to ESTL at the following address:

Space Tribology Handbook
ESTL
RD1/165
AEA Technology
Risley, Warrington
UK
WA3 6AT

Alternatively, telephone +44 (0)192525 3015 or send an e-mail to: emyr.roberts@aeat.co.uk

Acknowledgements
Much of the tribological data presented in the Handbook was generated through the dedicated efforts of present and former members of ESTL staff. The authors are grateful for the constructive comments made on draft chapters by members of ESTEC's Mechanisms Section.

Backdating at ESA
- Calculation of the Backdated Cost-at-Completion of Optional Programmes

I. Duvaux-Béchon & F. Petitjean
Budget Division, ESA Directorate of Administration, Paris

Backdating is the conversion of actual expenses and forecasts of expenses for a programme to a unique economic basis in order to be able to compare expenses incurred during different years under different economic conditions (price levels, conversion rates) and define the Cost-at-Completion (CAC) of a programme. The CAC is the total cost for a programme, expressed at certain economic conditions (the same for all the years of life of the programme). It is not the sum of actual expenses and forecasts, as these are expressed at different economic conditions.

The ESA Convention (Article III of Annex III; Fig. 1) states that a Member State can withdraw from a programme if the CAC is to go beyond a limit of 120% of the indicative financial envelope. This means that there should be a means of comparing actual expenses with the indicative financial envelope, whether it is explicitly requested in the Declaration for a programme or more generally to monitor the total cost of a programme. Backdating is a means of relating all expenses or forecasts back to the price and currency rate levels of the Declaration so that they can be directly compared with the envelope voted.

The basic principles

Backdating refers to two different types of financial data: the actual expenses that are well known and the backdating of which will not change, and the forecasts, the backdating of which is only indicative and depends on both the structure of expenses of the last year known N (last actual expenses) and the structure of expenses planned for year N+1 when its budget was prepared at the economic conditions 'N' (Fig. 2).

Actual expenses are accounting data registered as such in the ESA accounts. They are fixed after the closing of the relevant year. They represent the payments made and are associated with the currency used for this payment on a given budget line for each output.

Every year (let us assume it is year N+1) around February/March, when the actual expenses for year N are known and fixed, these actual expenses (that were paid at price level N by definition, using the conversion rates defined for year N) are converted into amounts at the economic conditions (e.c.) of the Declaration (for example year 'D' e.c.: price level D, conversion rates (D+1)). Actual expenses of previous years (N-1 and before) have already been converted to the same 'D' e.c.. The forecasts for current year (N+1) and for the further years are established at 'N' e.c., which are the last known economic conditions (price level N, conversion rates (N+1)) and they are also converted in amounts of D e.c.. All amounts are then expressed at the same economic conditions as those of the Declaration and can be added (thus giving the planned CAC) and compared with the budget voted by the Participating States in the Declaration.

The procedure

The data: actuals

Every year (N+1), after the annual accounts have been closed, actual expenses of the year just ended (N), expressed in ECUs, for all programmes to be backdated are imported from ESA's computerised financial system EFSY into the backdating application (for the time being). The data imported or used include:

- all expenses per sub-output, sub-heading and currency (Fig. 3)
- potential 'miscellaneous receipts' per currency to be deducted from the expenses (provided by the financial controllers); this corresponds, for example, to sale of equipment when the amount received by the programme has to be deducted from the CAC
- price indices that were used for the updating of current year (N+1 - price indices from N-1 to N) (Fig. 4)
- conversion-rate variations (updating of year N – from N-1 to N, for national currencies and ECUs; these data are already in the system from the year before).

The data: forecasts

For the backdating of the forecasts for year N+1 and the subsequent years, the following data are needed:

Figure 1

ESA Convention - Annex III - Article III

1. If the programme includes a project definition phase, the participating States shall, at the end of the phase, reassess the cost of the programme. If the reassessment shows that there is a cost overrun greater than 20% of the indicative financial envelope referred to in Article I, any participating State may withdraw from the programme. The participating States that wish, nevertheless, to continue with the programme shall consult among themselves and determine the arrangements for such continuation. They shall report accordingly to the Council, which shall take any measures that may be required.
2. ..
3. The Council shall lay down a procedure enabling the financial envelope or sub-envelopes to be revised in the event of price level variations.
4. When the financial envelope or a financial sub-envelope has to be revised for reasons other than those referred to in paragraphs 1 and 3, the participating States shall apply the following procedure:
   a. No participating State shall be entitled to withdraw from the programme unless the cumulative cost overrun is greater than 20% of the initial financed envelope, or of the revised envelope defined in accordance with the procedure laid down in paragraph 1.
   b. If the cumulative cost overrun is greater than 20% of the relevant financial envelope, any participating State may withdraw from the programme. Those States that wish, nevertheless, to continue with the programme shall consult among themselves, determine the arrangements for such continuation and report accordingly to the Council, which shall take any measures that may be required.

Figure 2

Economic Conditions

1996 e.c.: Established mid-1996, to be used in the draft budget for 1997.
Price level **1996** (known June 1996).
Currency rates level for **1997** (mean values of National Currencies towards the ECU between July 1995 and June 1996)

Actuals of 1996: Price level **1996** (expenses incurred during **1996**)

Figure 3

Definitions

–(Sub-)output: programme or part of a programme - e.g. ERS-2 Phase-E1
–(Sub-)heading: type of expenditure - e.g. salaries, manpower costs, etc.
–Grand heading: grouping of sub-headings of the same types

Figure 4

Updating

- A budget is established in the May-July time-frame for the following year, at the economic conditions known in spring, i.e. for the 1998 budget, at the economic conditions of 1996 (price level 1997, conversion rates for 1997).
- This budget has to be published at the economic conditions of 1997, known mid-97.
- This means that all planned expenses have to be converted from 1996 e.c. to 1997 e.c. by applying price variation indices from 1996 price levels to 1997 price levels, and conversion rates variation from 1997 to 1998.
- The indices correspond to categories of expenses (salaries, cost in an industrial sector, cost of goods).
- The price variation indices are established for all currencies used at ESA and for ecus/country by statistical offices independent from ESA (Wiesbaden Office for the indices in national currencies and Eurostat for the indices in ECUs).
- For each sub-heading, one index is applied, corresponding to its category of expenses.

- forecasts (provided by the programmes) per sub-output and grand heading, expressed at the economic conditions N (prices N, conversion rates N+1), including potential miscellaneous receipts; uncovered parts can be taken out
- mean conversion-rate variations per grand heading for each sub-output, as calculated during the updating of year N+1 (conversion rates from N to N+1, for national currencies and ECUs).

The method for backdating actual expenses
Actual expenses of year N-1 and before are already backdated and the results and indices used are kept in the system at sub-output grand heading/currency level for each year. The results are kept at grand-heading level in order to limit the volumes of data to be kept (more than 300 000 lines in the historical file).

In cases where a subheading was used in year N which was not used in the updating of year N+1 or for some of the former years, no price index is available at least for one of the years between N and 'D'. The first step in the backdating of actual expenses N, which in theory is a rather simple calculation, is then to compute all the indices necessary to backdate them to the economic conditions of the Declaration. The basic indices used are those that have been calculated by the independent statistical offices in charge of the elaboration of the indices. The Wiesbaden Statistical Office in Germany provides the price indices in national currencies, while Eurostat in Belgium calculates the price indices for ECUs/country, using the Wiesbaden indices and the conversion rates of the national currencies versus the ECU.

The corresponding price indices that were used in the updating for year N+1 (price indices from N-1 to N) are imported into the backdating application. When a given price index for a subheading is missing, the index used for the calculation is the IVPGTE (price variation index per grand heading for the corresponding sub-output). If this one is also missing, it is the IVPGT (price variation index per grand heading) defined every year for all the expenses on a given grand heading of all programmes to be backdated. The conversion-rate index used is then the IVTGT (currency rate variation per grand heading). Figures 5 and 6 show the correspondence between the IVPGTE and IVTGTE (price and rate variation indices per output and per grand heading) and the Wiesbaden document.

These same default indices (or even, if they are missing, the general price variation and currency-rate variation indices, IVPG and IVTG - mean value for one year for all ESA backdated outputs) are used when a programme had no expenses for one or more years, either between the e.c. of the Declaration and the first year of expenses or during the life of the programme.

When all indices necessary for the backdating of actuals to the e.c. of the Declaration are known, the price and variation indices are applied to the expenses until the e.c. of the Declaration are reached (Fig. 7), for all direct expenses (Grand Headings 1 to 5). The actual expenses (N prices and N conversion rates) per subheading are backdated to 'N-1' e.c. (by applying the price-variation index; see Fig. 8) and then aggregated per grand heading and

Figure 5

Price Variation and Exchange Rate Variation Indices as per Updating 1998

YEAR N	OUTPUT	GH	IVPGTE	% price	IVTGTE	% rate
1997	645	1	1.02425 =	2.43%		
1997	645	2	1.03504 =	3.50%		
1997	645	3	1.02703 =	2.70%		
1997	645	4	0.97949 =	-2.05%		
1997	645	5	1.03055 =	3.06%		
1997	645	A	1.01384 =	1.38%		
1997	645	B	1.02279 =	2.28%		
1997	645	C	1.02214 =	2.21%		
1998	645	1			0.97341 =	-2.66%
1998	645	2			0.97786 =	-2.21%
1998	645	3			0.99474 =	-0.53%
1998	645	4			1.00419 =	0.42%
1998	645	5			1.03129 =	3.13%
1998	645	A			0.9816 =	-1.84%
1998	645	B			0.98656 =	-1.34%
1998	645	C			1.02265 =	2.27%

in backdating database

as in ESA/FIN(97)4 - Wiesbaden report for 1998 budget

exchange rate variation 1997 to 1998 per output and GH in backdating database

price variation index 1996 to 1997 per output and GH in backdating database

Figure 6

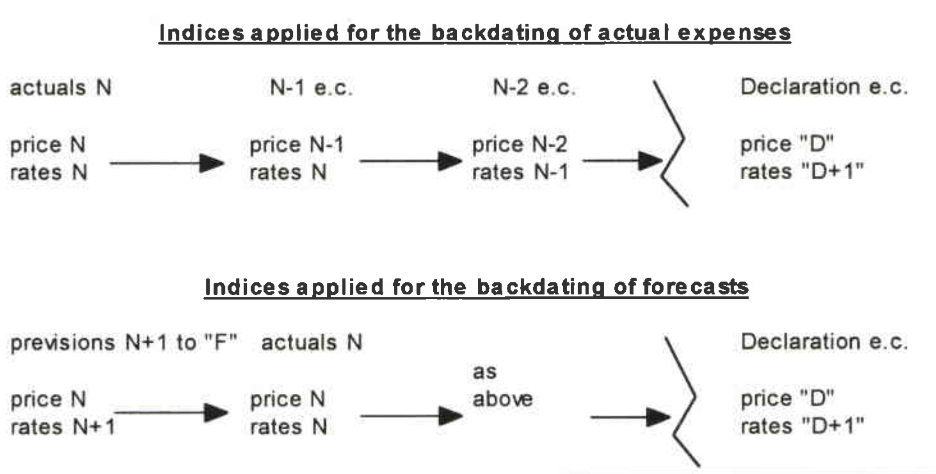
ESA/FIN/97/4
ANNEXE A

UPDATING OF DRAFT 1998 EXPENDITURE

(IN K.ECU)

OUTPUT 645 COLUMBUS - POLAR PLATFORM TOTAL	MID 96 PRICES RATES FOR 97	WEIGHTED PRICE VARIATION	MID 97 PRICES RATES FOR 97	WEIGHTED CONVERSION RATES VARIATIONS	MID '97 PRICES RATES FOR 98	COMBINED PRICE/RATES VARIATIONS	
111 SALARIES,ALLOW.,BENEFITS(NET)	2668	2.44	2733	-2.67	2660	-0.30	1A
122 LOCAL & PART-TIME STAFF	12	2.50	12	-2.83	12	-0.40	1A
GT1 STAFF EXPENDITURE	2680	2.43	2745	-2.66	2672	-0.30	
211 MISSION EXPENSES ESA STAFF	522	4.41	545	-2.39	532	1.92	2C
212 MISSION EXPENSES NON-ESA STAFF	32	4.30	33	-2.83	32	1.35	2C
223 PACKAGING & FREIGHT COSTS	33		33	-2.54	32	-2.54	2D
231 PUBLIC RELATIONS	50		50		50		1B
241 YOUNG GRADUATES	26	2.50	27	-2.83	26	-0.40	1A
252 MEETING COSTS	50	2.00	51		51	2.00	1B
273 EXTERNAL SERVICES	29	1.00	29	-2.83	28	-1.86	1B
GT2 RUNNING EXPENDITURE	742	3.50	768	-2.21	751	1.21	
312 RENTAL/EXT. FACILITIES & SERV.	1417	3.03	1460	-0.21	1457	2.82	1B
313 COMMUNICATION & DATA LINKS	50		50	-2.54	49	-2.54	3B
321 INDUSTRIAL MANPOWER	157	1.00	159	-2.83	155	-1.86	1B
322 MAINTENANCE OF TECH FACILITIES	25	1.00	25	-2.83	24	-1.86	1B
330 TECHNIC. CONSUM. & SPARE PARTS	16	1.00	16	-2.83	16	-1.86	3A
GT3 FACILITIES	1665	2.70	1710	-0.53	1701	2.16	
420 ADM EQUIPT VEHICLES & AIRCRAFT	5		5	-2.83	5	-2.83	4D
441 PERSONAL COMPUT & ASS EQUIPT	81	-4.94	77	-2.60	75	-7.41	4C
442 OTHER COMPUTERS & ASS EQUIPT	1104	-5.00	1049	-2.54	1022	-7.41	4C
450 TRACKING, TELEMETRY & RANGES	2223	-0.49	2212	1.94	2255	1.44	4A
GT4 CAPITAL EXPENDITURE	3413	-2.05	3343	0.42	3357	-1.64	
511 EXPERTS AND CONSULTANTS	170	1.00	172	-2.83	167	-1.86	1B
512 SPECIAL STUDIES (INCL. PHA A)	108	0.93	109	4.59	114	5.56	1B
521 SPACECR, AIRCRAFT INC SUB-SYST	55122	2.45	56473	6.25	60003	8.85	XP
527 SOFTWARE DEVELOPMENT	1321	3.18	1363		1363	3.18	1B
531 LAUNCH PURCHASE	40950	3.88	42538	-0.89	42160	2.95	99
533 ESA TEAM ON RANGE	50	1.00	51	-2.83	50	-1.86	1B
GT5 DEVELOPMENT	97721	3.05	100706	3.13	103857	6.28	
TOTAL DIRECT EXPENDITURE	106221	2.87	109272	2.81	112338	5.76	
A11 RECH SITE SERVICES ESTEC	502	0.20	503	-2.58	490	-2.39	
A13 RECH SITE SERVICES HQ	39	1.39	39	-1.01	39	0.37	
A15 RECH OFFICE AUTOMATION	85	1.50	86	1.24	87	2.76	
A20 RECH ADMINISTRATIVE SUPPORT	1036	2.03	1057	-1.80	1038	0.19	
GTA ADMINISTRATIVE + SITE COSTS	1662	1.38	1685	-1.84	1654	-0.48	
B11 RECH TECHN SUPPORT/MANPOWER	1190	1.89	1212	-1.77	1191	0.08	
B12 RECH OPS SUPPORT/MANPOWER	6888	2.52	7061	-1.32	6969	1.17	

Figure 7



backdated to 'D' e.c.. Once this backdating has been completed, the recharges on the backdated amounts are calculated using the same rules as for the recharging in the financial system.

Backdating of the forecasts
Forecasts for years N+1 until the end of a programme are expressed at N e.c. (price N, conversion rates N+1) per sub-output and grand heading. These economic conditions are the last known, and those of the current budget; no estimation of the evolution of the economic conditions for the future is performed. It is in fact not necessary, all forecasts being expressed at the same economic conditions. The forecasts are backdated to the e.c. of actual expenses N by applying the conversion-rate variation N+1 to N (used in the updating of year N+1). These conversion-rate variations are taken from the updating calculation (included in the so-called 'Wiesbaden document') as the mean value for each grand heading per sub-output (IVTGTE). Similar rules apply as for the backdating of actual expenses if some of the indices are missing. The indices to be used are linked by construction directly to the structure of expenses as planned when preparing the budget for year N+1. The backdating coefficients per grand heading (all currencies aggregated) as calculated for the backdating of actual expenses N are then applied. Note that for expenses in ECUs, the conversion rate variation N+1 to N is 1 by definition.

The method defined implies that the forecasts can only be backdated when expenses have been incurred and first indices are known. It is not possible to backdate forecasts alone, as the calculation links the forecasts to the result of the backdating of actual expenses.

National currencies and ECUs
The conversion-rate variations for the national currencies are defined as the variation in official rates between two years for each national currency considered. Today, the official conversion rate of a currency to the ECU for year N is equal to the mean value of the conversion rate between July N-2 and June N-1 (over a 12-month period).

These conversion-rate indices are combined with the price indices established by Wiesbaden to update and backdate expenses or forecasts expressed in national currencies.

The updating factors for price variations of expenses in ECUs are established by Eurostat. They are based on the variation of price indices versus the ECU from June in year N-1 to June in year N, and thus combine the price indices as established by the Wiesbaden Institute for national currencies with the effect of variation of conversion rates of the national currency vis-à-vis the ECU for the same June-to-June period (not the same period as the one used for the official conversion rates in national currencies), i.e. prices in ECUs June year N-1 to prices in ECUs June year N.

For the backdating of actual expenses, the two effects have to be separated (price variation/conversion-rate variation mixed effect for expenses in ECUs) as actual expenses are not expressed at 'normal' e.c. as in the Wiesbaden document (price N-1 to N, rates N to N+1 to go from N-1 to N e.c. - in the N+1 updating, when actuals N use prices N and rates N). This means that, for expenses in ECUs, the price index used will be the same as the one used for national currencies, and the conversion-rate variation will be the one defined for the ECUs (June N-2 to June N-1), which differs as from 1997 from the conversion rate for national currencies (July N-3-June N-2 to July N-2-June N-1).

For the backdating of forecasts, the rate

Figure 8

ACTUAL EXPENSES DATABASE FOR OUTPUT X

YEAR	OUTPUT	SH	CURR	IP	ACTUALS	BACKD N-1 E.C.
1996	X	513	F	1.5	142091	139991.133
1996	X	521	XB	3.009231	99984	97063.14549
1996	X	521	XD	3.009231	1391682	1351026.489
1996	X	521	XF	3.009231	891251	865214.6892
1996	X	521	XNL	3.009231	182000	176683.1941
1996	X	527	D	6.6	454965	426796.4353

actual expenses backdated at "N-1" e.c.
actual expenses year N in ECU as recorded in EFSY

price index (in %) as defined in the "Wiesbaden report"
valid for the currency and SH considered to go from "N-1" to "N"
"N" = 1996 here

variations N to N+1 of the Wiesbaden document are applied to data, so that they are brought back to the economic conditions of actual expenses N, when the overall backdating coefficient calculated for these actual expenses per Grand Heading (GH) is applied (going back to the Declaration e.c.). This means that for provisions in ECUs (structure of expenses used for the forecasts is the one that was planned in the updating for year N+1), the backdating coefficient to actual expenses N has a factor of 1 (by definition in the updating procedure, the conversion-rate variation ECU to ECU is one). The effect of conversion-rate variations for expenses in ECUs will only be seen for the backdating of actual expenses. This will disappear for all currencies in the Euro system as the conversion rates vis-à-vis the Euro will be fixed and no conversion-rate variation effect will then be included in the calculation of price indices for Euro/country expenses or forecasts.

If forecasts were planned during the updating calculation as being 'not subject to updating', the relevant price and conversion-rate indices are zero, and the backdated amount will be the same as the initial amount.

Backdating and charging policy

Charging policy is what defines the way in which programmes will pay for the administrative support and technical costs. These costs are 'recharged' to the programmes following rules defined in the Financial Regulations, and are termed 'indirect expenditure'.

For the years up to and including 1997, these indirect expenditures were composed of Grand Headings 6, 7 and 8. As from 1998, the indirect Grand Headings became GH A, B and C due to a new charging policy (Fig. 9). This means that the backdating programme has to be adapted to take into account this new rule.

As from the forecasts for 1998, GH A, B and C have been introduced into the system with the creation of a history, so that forecasts can be backdated to the origin. In view of the structure of the outputs discharged on these new GHs, it has been decided that :

- GH A will have the same past indices as GH 6 (both costs are of the administrative type)
- GH B indices will be composed of 100/130 of GH 7 and 30/130 of GH 6 as it includes expenses corresponding to former GH 7 and GH 6 (staff costs related to the support staff – recharged before on GH 6 – are now included in GH B)
- GH C will have the same indices as GH 8 (same type of expenditures).

As for the actual expenses of 1998 and subsequent years, the rules for recharging will of course reflect the new charging policy.

Economic conditions of the Declaration and first expenses

If expenses are incurred at economic conditions 'older' than in the Declaration, i.e. first expenses in 1990 and Declaration at 1995 e.c., the actual expenses before 1995 are updated to the conditions of the Declaration so that the CAC is composed of figures expressed at the same economic conditions as those of the Declaration.

Change in the economic conditions of a Declaration

It is always possible to change the reference year for a Declaration if it is to make it 'younger' (e.g. to go from 1992 to 1994), but the reverse is impossible as the indices to go 'earlier' either do not exist and cannot be 'constructed', or they have been erased by already changing the conditions to a 'younger' date.

Recent evolution in the definition of currencies

When payment in ECUs was introduced, it was necessary to define 18 more currencies in the system, as the price indices still depend upon the country in which the expenses are incurred, even if they are in ECUs. Expenses incurred in France, for example, can be in French Francs or ECUs/France. A 'history' for all of these currencies therefore had to be defined in order to have indices for the former years. The same indices as those of the corresponding national currency have been defined (same price indices and reference months for the calculation of conversion-rate variations up to 1996). From 1997, rates in ECUs are different from those in national currencies (different reference as ECU conversion rates are calculated from June to June for combination with the price-variation indices in ECUs).

Figure 9

GH 6	Administrative and Site Costs
GH 7	Variable Support Costs
GH 8	Fixed Support Costs and Investment
GH A	Site Services & Office Automation & Administrative Support
GH B	Technical & Operational Support
GH C	Technical Infrastructure & Capacity Support

Creation of the Euro

In addition to the fact that the introduction of the Euro will mean the suppression of several currencies and will allow the backdating of forecasts in Euros to be closer to the final result (no more conversion-rate variation effect that would not be taken into account in the backdating of forecasts), the real impact of this change has still to be studied.

Already for the 1999 budget, two updating exercises will probably have to be performed, one as usual to bring the 1997 e.c. to 1998 e.c, but with the conversion rates of the currencies going into the Euro defined in a different way: not the mean value July 1997 to June 1998, but the provisional conversion rate that will be defined in May 1998. Another updating exercise will be done in January 1999, as soon as the official conversion rates vis-à-vis the Euro have been defined. The backdating of the forecasts for 1999 and later actuals for 1999 will have to take into account this double conversion-rate variation. Appropriate proposals have been made to ESA's Administrative and Finance Committee and are being discussed by the Member States.

The database

In addition to the parameters necessary to backdate the budgets and interface correctly with the financial system (list of outputs, rules for backdating, exceptions and fixed amounts for the recharging, Declaration and subscription envelopes, grouping of sub-outputs into outputs, the default indices, all conversion rates for the national and ECU currencies), the history file (more than 300 000 records) maintains the results of calculations for all actual expenses, i.e. per sub-output, grand heading, currency and year, the amount spent, the backdated amount and the price-variation index to go from the year of the expenses to the previous one (Fig.10). When a printout is needed for a given output, the system recalculates the final coefficients from this database.

For the last actual expenses, a file contains all the detailed data, replaced every year by the new year's data (only the results per grand heading are kept permanently). This 'actuals' file contains per sub-output, subheading and currency, the price index used to backdate from actual expenses N to N-1 e.c., the amount spent and the amount backdated to the N-1 e.c. (Fig. 8).

A specific file contains the forecasts per sub-output, grand heading and year, for the current exercise.

A backdating-calculation example is given in Figures 11 and 12, and Figure 13 shows a typical schedule for such work.

Figure 10

HISTORICAL DATA KEPT IN THE DATABASE FOR OUTPUT X

GH	YEAR	CURR	OUT	ACTUALS N	BACKD TO DECL	PRICE VAR
5	1994	B1	X	0	0	1.029
5	1995	B1	X	722	672.4554312	1.031
5	1994	D	X	0	0	1.029
5	1995	D	X	2896	2686.255171	1.033
5	1996	D	X	454.965	382.848701	1.066
5	1994	DK	X	0	0	1.029
5	1995	DK	X	50	47.93567606	1.023
5	1994	F	X	0	0	1.029
5	1995	F	X	860.971	813.8439647	1.029
5	1996	F	X	142.091	131.4813377	1.015
5	1994	I1	X	0	0	1.029
5	1995	I1	X	94.31	94.3381273	1.031
5	1994	NL	X	0	0	1.029
5	1995	NL	X	1559.296	1448.913626	1.031
5	1994	XB	X	0	0	1.029
5	1995	XB	X	0	0	1.031
5	1996	XB	X	99.984	87.22992902	1.030
5	1994	XD	X	0	0	1.029
5	1995	XD	X	0	0	1.033
5	1996	XD	X	1391.682	1211.909691	1.030
5	1994	XDK	X	0	0	1.029
5	1995	XDK	X	0	0	1.023
5	1994	XF	X	0	0	1.029
5	1995	XF	X	0	0	1.029
5	1996	XF	X	891.251	812.6199304	1.030
5	1994	XI	X	0	0	1.029
5	1995	XI	X	0	0	1.031
5	1994	XNL	X	0	0	1.029
5	1995	XNL	X	0	0	1.031
5	1996	XNL	X	182	158.5238768	1.030

all price variation factors are kept back to the declaration for each currency needed

price variation between "N" and "N-1"

actual expenses backdated to the origin (Declaration e.c.)

actual expenses year N in ECU as recorded in EFSY price level N, exchange rates N

Figure 11

BACKDATING DONE IN 1997

OUTPUT : 999 - X at 1993 economic conditions

GH	CURRENT PRICE LEVEL	1995	1996	1997	Total
R	MISC. RECEIPTS				
1	STAFF EXPENDITURE	540.916			1,190.680
2	RUNNING EXPENDITURE	110.994			225.994
3	FACILITIES				-
4	CAPITAL EXPENDITURE	10.153			10.153
5	DEVELOPMENT	6,182.577	3,161.973	567.000	9,911.550
	Direct	6,844.640	3,161.973	567.000	11,338.377
6	RECHARGE ADM. SUPP. & SITE SERV.	761.040			1,670.580
7	RECHARGE OF VAR. SUPPORT COSTS	161.000			191.000
8	RECH. FIXED SUPP. COSTS & INVEST.	177.173			205.389
A	RECHARGE ADM. SUPP., SITE SERV. & OFF. AUT.				-
B	RECHARGE OF TECHNICAL & OPERATIONAL SUPP.				-
C	RECHARGE TECHN. INFRAST. & CAPACITY SUPP.				-
	Indirect	1,099.213	-	-	2,066.969
	Total	7,943.85	3,161.97	567.00	13,405.346
GH	BACKDATING FACTORS	1995	1996	1997	Total
R	MISC. RECEIPTS				
1	STAFF EXPENDITURE	1.0740			1.0534
2	RUNNING EXPENDITURE	1.0670			1.0389
3	FACILITIES				
4	CAPITAL EXPENDITURE	1.0210			1.0211
5	DEVELOPMENT	1.0730	1.1360	1.1270	1.0950
	Direct	1.0726	1.1355	1.1273	1.0893
6	RECHARGE ADM. SUPP. & SITE SERV.	1.0590			1.0407
7	RECHARGE OF VAR. SUPPORT COSTS	1.0560			1.0528
8	RECH. FIXED SUPP. COSTS & INVEST.	1.0500			1.0468
A	RECHARGE ADM. SUPP., SITE SERV. & OFF. AUT.				
B	RECHARGE OF TECHNICAL & OPERATIONAL SUPP.				
C	RECHARGE TECHN. INFRAST. & CAPACITY SUPP.				
	Indirect	1.0570			1.0424
	Total	1.0704	1.1355	1.1273	1.0818
GH	ECONOMIC CONDITIONS LEVEL	1995	1996	1997	Total
R	MISC. RECEIPTS				-
1	STAFF EXPENDITURE	503.688			1,130.269
2	RUNNING EXPENDITURE	104.005			217.529
3	FACILITIES				-
4	CAPITAL EXPENDITURE	9.943			9.943
5	DEVELOPMENT	5,763.742	2,784.613	502.954	9,051.309
	Direct	6,381.378	2,784.613	502.954	10,409.050
6	RECHARGE ADM. SUPP. & SITE SERV.	718.749			1,605.297
7	RECHARGE OF VAR. SUPPORT COSTS	152.462			181.422
8	RECH. FIXED SUPP. COSTS & INVEST.	168.744			196.208
A	RECHARGE ADM. SUPP., SITE SERV. & OFF. AUT.				-
B	RECHARGE OF TECHNICAL & OPERATIONAL SUPP.				-
C	RECHARGE TECHN. INFRAST. & CAPACITY SUPP.				-
	Indirect	1,039.955	-	-	1,982.927
	Total	7,421.333	2,784.613	502.954	12,391.977

actual expenses — forecasts

Actuals year N expressed at price level N and exchange rate N for each column (total given for information - it is a mix of e.c.) Data coming from EFSY

backdating coefficients - division of actuals figure by backdated figure (approximation)

backdated figure this figure is the result of the calculation, expressed at Declaration e.c. here : price level 93 and exchange rates 94

Conclusion

Backdating is an essential exercise for ESA to be able to calculate the Cost-at-Completion of programmes as defined in the Convention. The calculation system as defined and used for 'traditional' national currencies has already been adapted with the introduction of payments in ECUs. It will be further adapted in the coming months to accommodate the introduction of the Euro.

Figure 13

Typical Planning for Calculation

- February-March: Calculation of the backdating for the actual expenses (starts as soon as the ESA accounts are closed)
- April: Integration of the forecasts
- End May: Reporting in the Quarterly Report to Council

Figure 12

OUTPUT : 161 EMIR 2
Including sub-outputs :

DECLARATION ENVELOPE	:	366 300.000 KAU
FINANCED ENVELOPE	:	**153 956,000 KAU**
COVERED	:	42,03 %
REFERENCE ECONOMIC CONDITIONS	:	1995
CTC at current price level	:	156 673,000 **KAU**
CTC backdated at 1 995 **economic conditions**	:	153 957,793 **KAU**
Percentage of financed envelope	:	100,00 **%**

SUMMARY OF YEARLY COSTS

	Current Price Level	Backdated to reference 1 995
1996	839,000	826,601
1997	14 895,000	14 636,022
1998	37 323,000	36 678,814
1999	36 818,000	36 182,508
2000	34 760,000	34 159,596
2001	30 897,000	30 361,466
2002	1 141,000	1 112,786

High-Performance Heat Shields for Planetary Entry Systems

R. Rouméas
Structures and Mechanisms Division, ESA Directorate for Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

T. Pichon & A. Lacombe
SEP Division, SNECMA, Bordeaux, France

Given that the mission scenarios of several potential future European space projects will require spacecraft entries into the atmospheres of various planetary bodies, including Earth, a number of advanced heat-shield technologies are currently under investigation. Besides the cold-structure option using materials such as beryllium, SEP has been developing a very promising concept using a hot structure of carbon/carbon or carbon/silicon-carbide. Depending on the particular mission requirements, this hot structure can be protected from extreme heat fluxes by an additional ablative layer. This modular approach, which allows the thermal protection system's performance to be tailored to the exact needs of the mission, forms the basis of the Sepcore® concept (Fig. 1).

The Sepcore® concept

The Sepcore® concept has a three-layer sandwich structure which can be adapted to a specific mission profile. The core of the system is a high-temperature-resistant ceramic matrix composite structure onto which a thin ablative layer is deposited. The payload is protected from the hot structure by a lightweight insulator. This layering approach allows one to design the heat shield with just the strictly necessary thickness of ablative material, which will be charred. The additional thickness of ablative material used in conventional heat shields to soak up the extra heat is replaced in the Sepcore® concept by lightweight internal insulation.

The main advantages of this concept are a potential mass saving of up to 50% (depending on the mission), its adaptability to particular mission requirements, and an increased failure tolerance due to the high temperature capacity of the carbon/silicon-carbide (C/SiC) structure.

The Sepcore® mock-up

In order to investigate the manufacturing feasibility of the Sepcore® concept, a reduced scale mock-up was designed and manufactured (Fig. 2). The mock-up's design complied with the high-energy reentry requirements of the proposed Comet Nucleus Sample Return (CNSR) mission (Fig. 3). The mock-up itself is made up of several components:

- a 15 mm-thick carbon/phenolic ablative heat shield
- a 1 mm-thick C/SiC hot structure stiffened by stitched and co-infiltrated 15 mm-high stiffeners
- an RTV bonding layer between the ablative layer and the hot structure, to prevent voids during assembly
- a high-temperature fastening system including carbon/carbon (C/C) screws, one central insert and three lateral inserts
- an isostatic six-strut payload-support structure
- an internal lightweight multi-layer insulation made of radiative barriers held in place by alumina felt pads.

As the mock-up was practically manufactured to test standards, it was decided to upgrade and configure it for testing under conditions representative of a re-entry in the IRS plasma test facility in Germany, with the pre- and post-test analysis carried out by FGE in the United Kingdom.

Testing the mock-up

The fully equipped mock-up is a cylinder 400 mm in diameter and 220 mm long and weighs approximately 13.8 kg, the Sepcore® heat shield weighing just 2.3 kg. It was linked to the test facility's sample support system via special test equipment, as shown in Figure 4.

A plasma generator was used to apply a heat flux to the front face of the mock-up. The test gas used as the plasma source propellant was 80% nitrogen and 20% oxygen. The incoming flux was limited to the ablative layer, i.e. a circular area 320 mm in diameter, with the radial distribution indicated in Figure 5.

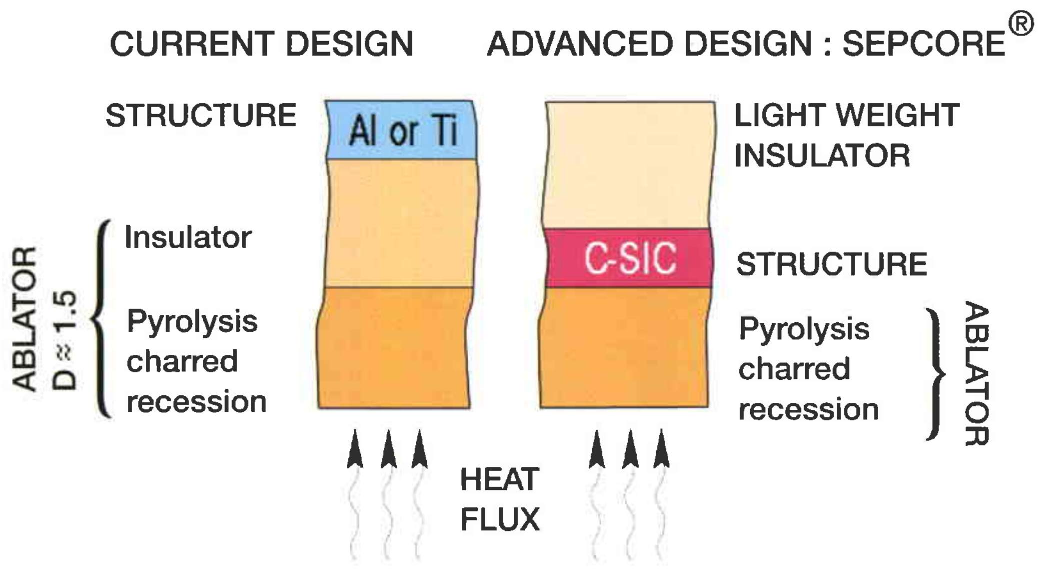


Figure 1. Current and advanced thermal-protection-system concepts

Figure 2. The Sepcore® mock-up

Preliminary testing on a graphite plate to check the possibility of achieving 10 MW/m^2 without interaction between test sample and plasma generator was carried out successfully. To avoid transient-phase heating, the plasma flow was ignited and stabilised with the mock-up in stowed condition. The mock-up was then moved into the test position as rapidly as possible to limit the transition phase from low heat flux to the nominal value of 10 MW/m^2 at an ambient pressure of less than 50 Pa.

The test end-criteria were :

- C/SiC structure back face temperature exceeds 1000°C
- aluminium struts reach 170°C
- testing time reaches 600 s.

Testing was stopped when the first criterion was fulfilled, after 270 s of firing.

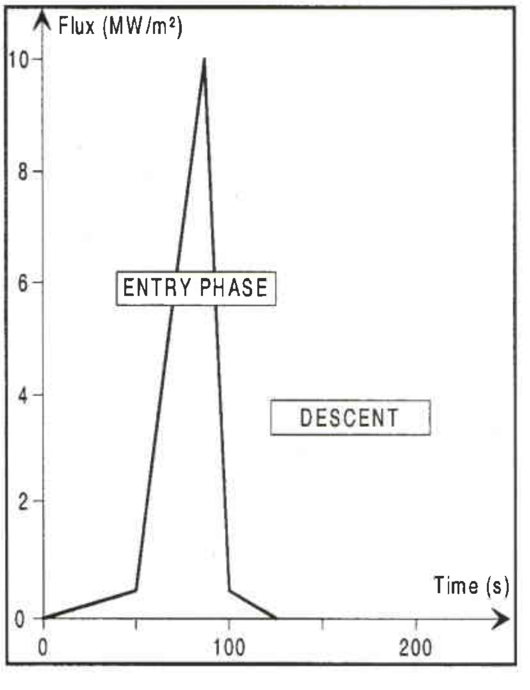
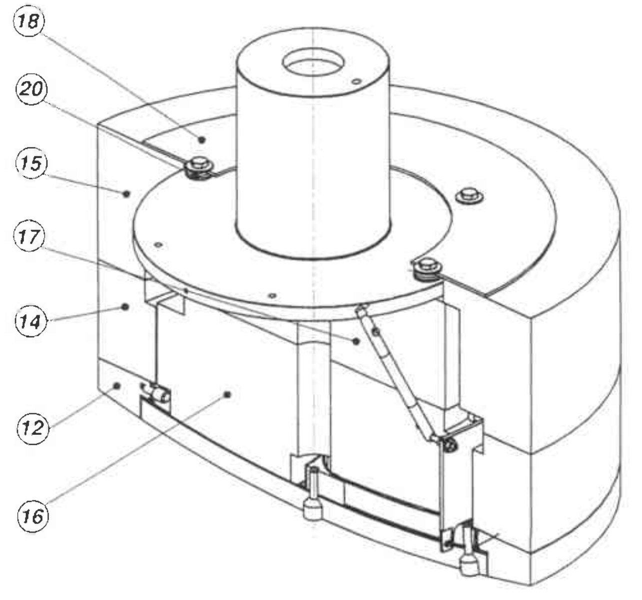


Figure 3. Re-entry heat flux data for the CNSR mission

Figure 4. Mock-up test equipment



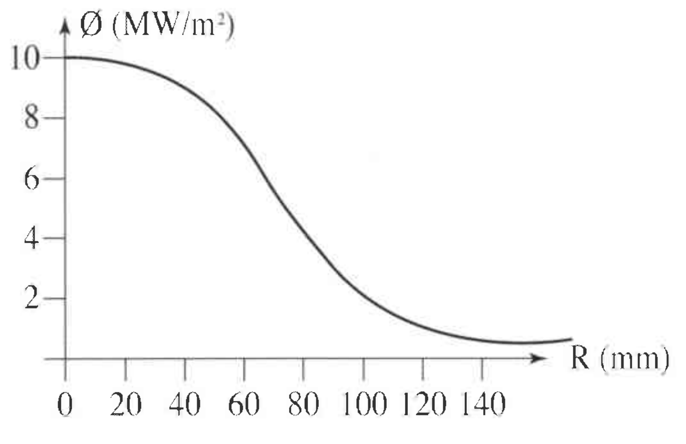


Figure 5. Heat-flux distribution applied in the mock-up test

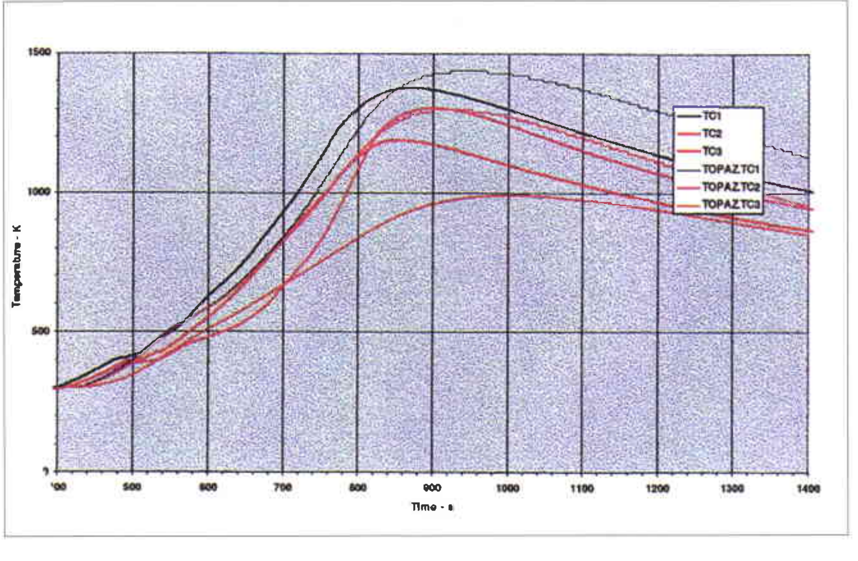


Figure 6. Test/analysis temperature comparison

Test results and analysis

The thermal performance of the Sepcore® mock-up was better than first predicted by analysis, which shows good design potential for further mass reduction in the ablator. After readjusting the material properties in the analytical model, good matching was achieved between the test results and calculated temperatures.

Satisfactory mechanical prediction was also achieved for the stiffeners of the C/SiC structure. Results on the skin were not as precise, due to insufficiently refined modelling of the link between the ablator and the structure. Escape of the pyrolysis gasses through the venting holes proved to be very efficient, contributing to the lower temperatures observed. On the other hand, the ablator delaminated from the C/SiC hot structure at the end of the test, in the region where the ablator plies were not drilled. This proved that it is necessary to vent the entire ablator.

A characterisation and morphological analysis was performed which confirmed the tensile failure mode of the C/C screws, due to the pressure build-up of pyrolysis gasses in the unvented part of the ablator. It also showed that the ablative material was fully pyrolised, but without any surface recession, which indicates a higher than expected surface enthalpy during the test. The C/SiC structure was undamaged.

Technology testing

Two sets of technology test samples were also designed and tested in SEP's Bordeaux (F) laboratory and ETCA's Odeillo (F) solar furnace

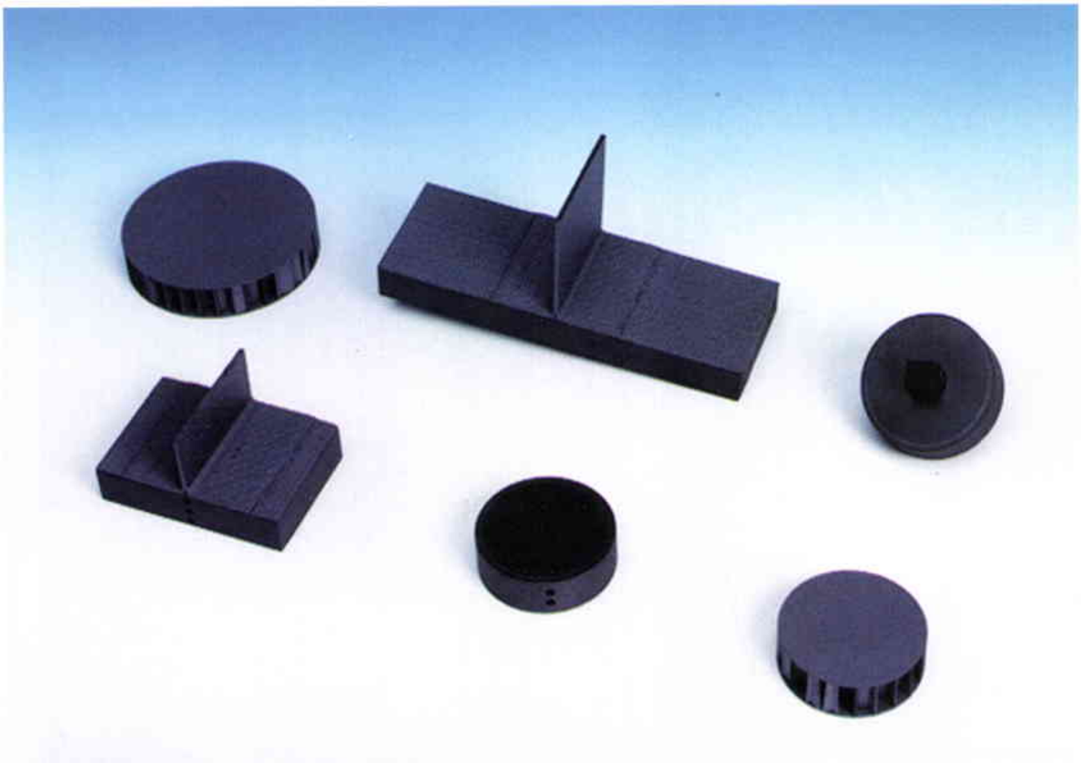


Figure 7. The technological test samples

in support of the experimental validation of the Sepcore® concept (Fig. 7). The objectives were twofold:
- to represent those zones of the Sepcore® mock-up, and hence also of the heat shields, that exhibit very specific behaviours under thermal and mechanical loads, in order to improve our overall understanding
- to evaluate candidate improvements to the Sepcore® concept, with a view to implementing them in future developments if they proved interesting.

The sets of test samples were manufactured to be representative of:

- the link between the skin and the stiffener of the C/SiC hot structure
- assembly technologies between the ablative layer and the C/SiC hot structure
- a C/SiC sandwich to be used for the hot structure.

The skin/stiffener link test specimen showed that the concept of sewn and co-infiltrated parts could withstand the thermal and mechanical loads encountered during a re-entry. The assembly technology specimen demonstrated that the concept is indeed suitable for the planned application, but that special care will have to be taken to dimension the insulation beneath the bolts correctly, as the heat fluxes are higher in this area due to the higher conductivity of the screw. No delamination between the ablator and the C/SiC hot structure was observed.

Direct moulding of the ablator onto the C/SiC hot structure was foreseen as an alternative means of bonding the ablator. However, this proved not to be feasible and the RTV bonding was retained as the baseline solution.

Finally, although the C/SiC sandwich hot structure is interesting due to its high specific stiffness, it is not sufficiently well developed to be incorporated into the Sepcore® concept. In particular, the bonding between the C/SiC honeycomb structure and the two skins will have to be improved, so as to prevent premature delamination.

Conclusion

The tests described above demonstrated that the thermal performance of the Sepcore® mock-up is better than first predicted by analysis, providing the potential for further mass reduction in the ablator whilst maintaining the same level of performance. Both the concept and its architecture have been proven, and a modular, low-mass, high-performance heat shield is now available for the European reentry vehicles currently under development and for future missions with similarly demanding requirements. esa

Advanced Tools for Efficient On-line Support of Test Campaigns

P. Deloo
ATOS BV, Leiden, The Netherlands

M. Klein
Structures Division, ESA Directorate for Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

J. Merlet
Intespace, Toulouse, France

Two new tools have been developed for processing vibration test data: one for comparing responses from different tests, and one for predicting the notches in an intended excitation profile. The 'Test Comparison' tool allows the automatic comparison of responses in two or more tests, such as pre- and post-test low-level runs. The quality of the match is given in terms of numerical indices and a flexible, user-friendly interface permits an efficient assessment of the results. The 'Notching Prediction' tool computes the notches required for a given excitation profile, knowing the responses to a previous excitation profile and the maximum accelerations allowed for each sensor. The new excitation profile incorporating the possible notches is computed automatically based on all the responses selected by the user. Various options are available to customise the processing. These new tools have been used to support the recent qualification testing of the Polar Platform and XMM.

Introduction

Vibration test campaigns for the qualification and acceptance of spacecraft structures are usually expensive to run. Test duration is one major driver of the total cost and solutions for performing the various tasks more quickly have to be applied wherever possible. One area in which time-savings are possible is the processing of the test results. Indeed, once the spacecraft has been instrumented and installed on the shaker, most of the time spent is related to assessment of the results from the latest run and definition of the strategy for the next one. These activities usually take several hours, and sometimes days, while the vibration run itself lasts only a few minutes. This is even more critical for tests using a multi-axis vibration facility, where tests in all axes can be performed sequentially without down time for spacecraft orientation changes.

To minimise the duration of a test campaign, it is therefore essential to speed up the evaluation of test results as much as possible by employing efficient tools. In fact, such tools are becoming indispensable as the spacecraft become more and more complex and the amount of data to be examined is growing enormously as a consequence.

The two new tools, which have been developed in DynaWorks 4.0, form an additional optional module of the DynaWorks package called the 'Sine Vibration Tool Box'. The development effort was conducted by Intespace in Toulouse, under the technical supervision of ESTEC's Structures Division.

Test comparison

To verify that a spacecraft or its subsystems have not been adversely affected by a full-level vibration test, a low-level run is again performed and the responses obtained compared with those of the initial low-level run. The most common method of comparing responses is to superimpose the printouts of the two runs for each measurement point, which is time-consuming and cumbersome, particularly for heavily instrumented spacecraft, and sometimes not appropriate if the plotting scales are different. In addition, this procedure is prone to human error and significant differences in responses can easily be overlooked. The new automated tools that have been developed in Dynaworks 4.0 make the comparison more reliable, as well as simplifying and speeding up the overall comparison process.

The 'Test Comparison' module is a user-friendly tool enabling the user to automatically compare the responses from tests on one or more specimens and to detect any deviations. The latter could be due, for instance, to structural damage resulting in frequency shifts and/or different response spectra. Two or more tests can be compared simultaneously, and they can be of the same or different excitation levels, e.g. two low-level tests and a qualification test.

The test comparison consists of four main steps :
- preparation
- comparison
- display, and
- diagnosis.

Preparation
This is an interactive step to define the tests, the responses to be compared and the options to be used in the comparison. The preparation window is presented in Figure 1. The selection of tests and responses is extremely easy due to the archiving and retrieval capabilities of the DynaWorks database system. Just a cut and paste on a single database element is necessary to select all the responses of a test. A pairing table to establish correspondence of the sensors from different tests can be created automatically when the second or subsequent tests are specified. Manual updating of this pairing table is also possible for customised applications. An option to apply a function to the responses before performing the comparison is also available.

Comparison
This step prompts the user for the selection of an indicator and runs the comparison. Indicators compute index values which are a measure of the correspondence between responses*. There are four categories of indicator: 2D, 3D, Peak and MinMax.
- The 2D indicators provide one index value per sensor and per test pair for the whole frequency range of comparison.
- The 3D indicators provide one index value per sensor, per test pair and per frequency point.
- The Peak indicator computes an index value for a given number of response peaks selected by the user.
- The MinMax indicator is identical to the peak indicator, but is applied to maximum and minimum peaks.

Display
Once the comparison has been performed, the results are displayed in several windows as:
- a plot of the repartition and cumulative distribution of indices as a function of the index value (Fig. 2), providing an overview of the quality of the agreement between the responses used in the comparison
- 3D plot of 2D index values as a function of the tests and sensors (Fig. 3)
- 3D plots of 3D index values as a function of tests, sensors and frequency, the magnitude of the index being given as a fringe plot.

Selection criteria are available to display only indices in a given range, for instance indices greater than a specified threshold. This is particularly useful in combination with the

*A low index indicates a good correspondence.

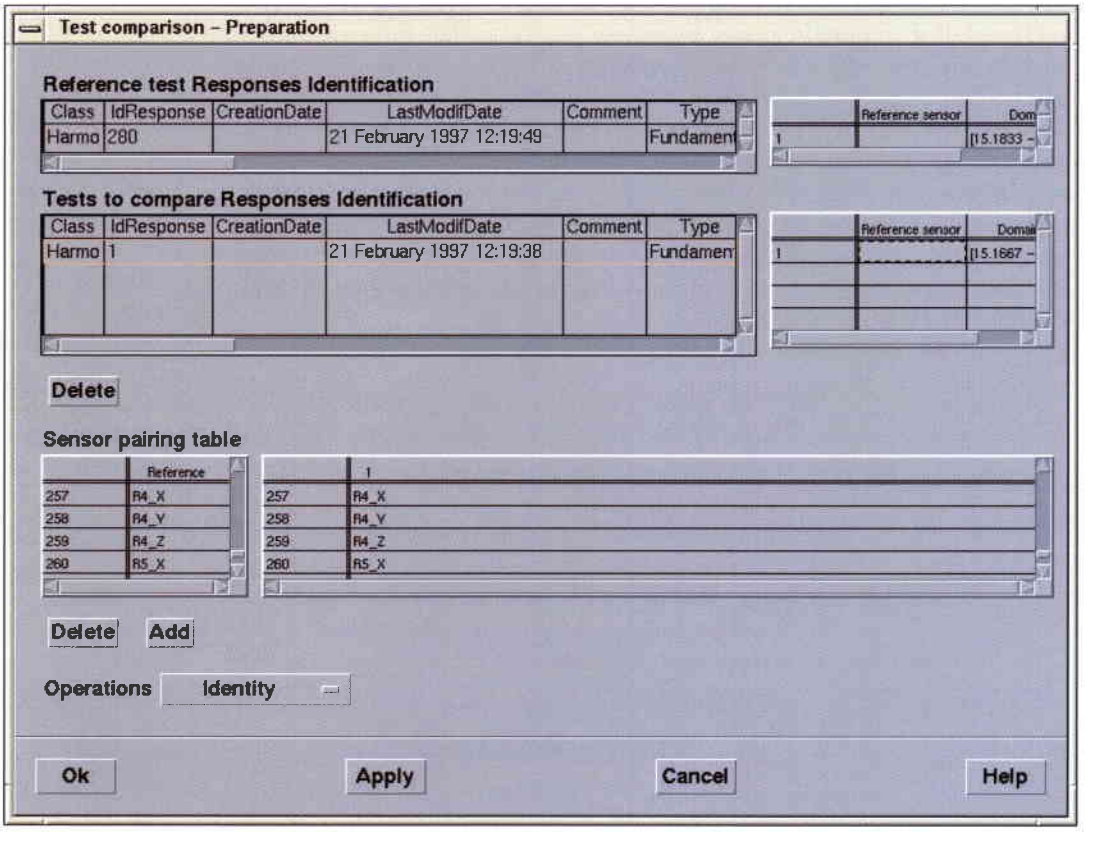


Figure 1. The Test Comparison preparation window

Diagnosis feature to identify sensors exhibiting larger deviations than a pre-defined maximum limit.

A Status window can be displayed informing the user in which registers of the analysis window the data being displayed are located.

Diagnosis
The diagnosis step is designed for the graphical examination of responses having generated an index that meet the selection criterion. A database view of the Response class opens automatically (Fig. 4). It contains only the curves satisfying the criterion defined in the display step. Simultaneously, a 'graphic' window (Fig. 5) is opened displaying the selected curve in the 'view on database' window superimposed on the response of the reference test to which it was compared (according to the pairing table).

A dynamic link between the 'view on database' window and the 'graphic' window allows the automatic updating of the latter when another record is selected in the 'view on database' window. Selection only requires a mouse click or the pressing of an arrow key to move to another record. This feature provides a very efficient means of going through all responses satisfying the selection criterion.

Application
The module was applied in the framework of the Envisat/Polar Platform and XMM qualification testing at ESTEC. The results of the comparisons were available shortly after the tests, allowing the project engineers to hold their post-test assessment meeting without delay. Most of sensors exhibited indices lower than the agreed maximum threshold and did not require additional work. The few sensors that did exhibit higher than threshold values required further inspection and so plots with superimposed responses generated for these sensors were examined for acceptance on a case-by-case basis.

This represented the first application of the new tool in a real tests and the efficiency of the on-line support was much appreciated by the projects. Some potential improvements to the software that were identified during the Polar Platform tests were already implemented by Intespace for the XMM tests.

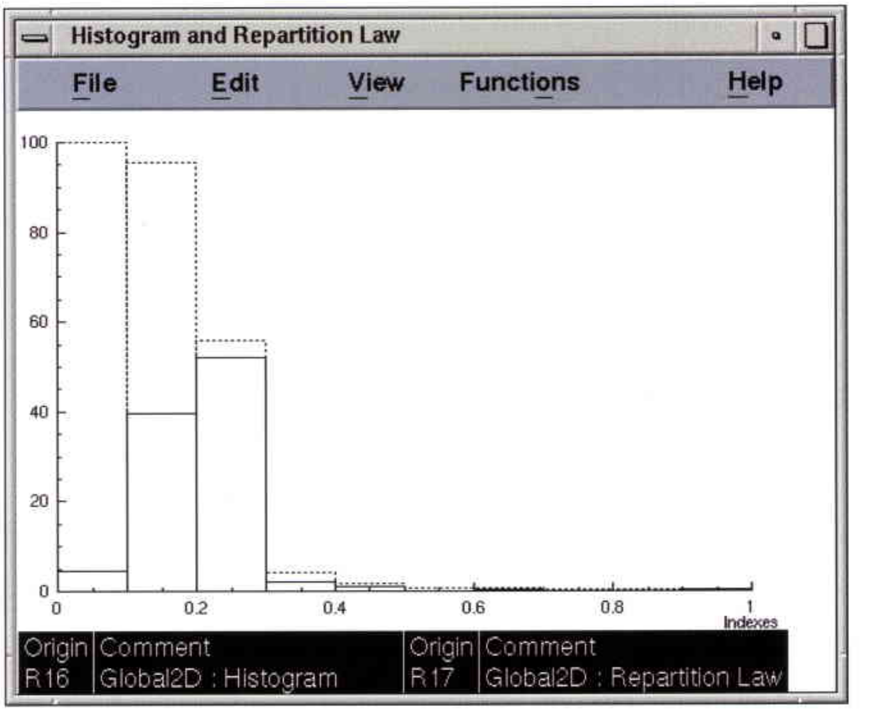


Figure 2. Distribution and repartition-law window

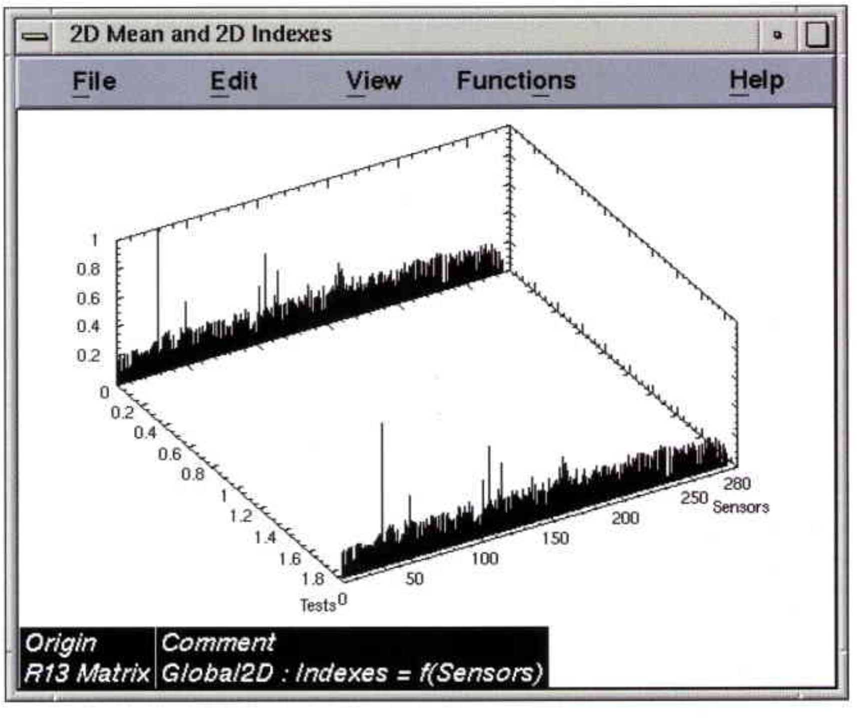


Figure 3. 2D mean and indices window

Notching prediction
In order not to damage a specimen/instrument, it is usually necessary to notch the shaker excitation in the frequency ranges of specimen resonance. The final notched profile is ultimately determined by extrapolation of the responses obtained during the low- or intermediate-level runs. The purpose of the 'Notching Prediction' tool recently implemented in DynaWorks is to automate this activity in order to speed up and increase the reliability of the derivation of the notched excitation profile.

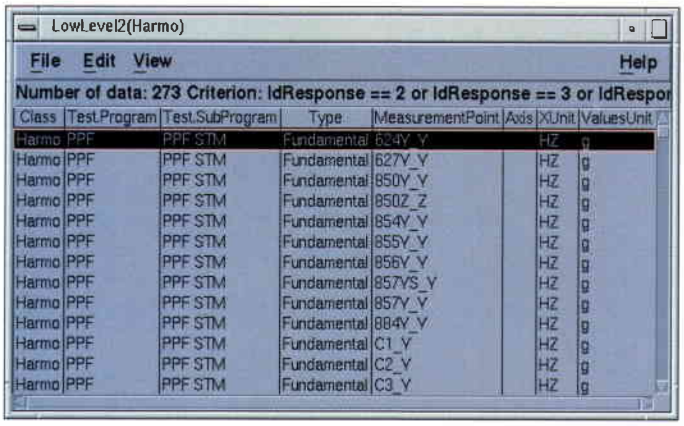


Figure 4. Database view of selected responses

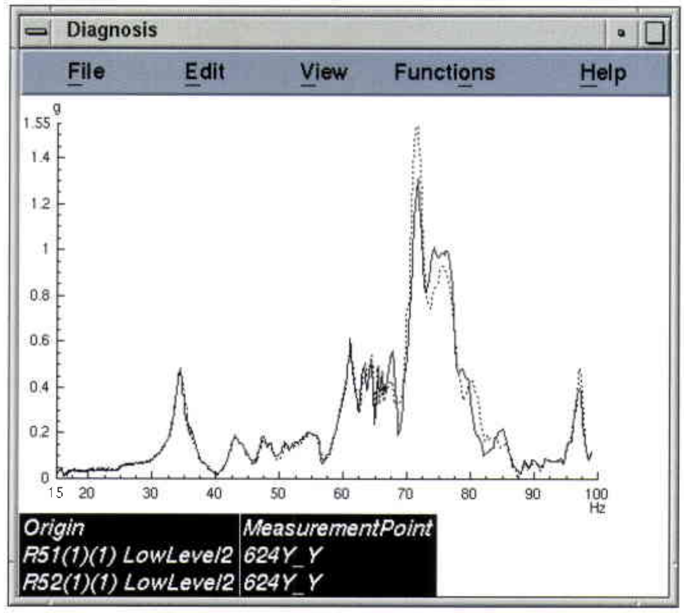
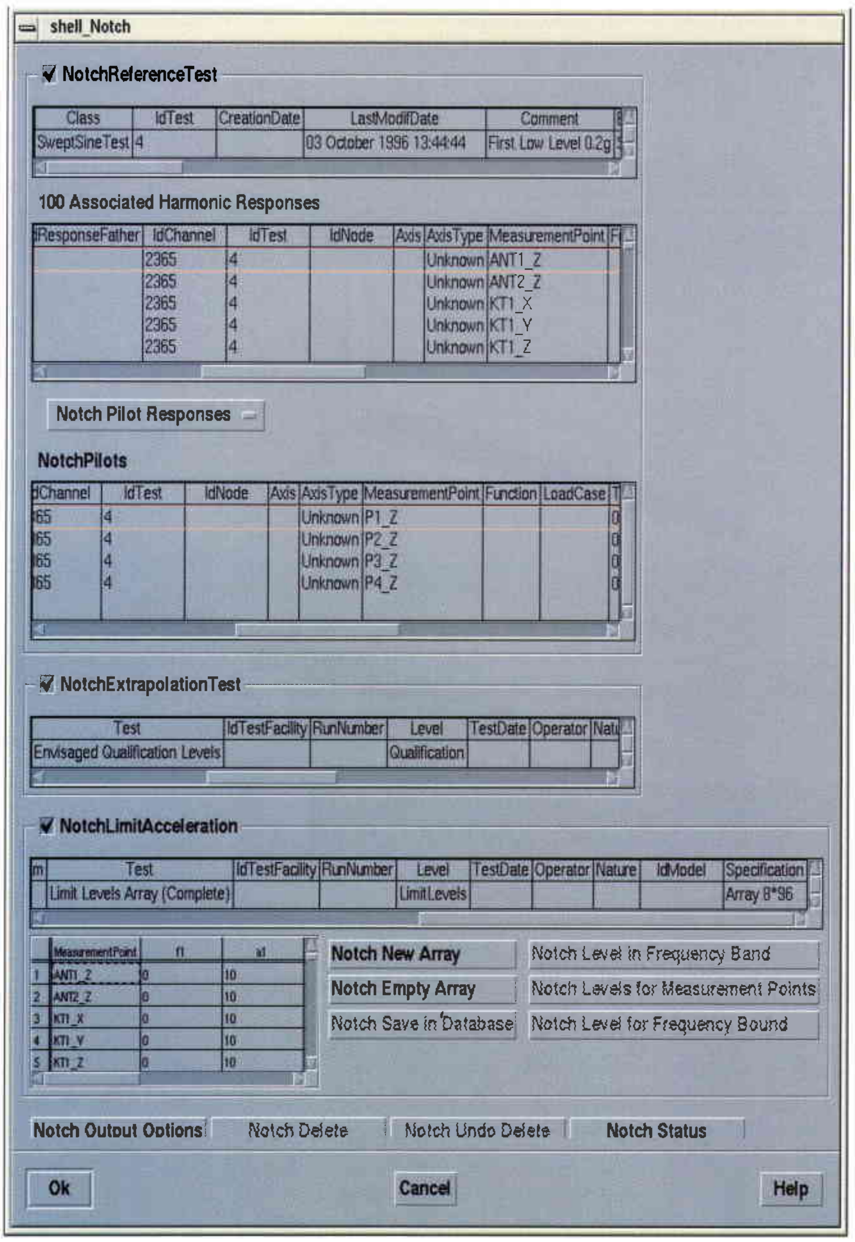


Figure 5. Diagnosis window

Figure 6. Data definition window



The 'Notching Prediction' tool computes the notches required to a given excitation profile knowing the responses to another excitation profile and the maximum accelerations allowed for a selected set of sensors. It consists of two main inter-active steps:
- definition of input data for the automatic prediction
- updating of the proposed notched profile with a graphics tool.

The process starts with the definition of the input data in the window presented in Figure 6, by cutting and pasting database items into the various areas on the screen. The items to be defined are:
- the reference test from the test class
- the associated harmonic responses from the response class
- the reference excitation from the response class if the pilot response option is selected
- the extrapolation test from the test class
- the limit acceleration table from the test class.

All responses of the reference test – for example a low-level test for which responses are already available – can be specified, or only a subset, according to the user's wishes.

There are two options for defining the reference excitation:
- *test specification*: the test specification stored with the test definition in the DynaWorks database is used
- *pilot average*: the average of a list of responses, usually the pilot responses, is used, and a new sub-window allows the definition of these responses for this option.

The extrapolation test is the test for which the notching prediction is to be made. The database item pasted into this area must contain the excitation specifications of the test. The table of limit accelerations contains the maximum allowable acceleration values per sensor and is unique for each test specimen, i.e. it does not depend of the excitation level for which the notching prediction is foreseen. Maximum limits can be defined for each sensor in multiple frequency bands. Built-in functionalities are available to help define this table easily.

Once all of the input data has been defined, the computation of the prediction can be started. After a few seconds, a graphics window appears with the profile of the new test with the derived notches. A table is also created providing, for each sensor, the maximum value in each frequency band and the ratio to limit the allowable acceleration defined for that sensor in that frequency band. A value greater than one indicates that a notch will result from that response.

Updating of computed specification

Two options are available in the graphics window for updating the computed notched specification. The first option is automatic. A notched excitation profile with constant levels which best fits the computed profile is computed based on the definition of a minimum frequency bandwidth and a tolerance on the level. The second option is to construct manually a minimum envelope either graphically with the mouse or by typing-in numerical data (Fig. 7).

The user has the option of storing the updated notched specification and some intermediate results in the database for later use.

Application

This module was also exploited within the framework of the Envisat/Polar Platform (PPF) qualification testing at ESTEC. The notched profiles generated have been compared with those derived by the contractor with a tool specifically developed for these qualification tests. In all cases, there was excellent agreement between the two sets of predictions.

The limitation of the DynaWorks tool available at the time of the PPF test has been removed in the version used for XMM. It relates to the definition of the excitation profiles and maximum allowable acceleration curves which could only be represented with constant values in each frequency range. It is now possible to have ramps in the definition of these items. Similarly, the notched specification updated manually can now incorporate ramps. esa

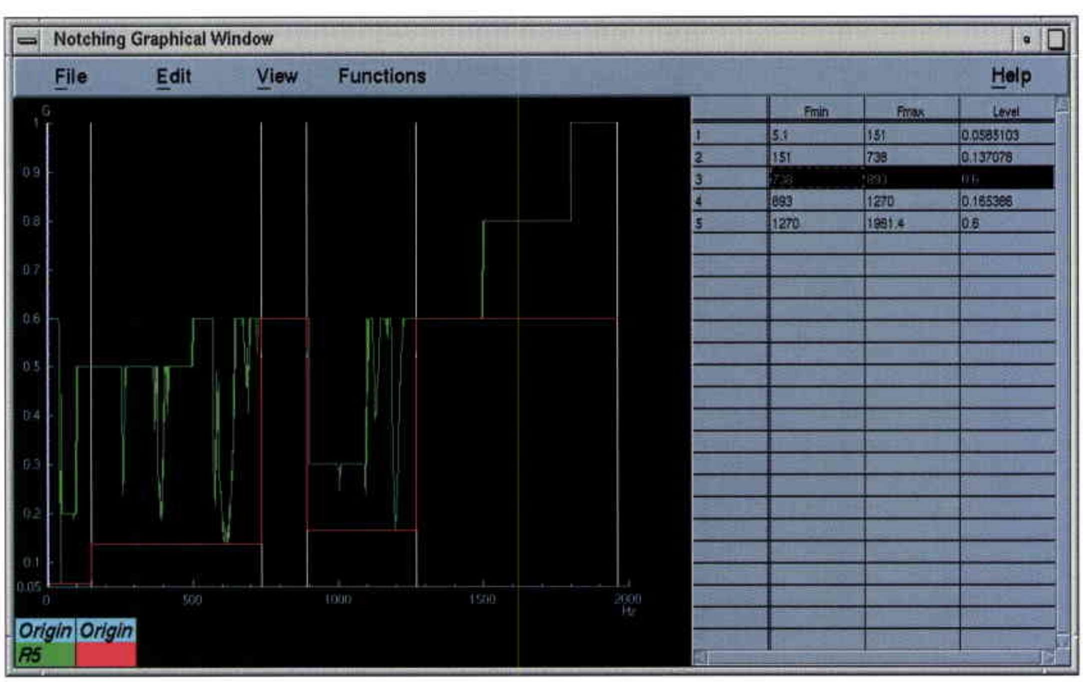


Figure 7. Graphical window

Space Marketing: A New Programme in Technical Education*

Ph. Willekens
Office of Space Commercialisation, ESA Directorate of Industrial Matters and Technology Programmes, Paris

W.A. Peeters
European Astronauts Centre, ESA Directorate of Manned Spaceflight and Microgravity, Cologne, Germany

Thirty years ago, space was in its infancy. The European space industry was almost non-existent and most international space programmes were driven by captive markets, not least Government orders associated with military programmes. With the development of commercial telecommunications satellites and new launchers, new services created new customers and the commercialisation of space was initiated. Today, this process has led to the development of new markets, each of which is at a different stage of maturity. Applications in the fields of navigation, direct-broadcast television and mobile telephony are just three examples of services for which the space industry has definitively taken the lead, investing its own resources and competing for market share on a world-wide basis.

Introduction: space markets

It is not easy to extrapolate market shares and turnovers in the rapidly developing space environment and certainly most predictions tend to be slightly optimistic. However, experts estimate that space activities will soon account for 70 to 100 billion US$ in annual turnover, and this relates only to the space segment; the associated ground segment is estimated to generate a similar turnover.

The challenge for European industry now is to maintain its market share with Ariane and to compete effectively in the global telecommunications and remote-sensing markets that have been initiated in the last decade.

Although Table 1 relates to two of European space industry's best successes, it does illustrate that after a delayed start we are now catching up in the World's space markets. If this trend is maintained, an annual turnover in range of 20 to 30 billion US$ can be achieved within the next decade. Clearly, in such a rapid-growth environment, the 'marketing' of space industry will be vital.

Marketing in space agencies?

Let us first examine the applicability of marketing in the context of non-profit organisations, and then see how the concept might be applicable to ESA:

Marketing in the non-profit sector

At first glance, one may have the impression that marketing techniques are less applicable for the non-profit sector. This was indeed the case until the end of the 1970s, but since then a number of elements have changed the macro-economic environment:

- Public funding has decreased and major cutbacks have been introduced, partly due to the fact that social priorities are being more vigorously pursued.
- Many non-profit organisations were founded upon income from donations, but the philanthropic nature of our society is decreasing.
- The economic structure has changed, with private companies 'attacking' the traditional non-profit sectors such as health care, public transportation, postal services, etc.
- Due to problems with government spending profiles, a number of protected markets have been 'liberated' and services privatised in order to reduce debts (telecommunications, airlines, motorways, etc.).

In such an environment, the non-profit sector is confronted with the same powerful competition as any commercial organisation. These competitors include the large space conglomerates offering end-to-end products. Of the 20 leading companies in the USA aerospace sector in 1980, only 10 were left in 1995 after the many mergers. A new wave of mergers in the last two years has reduced this figure to 3. European space industry is currently experiencing similar mergers and of the 5 largest European companies soon probably only 2 will remain.

Most non-profit organisations are reacting too late to such growing competition due to their internal resistance to change. They develop what is called a 'marketing myopia', as described by Ted Levitt from Harvard Business School in 1960, whereby they do not always

* Most of the concepts presented in this article have been extracted from courses given by the authors to young engineers and business students attending the European School of Management in Paris, the International Space University (ISU) in Strasbourg, and the Technical University of Delft, in The Netherlands

'Marketing is a pervasive societal activity that goes considerably beyond the selling of toothpaste, soap and steel. Political contests remind us that candidates are marketed as well as soap; student recruitment in colleges reminds us that higher education is marketed; and fund-raising reminds us that causes are marketed... Yet no attempt is made to examine whether the principles of 'good' marketing in traditional product areas are transferable to the marketing of services, persons and ideas.'

Philip Kotler, 1975

realise that such competition exists. This is not the case for industry, where falling profits and erosion of market share are early indicators of impending difficulties.

One example is provided by the commercial blood banks in the USA, which suddenly overtook the Red Cross in numbers of voluntary donors simply because the latter counted on 'fair-play' and the public's philanthropic attitude. Only a specially tailored marketing campaign emphasising such values partially recovered the situation.

Every organisation, whether profit- or non-profit-based, has to 'sell' a service to its 'customers'. Non-profit organisations are often asking for a sacrifice on the part of their customers (frequently in the form of donations) and have to convince them that, in return, they will give them 'value for money' in terms of economic, social or psychological benefits. This process is the real basis of marketing in the non-profit environment.

Marketing in the framework of ESA

ESA' s own objectives

Non-profit organisations are an essential ingredient for society's long-term survival. In a competitive market, industrial companies can only devote a small percentage of their funds to basic research; higher percentages would influence their overheads and hence their prices, and ultimately their mid-term survival. Moreover, industry concentrates mainly on applied research, to stimulate the development of new products and thereby enhance its competitiveness.

Where long-term objectives are pursued, which is essential for mankind's long-term prosperity, the development costs can only be borne by governmental or delegated bodies funded from taxes. When the funds involved are too high, cooperation at supranational level is often required, e.g. via CERN, the World Bank or UNESCO. Because objective performance measurement is more difficult in such organisations due to the lack of profitability indicators, there is obvious room for easy criticism and objective doubts. Therefore, the organising parties founding such organisations build-in a number of rules and mechanisms to maintain a certain degree of control over the effective use of resources. In ESA's case, such rules are contained in its Convention. Among its goals, ESA should contribute to the development of a European space industrial capacity, as well as supporting European space industry's competitiveness. On the other hand, ESA's procurement policy is also based upon these rules and is aimed at optimising these boundary conditions, which are not the same as those in a 'free-bidding' competitive environment.

It is important to recognise some basic marketing boundary conditions that stem from this:
- There can, a priori, be no competition between ESA and European space industry.
- Products to be highlighted are those with long-term potential interest for European industry (spin-off principle).
- Efficiency in pursuing these goals cannot only be based upon cost measurement. Emphasis has to be put on demonstrating efficient use of resources and the return — in tangible terms — to European space policy.
- Promotion of the development of European space capacity is the main objective.

One cannot stress sufficiently the difference between a budget-driven organisation and a profit-making, cost-driven, organisation. A non-profit organisation has a given budget and its aim is to ensure a maximum return in terms of its customer values within that budget.

Table 1. Evolution in European market share

Segment	Market Share 1970-1979	1980-1989	1990-1999
Communication satellites	0 %	25.2 %	28.1 %
Launch systems	0 %	31.8 %	41.5 %

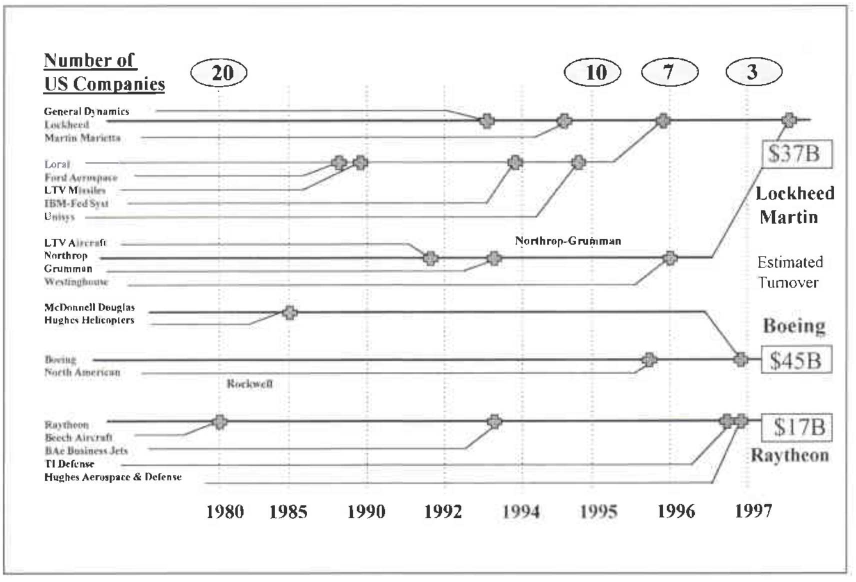


Figure 1. Space industry fusions and mergers in the USA

What are ESA's products and who are its customers?

ESA's customers at the end of the day are the taxpayers in the various Member States. Their expectations of the value of space are translated, via the science policy in each Member State, in a democratic process. As this process is relatively long and because some budgets are relatively fixed over longer periods, the risk is that changing expectations cannot be satisfied in the medium term.

In the USA, for example, the so-called Augustine-Committee concluded in December 1990 that the goals being set by NASA were not reflecting the expectations of the general public. In August 1991, a US House Subcommittee opened an investigation into NASA's management practices 'to learn why the Agency that for so long epitomised excellence has lost the claim to that honour'. The report was called 'NASA's Mid-life Crisis' and accelerated important changes.

The Sojourner, a relatively low-cost mission, which landed on Mars on Independence Day in 1997 and captured the nation's attention for several weeks with its pictures accessible via the World Wide Web (WWW), was a clear illustration of this changed, more marketing-oriented approach.

In ESA's case also, the general public wants to see definite European products:
- direct products, e.g. meteorological or Earth Observation data
- indirect products, e.g. spin-off
- non-tangible products, e.g. Space Station.

The direct product derived from the space programme itself consists of the successful launch and its associated services, data from the satellites, operational services, specific generic technology, etc. These products are tangible and form the basis of ESA's promotion and publication policy.

The indirect products are not only the spin-offs in the form of tangible products, technologies or techniques derived from space programmes and applied in non-space industrial sectors, but also include the intangible know-how and ESA's internal competence. These products are promoted with difficulty even if they touch the general public in their daily lives, e.g. surgery, automobile technology, energy and environment, etc.

Finally, the non-tangible products are those which can be derived from long-term space programmes. Although these have a clear set of scientific and technical objectives, there is room for the unknown, the unforeseeable. Political commitment to this type of product is hard to achieve.

The conclusion of the 'Council of Wise Men of Salamanca' about the proposal of Christopher Columbus, now more than 500 years ago, should perhaps be recalled here:

'There can be no justification for your Majesty's support for a project based on extremely weak foundations and plainly, to anyone who knows about such things, impossible to achieve.'

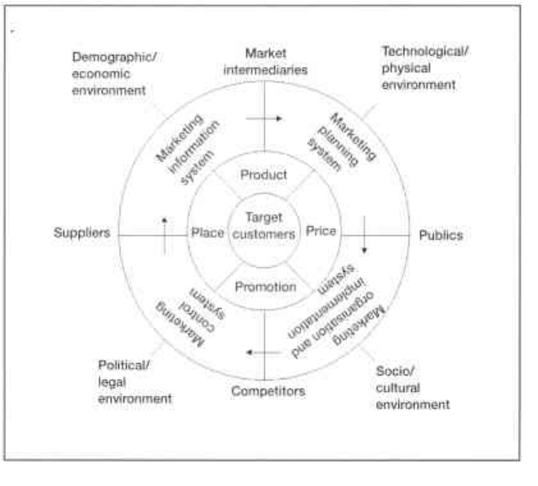


Figure 2a. The 4P's of P. Kotler's Marketing Mix

Figure 2b. Factors and components of a marketing strategy

Key questions if ESA is to play a more active role in the marketing of its direct products:

Product
- Can we define more precisely what the product line is? Example: ERS-1 and 2 series, followed by Metop and Envisat. How do we differentiate the different systems?

Price
- Can we estimate the benefits of the space programmes versus their costs? Studies performed by the University of Strasbourg have estimated that, for every ECU invested in the Ariane-4 programme, the direct revenue generated in industry is 4 ECU. Similar studies have been performed for the ECS and Meteosat programmes.

Promotion
- Can we advertise our products and services? Together with our partners?
- How can we measure the effects of a direct promotion campaign?

Physical Distribution
- What is ESA's role and position in Earth Observation operations and data dissemination vis-a-vis other organisations, such as added-value companies, user organisations, etc.?

But even more recently, in 1902, we find such statements as:

'Flight by machines heavier-than-air is impractical and insignificant, if not utterly impossible' (Newcomb)

What about the other P's of the Marketing Mix ?

With our students we have tried to identify a possible application to space programmes of the '4P's' of the classical Marketing Mix elaborated by Philip Kotler (see Figs. 2a, b).

ESA traditionally promotes its programmes as they are approved and on a case-by-case basis. In the Marketing Mix, 'Products' often refers to a 'Product Line', covering a whole range of satellite services or launcher family. In the case of Earth Observation, we would have to promote the series from ERS-1 through ERS-2 and subsequent missions such as Metop and Envisat as a family of products. A similar approach is followed with the Ariane launcher family, which offers a versatile launch vehicle easily adaptable to the customer's needs.

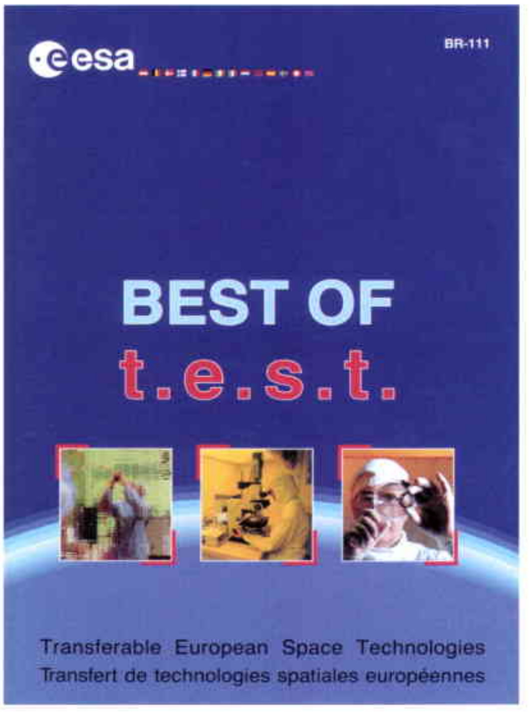
The notion of Product then leads to the definition of a 'Price', which of course will vary with the type of product and its conceived value. The price of products even from non-profit organisations such as ESA has to been seen as a cost, being the result from the taxpayer's standpoint of a political trade-off in terms of public investment against other options/activities. In general terms, the feeling of the average taxpayer is that space costs 'a lot'. It is a considerable shortcoming of the space era that such costs are not put in comparative, and therefore more realistic, terms sufficiently often. The development costs for a popular car can be 5 billion ECU, and those for a jet fighter, including a limited

Key questions raised in the case study on how to increase the ESA marketing action for technology transfer:

Product
- Besides ESA patents, how can we identify the ESA's internal and marketable know-how?

Price
- Can ESA 's expertise be charged to an external customer ? How can this consulting service be set up without disturbing ESA's core business?

Promotion
- Can we appear in the advertisements produced by companies which acquired ESA's technology? If so, how?



number of prototypes, of the order of 8 billion ECU. Even the organisation of the Olympic Games is costing about 2 billion ECU.

This brings us logically to the promotion of ESA activities, which has traditionally been targeted at the decision-makers and the specialised scientific and technical press. More recently, however, in response to the need to increase general awareness of ESA's programmes, pilot events have been organised with a new focus on youngsters and the general public. The special parabolic-flight campaigns for students, for example, have received substantial coverage in the general press. Demonstrations and animations tailored specifically for the general public have also shown that, even in the very particular forum of the Le Bourget Air & Space Show, a considerable amount promotion can be achieved if the appropriate messages and presentation style are used.

In today's rapidly growing information society, Place or Physical Distribution of results is an important topic. Modern communications tools allow the results to be conveyed directly to the customer, and we no longer need to bring the customer to the results. For example, NASA, anticipating that the Sojourner rover's exploits on Mars would be of considerable interest to the general public, installed 25 Web servers. Even they, however, had not counted on a peak of 35 million 'hits' per day, which completely overloaded the system. Systems like Teledesic can be expected to accelerate such developments exponentially. It is therefore of paramount importance to stay in tune with developments in the latest means of communication and use them appropriately.

Case studies

Marketing ESA's direct products

ESA's direct products such as the remote-sensing data and telecommunications-satellite services, the Ariane launcher and the ground operations systems, are easy to analyse from a marketing standpoint since they represent the Agency's 'core products'. The marketing and commercialisation of these products and services has been transferred, with a few exceptions like Earthnet, to public institutions or private companies such as Arianespace, Eurimage, Eutelsat, Eumetsat, etc. These organisations are in charge of the marketing of the remote-sensing data products, the launch services, the telecommunication operations, etc. ESA's part in the marketing activity is limited to the promotion of the approved programmes and their results, with the main objective of fostering the decision-making process and the approval of new programmes for the future. Having no resources for advertisements or publicity, ESA's effort to promote its programmes to the general public is presently limited to just a few events such as Le Bourget Air & Space Show, the Farnborough Air Show, ILA in Berlin, etc. As far as educational activities are concerned, ESA's effort is limited to supporting national initiatives with the aim of adding a 'European dimension' to such events.

Marketing technology and technology transfer

The marketing of space technology, and technology transfer from space to non-space industrial sectors, has been delegated to Spacelink Europe, a network of brokers working under contract to the ESA Office of Space Commercialisation. This Technology Transfer Programme is a good example of the more active role that the Agency can play in marketing its technology and knowhow.

Initially, the marketing technique used was a 'push' approach, with promotion through a catalogue of space technologies that have real potential for application in a non-space sector. These TEST Catalogues were largely distributed to European industry. Although they served as a showcase for the best transferable space technologies, experience showed that as a marketing tool it was not sufficient. Specific parts of the catalogues were therefore selected and direct-mailed to target industrial groups. From the 2 to 3% response to the TEST catalogues, the response rate grew to more than 10% with the direct mailing. The new method was complemented by a marketing 'pull', consisting of contacting industrial companies in various target sectors to identify their technology needs. The resulting matching of the 'market's needs' with the 'space technology on offer' has led to several successful technology transfers.

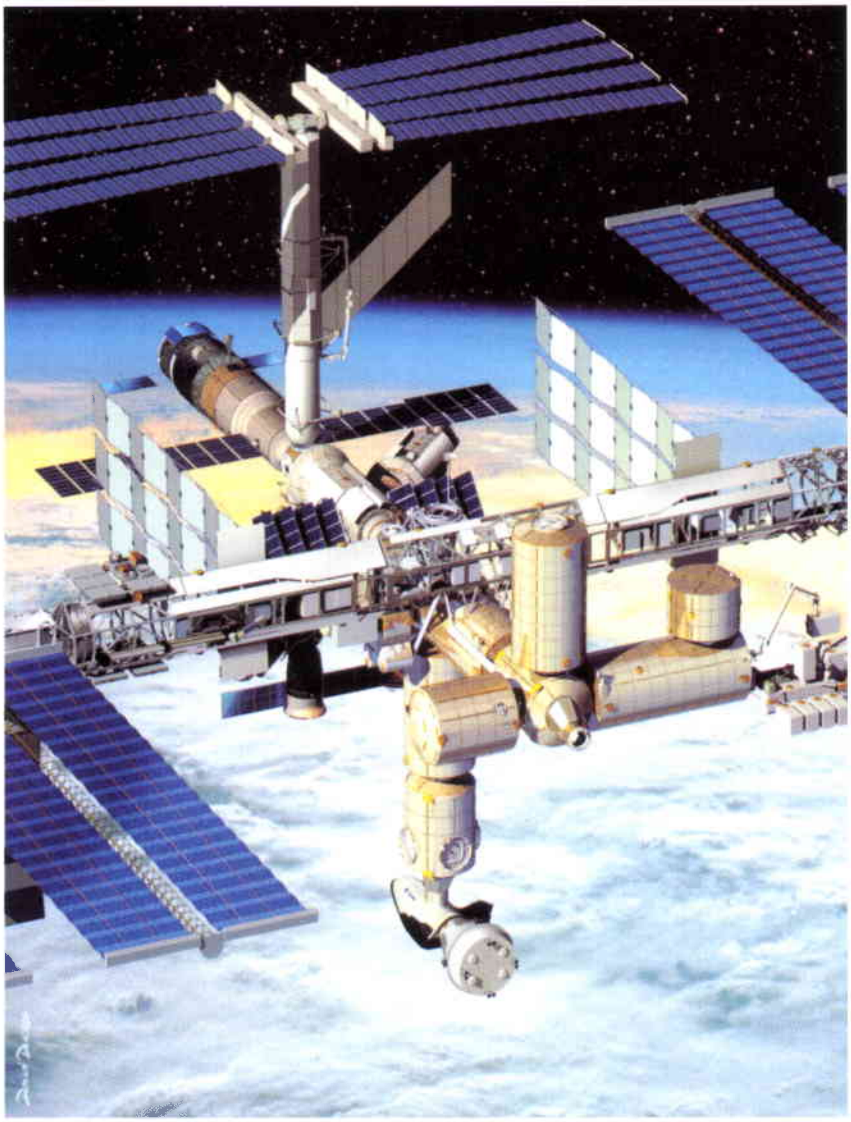
Another marketing technique that appears well-suited for technology transfer or exchange relies on the concept of 'interactive marketing'*, which involves anticipating the need for new technologies in two or more industrial sectors. In ESA's case, the idea is to search for non-space applications of a space technology before starting development of this technology. This method has been introduced into the ESA Technology Research Programme (TRP) by adding a 'commercial evaluation clause' in the contracts, requiring the contractor to study the commercial potential of the proposed technology for non-space applications. The first test cases showed that the early identification of potential partners or customers in sectors such as the offshore, chemical, pharmaceutical and biomedical industries, would not only offer a possibility to share part of the development costs of the technology, but would also avoid the heavy adaptation costs that, in the past, have blocked the commercialisation of several space technologies.

The closer interaction between the space industry and the non-space industrial sector has facilitated the transfer of knowhow and has thereby contributed to the success of the Technology Transfer Programme. In less than seven years, the Programme has resulted in more than 70 successful deals, accounting for more than 4 MECU in revenue for the space donors and a turnover of more than 30 MECU for the recipient companies.

Marketing the International Space Station
In terms of a Product, the Space Station has a number of unique benefits in the technical field:
- continuity of experimentation thanks to the long design lifetime
- availability of larger resources than previous stations (power, data capacity)
- quick access for samples, specimens etc. to and from space
- permanent presence of crew who can take care of unexpected events.

The difficulty with the Space Station is that the characteristics of the Product are of different natures: scientific, technical, socio-economic and geopolitical.

Although the subject of lengthy negotiation, the scientific use of the Space Station is being intensively prepared by the International Partners, with a strong focus on the life- and



materials sciences in order to derive maximum benefit from the astronautsí presence in the laboratories. However, use of the Space Station for technology development has been attracting substantial interest from industry, particularly since the last Call for Ideas and Proposals issued in 1997. Nevertheless, the strongest motivation for the Space Station is probably non-tangible. The international dimension of the project has no past equivalent. It will be a unique multi-cultural endeavour, a typical viewpoint being :

'It is fair to say that the International Space Station Programme is a test bed for future international space cooperation (...). The International Space Station collaboration is widely viewed by the nations participating as a test of our ability to sustain commitment over the long-term to a complex science and technology project.'

The price that we have to pay for this is certainly still the biggest problem when trying to 'sell' the Space Station in absolute terms. More

* Interactive Marketing, by Jean-Marc Lehu, Les Editions Organisations, 1996

Examples of questions raised about the marketing of the Space Station:

Product

- Can we market the Space Station emphasising the non-tangible product, namely the 'space frontier' dimension? Should we emphasise the Space Station as a self-standing product or as a stepping-stone for interplanetary space exploration ?

Price

- Could we approach the general public with dedicated relative cost indicators (market survey)?

Promotion

- Should we allow commercial sponsorship on the Space Station ?
- What about creating a cartoon character to represent the COF? Such a character could be used to promote the Space Station to youngsters in the various countries?

Physical Distribution

- How do we establish the link with the non-space industry to encourage them to propose experiments to be conducted on-board the Space Station? The RADIUS (Research Association for Industrial Use of Space) was based on access to the industrialists by scientists involved in microgravity experimentation, who already have their networking and contractual relations with the various potential customers in the various industrial sectors such as the petrochemical, environmental and pharmaceutical industries. This approach led to the successful involvement of several private companies in the ground-based research, and some have even participated in the in-flight space experiments. In May 1998, for example, experiments prepared with a consortium of oil companies will be carried aboard the Space Shuttle.

than ever, it has to be stressed that the costs are spread over a large number of nations, bringing the cost per capita down to very acceptable orders of magnitude, namely annual costs of 10 ECU per person over the more than ten-year lifetime of the Station.

Scientifically, a different approach could be to compare the price of time in microgravity per kilogram. Such an assessment shows that the price will be in the order of 2 US$ per kg.h for the Space Station, compared with 17 US$ for the Space Shuttle.

As far as Physical Distribution is concerned, there are a number of techniques that can bring the general public closer to Space Station activities. The development of Computer Based Training Courses* which, besides being a training tool, can also be brought to the general public's attention via the World Wide Web (WWW), and the development of virtual-reality models distributed on CD-ROM are examples of means that can to help bridge the gap between the space world and the general public.

Conclusion

For non-profit organisations, as for commercial companies, 'marketing' involves a mixture of elements, analogous to the ingredients for a cooking recipe. The marketing 'strategy' forms the key for the preparation of a set of actions directed towards a clearly defined customer or target group. The various target groups as far as ESA is concerned are: the taxpayers (general public) as ESA's main 'end customer', the youngsters as ESA's future 'end-customers', the politicians, ESA delegate bodies, space industry, international partner organisations, operators of space systems, users of data supplied by space systems, etc.

By analogy with finance principles, ESA's 'net present value' could be compared to its accumulated successes, its present assets in terms of people and programmes, and its potential in maintaining European space industry in the forefront of the space-faring nations. The main difficulty is that the various target groups mentioned above have different perceptions of this value.

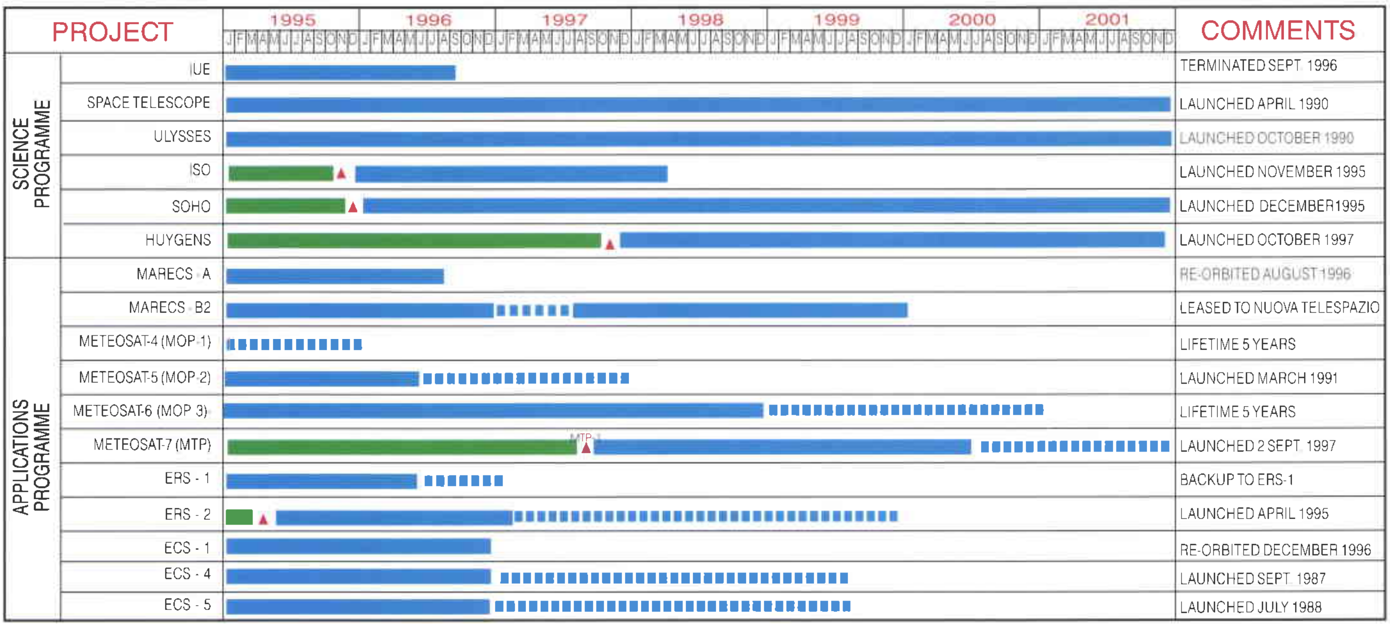
The advantage of elaborating a marketing strategy, even in a non-profit-making organisation such as ESA, is to increase confidence in the organisation's own capacity, identifying the key products — i.e. the 'technology champions' — and promoting these in the right format to the right target group. It also serves notice that the Agency is responding to its changing environment and actively focussing on new ways of doing business. esa

*http://www.estec.esa.int/spaceflight/astronaut/eaccbt/cbt.htm

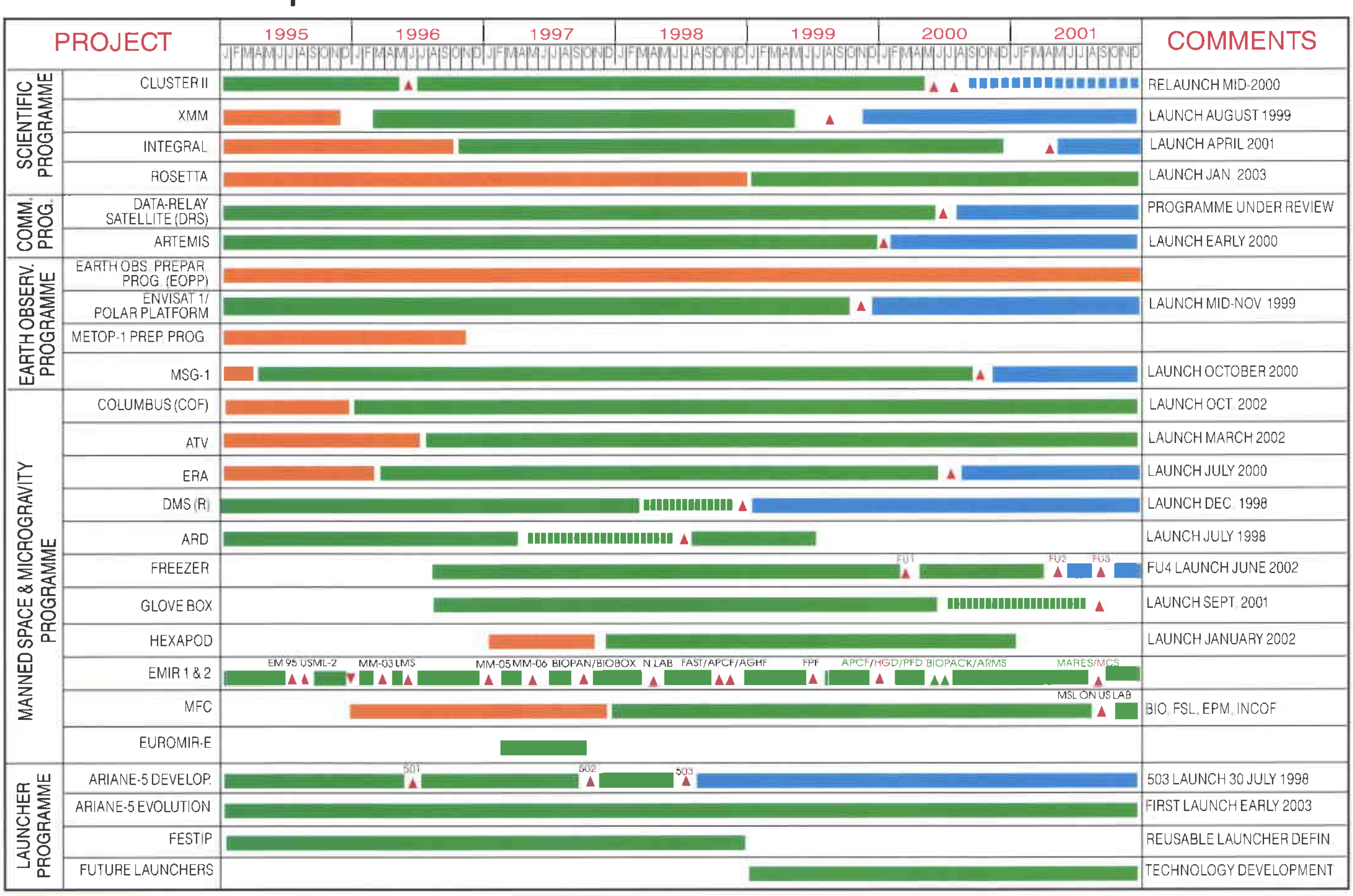
Programmes under Development and Operations
Programmes en cours de réalisation et d'exploitation

(status end February 1998)

In Orbit / En orbite



Under Development / En cours de réalisation



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

■ OPERATIONS ■■■ ADDITIONAL LIFE POSSIBLE ▼ RETRIEVAL ▮▮▮▮▮ STORAGE

ISO

La réserve d'hélium liquide d'ISO s'est épuisée le 9 avril, mettant ainsi fin à la phase d'opérations de routine parfaitement réussie de ce premier observatoire spatial du monde à travailler dans l'infrarouge. Cette phase a duré presque un an de plus que prévu. Les activités reviennent maintenant à une période d'un mois d'étalonnage et d'essais techniques avant la mise hors service du satellite à la mi-mai. Au cours des trois années et demie suivantes, les astronomes du monde entier vont mettre leurs efforts en commun pour analyser et étalonner de nouveau l'ensemble des 26 000 observations individuelles d'ISO afin d'en tirer le maximum d'informations de cette mission unique et de construire une base de données solide au service de la communauté scientifique au cours des prochaines décennies.

Le 8 avril à 07:00 h (heure locale), l'équipe de contrôle du satellite à la station sol de Villafranca près de Madrid a fait savoir que le télescope commençait à se réchauffer au-dessus de sa température normale de fonctionnement qui est proche du zéro absolu; ce qui signalait, pour la première fois, qu'ISO avait épuisé sa réserve d'hélium superfluide permettant d'atteindre de très basses températures requises pour faire de l'astronomie dans l'infrarouge. A 23:07 h, alors que les températures à l'intérieur des instruments avaient monté au-dessus de 4,2 K, l'ordre a été donné de couper le circuit. A ce moment, ISO était en train de faire des observations de polarisation dans la galaxie NGC1808 avec sa caméra (ISOCAM) pour l'expérience du Prof. J. Hough (R-U).

Au cours du programme d'essais technologiques, quelques-unes des principales activités consisteront à tester le fonctionnement des suiveurs stellaires aux basses latitudes, c'est-à-dire dans les ceintures de radiation, à utiliser les unités redondantes de bord qui n'étaient pas nécessaires lors des opérations de routine, et à évaluer le logiciel qui devait servir à surmonter les multiples défaillances du gyroscope. Au cours des temps morts du programme, les détecteurs des longueurs d'onde les plus courtes dans le spectromètre SWS seront utilisés pour mesurer le spectre de 2,38 à 4,08 microns de nombreuses étoiles afin d'étendre leur classification spectrale vers l'infrarouge. Une fois ces tests terminés, le périgée sera baissé au maximum et le satellite mis hors circuit. La rentrée dans l'atmosphère est prévue autour de l'an 2020.

Juste avant l'épuisement de l'hélium liquide, quelques-uns des tout derniers résultats d'ISO ont été annoncés lors d'une conférence de presse donnée à Londres. Parmi les découvertes, il convient de mentionner la détection de la vapeur d'eau sur la lune de Saturne, Titan - ce qui complète les nombreuses autres détections d'eau faites par ISO partout dans le cosmos, les détections d'étoiles jeunes dans la région d'Orion et les mesures des galaxies dans l'infrarouge à de très grandes distances (voir la rubrique 'In Brief').

L'analyse et l'interprétation des résultats d'ISO ne font que commencer. Toutes les données seront soumises à un nouveau traitement pendant l'été grâce à un logiciel dernier cri, et en automne une archive sera ouverte à la communauté des astronomes. S'ensuivra un programme de coopération, à coordonner au niveau international par le Centre des données ISO de l'ESA à Villafranca, pour exploiter au maximum les données et pour préparer la meilleure archive de référence qu'ISO puisse léguer aux astronomes du futur. De nombreuses autres découvertes nous attendent.

Cluster-II

La fabrication de l'équipement des satellites et des charges utiles a progressé conformément au calendrier établi, ce qui permettra d'entamer comme prévu l'intégration du premier des nouveaux satellites Cluster-II au troisième trimestre 1998. Quatre-vingt-dix pour cent des éléments de ce satellite ont été livrés aux sous-traitants. Les revues préliminaires de conception (PDR) du nouveau matériel – enregistreur à semi-conducteurs et amplificateur haute puissance – ont été réalisées avec succès. La modification des bras rigides servant de support à certaines expériences, qui doit permettre de loger le satellite dans la coiffe du véhicule de lancement Soyouz, a été acceptée.

L'analyse par Starsem de l'ensemble des éléments du lancement de Soyouz susceptibles d'influer sur la mission sera achevée à la mi-1998, avant la signature du principal Accord sur les services de lancement.

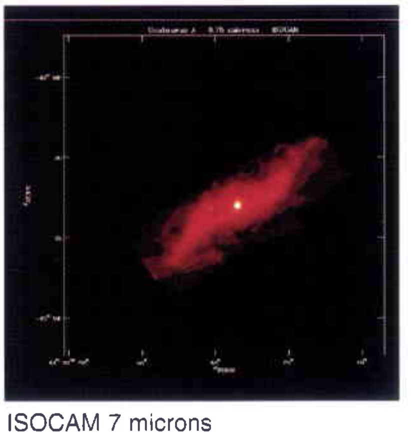
Centaurus A, as viewed by ISO's camera and other observatories

Centaure A vu par la caméra d'ISO et d'autres observatoires

Visible light

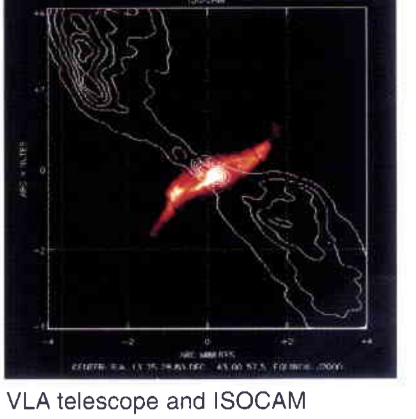
UK Schmidt telescope

Infrared



ISOCAM 7 microns

Radio (+ infrared)



VLA telescope and ISOCAM

ISO

ISO's supply of liquid helium ran out on 8 April, thus bringing to an end the highly successful routine operations phase of the world's first true orbiting infrared observatory. This phase lasted nearly one year longer than specified. Activities now turn to a 1-month period of calibrations and technology tests prior to de-commissioning of the satellite in mid-May. During the following 3.5 years, astronomers all over the globe will collaborate to re-analyse and re-calibrate all of ISO's 26000 individual observations to extract the maximum scientific return from this unique mission and to leave behind a legacy archive to serve the community for the next decades.

At 07:00 (Spanish time) on 8 April 1998, the spacecraft control team at ESA's ground station at Villafranca near Madrid reported that ISO's telescope was beginning to warm up, above its nominal operating temperature close to absolute zero. This was the first sign that ISO had exhausted the superfluid helium used to achieve the very low temperatures necessary for infrared astronomy. At 23.07, temperatures in the instruments had risen above 4.2K and the instruction to switch off was given. At the time, ISO was making polarisation observations of the galaxy NGC1808 with the camera (ISOCAM) for Prof. J. Hough (UK).

Some of the main activities during the technology test programme will be testing the operation of the star trackers at low altitudes, i.e. in the radiation belts, use of the on-board redundant units that were not needed during the routine operations, and evaluation of the software intended to overcome multiple gyro failures. During gaps in this programme, the shortest-wavelength detectors in the Short Wavelength Spectrometer will be used to measure the 2.38 - 4.08 micron spectrum of many stars to extend their spectral classification to the infrared. After completion of these tests, the perigee will be lowered as much as possible and the satellite switched off. Re-entry is foreseen for around the year 2020.

Just prior to exhaustion of the liquid helium, some of ISO's latest results were announced to the Press at a briefing in London. Among these discoveries were the finding of water vapour on Saturn's moon Titan, complementing ISO's many detections of water throughout the cosmos, detections of young stars in the Orion region of the sky and measurements of infrared galaxies at immense distances (see 'In Brief' article in this issue of the Bulletin).

The analysis and interpretation of the ISO results is only just beginning. All ISO data will be re-processed with the latest software over the summer and an archive will be opened to the astronomical community in the autumn. Thereafter, there will be an international effort, co-ordinated by the ESA ISO Data Centre at Villafranca in Spain, to maximise the exploitation of the ISO data and to prepare the best possible final archive to leave as a legacy from ISO to future astronomers. Many more discoveries still await us!

Cluster-II

The manufacture of all spacecraft and payload equipment is progressing according to plan, consistent with the start of integration of the first new Cluster-II spacecraft in the third quarter of 1998. Ninety percent of all parts for all spacecraft have been delivered to the subcontractors. The Preliminary Design Reviews (PDRs) for the new equipment - Solid-State Recorder and High-Power Amplifier - have been successfully completed. The changes to the experiment-carrying rigid booms needed to fit inside the Soyuz launch vehicle's fairing have been agreed.

The contract with Starsem, which is assessing all mission-analysis aspects of the Soyuz launch, will be completed by mid-1998, before the main Launch Services Agreement is signed.

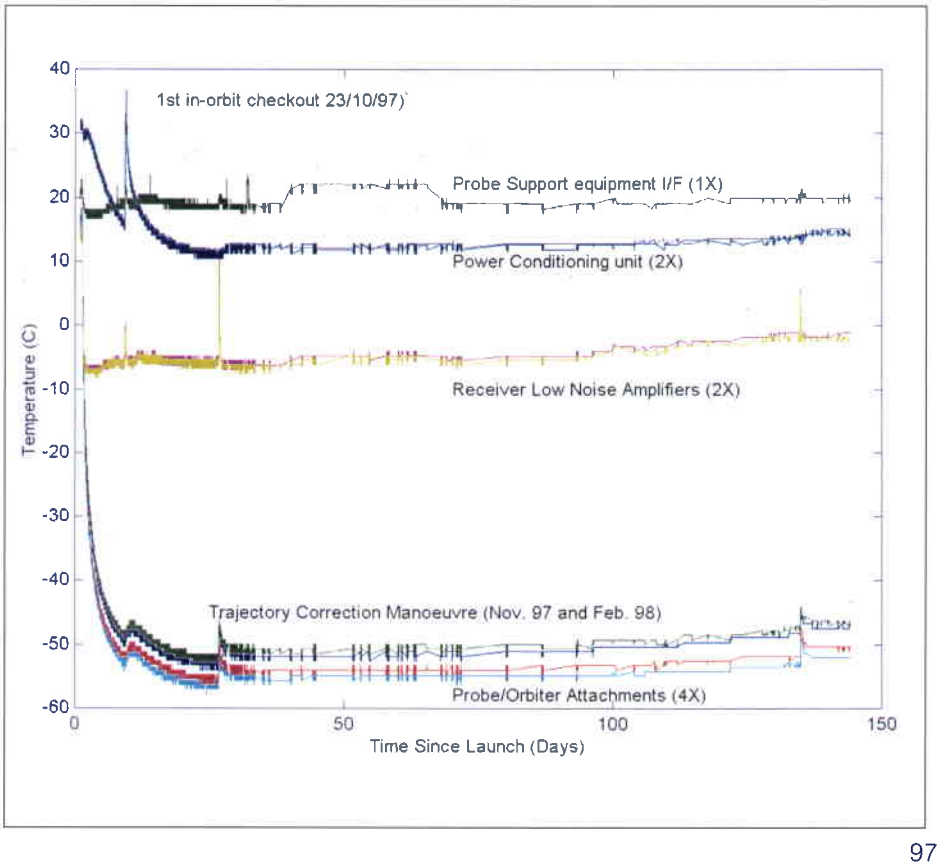
Huygens

The Cassini/Huygens spacecraft is on its way to Venus with its High-Gain-Antenna (HGA) pointing at the Sun, and everything is nominal on-board. The first Venus flyby will occur on 26 April. The spacecraft is flown in a HGA-to-Sun attitude in order to keep the spacecraft, and the Huygens Probe in particular, in shadow.

The spacecraft was continuously monitored through NASA's Deep-Space Network (DSN) during the post-launch one-month commissioning phase. Since

Huygens Probe temperature since launch

Courbes température de la sonde Huygens depuis son lancement



Huygens

Le véhicule spatial Cassini/Huygens se dirige vers Vénus, son antenne à haut gain (HGA) pointée vers le Soleil, et tout fonctionne normalement à bord. Le premier survol de la planète devait avoir lieu le 26 avril. Le pointage de l'HGA vers le soleil permet de maintenir à l'ombre le reste du véhicule, et spécialement la sonde Huygens.

Le Réseau de l'espace lointain de la NASA (DSN) a permis de suivre constamment le véhicule lors de la phase de recette d'un mois qui a suivi son lancement. Depuis lors, les données techniques du vol sont stockées par l'enregistreur à semi-conducteurs (SSR) de l'orbiteur et transmises une à deux fois par semaine, à l'occasion d'un passage approprié dans la zone de couverture du DSN. Les températures clé de la sonde sont mesurées en permanence par l'orbiteur et les données obtenues transmises sur Terre lors des passages dans la zone DSN. Le comportement thermique de la sonde répond parfaitement aux spécifications. Son modèle thermique est remis à jour à des fins opérationnelles, en tenant compte des mesures réalisées pendant le vol sur l'interface orbiteur/sonde.

Le modèle d'identification de la sonde a été adapté par l'industrie et livré en février à l'ESOC, à Darmstadt. Ses systèmes de télécommande et de gestion des données (CDMS) sont la réplique de ceux du modèle de vol (tant du point de vue du matériel que des logiciels, y compris pour les interfaces avec les expériences). Il servira ainsi de banc d'essai pendant les sept années que durera la phase de croisière, permettant de valider ou de modifier les séquences de vérification en orbite qui pourraient s'avérer nécessaires et de valider les éventuelles modifications à apporter aux logiciels de bord. Le modèle d'identification a été installé à proximité immédiate de la salle de contrôle de Huygens, à l'ESOC.

La deuxième vérification en orbite devait être réalisée le 27 mars en aveugle, l'antenne HGA ne pouvant être utilisée pour des télécommunications à haut débit avec la Terre. Les données de la vérification doivent être enregistrées sur le SSR de l'orbiteur et renvoyées vers la Terre au cours de neuf passages dans la zone du DSN, à un faible débit de 948 bits/s. Toutes les données devaient être fournies pour analyse par les responsables de recherche et par l'industrie le 9 avril.

Testing of the XMM spacecraft in the LEAF at ESTEC (NL)

Essai du véhicule spatial XMM dans l'installation LEAF à l'ESTEC (NL)

XMM

La campagne d'essais entreprise sur le modèle structurel et thermique du satellite s'est achevée avec succès début mars. Le système intégré du modèle d'identification fait parallèlement l'objet d'essais réalisés chez Dornier (D). Les résultats de tous les essais entrepris à ce jour ont été analysés lors d'une revue de qualification organisée à la mi-mars. Celle-ci a confirmé que le projet était then, the engineering data have been stored on the Orbiter's Solid-State Recorder (SSR) and dumped once or twice per week when a suitable DSN pass is available. Key Probe temperatures are measured continuously by the Orbiter and the data transmitted to Earth during the DSN passes. From the thermal point of view, the Probe's behaviour is well within specification. The thermal model of the Probe is being updated for operational purposes, taking into account the in-flight measurements at the Orbiter/Probe interface.

The Probe engineering model has been retrofitted by Industry and was delivered to ESOC in Darmstadt (D) in February. Its command and data-management systems (CDMS) are replicas (both hardware and software, including the interfaces with the experiments) of the flight-model configurations. It will therefore serve as a testbed during the mission's 7-year cruise phase for validating any modifications to the in-orbit check-out sequences that may be required, and to validate the eventual on-board software modifications. The engineering-model Probe has been set up next to the Huygens Dedicated Control Room in ESOC.

The second in-orbit check-out will be executed on 27 March in the blind, as the HGA cannot be used for high-data-rate communication with the Earth. The check-out data will be recorded on the Orbiter's SSRs and played back to Earth over nine DSN passes at a low 948 bit/s. All data will be available for analysis by the Principal Investigators and Industry on 9 April.

XMM

The test campaign on the structural and thermal model of the satellite was successfully completed in early March. In parallel, integrated system tests are being run at Dornier (D) on the engineering model. The results of all tests conducted so far were assessed during a qualification review in mid-March and the readiness of the project to proceed with flight-satellite integration was confirmed.

In line with the model philosophy for XMM, the last elements of the spacecraft qualification will be part of the proto-flight model test programme. Flight equipment is being delivered on time and integration of the flight satellite has started with the mounting of the reaction control system, harness and thermal hardware on the service module at BPD (I) as foreseen. At the same time, tests are being conducted at Matra Marconi Space (UK) on the attitude and orbit control subsystem prior to its final integration into the spacecraft later this year.

Tests at Centre Spatial de Liège (CSL) have continued, involving the third flight mirror module together with the second flight model of the reflection grating assembly, as well as the associated X-ray baffle. The assembly was later transported to Munich, where calibration tests will be conducted at the Max-Planck X-ray facility (PANTER).

In the meantime, final integration activities have been taking place at Media Lario (I) on the spare mirror module, in preparation for the acceptance tests at CSL.

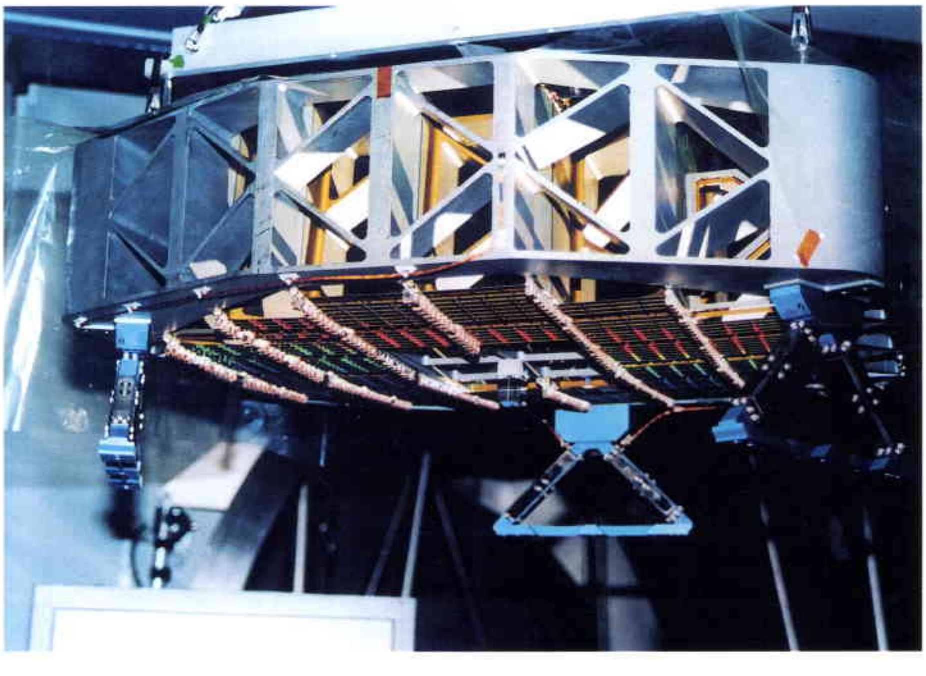
The instrument consortia are adhering to the new flight-model schedule for the scientific instruments, which had to be re-arranged at the end of 1997. The model philosophy for the Optical Monitor experiment has been streamlined to ensure compatibility with the launch date. These modifications are being accommodated within the spacecraft's integration schedule without impacting on its delivery date.

Ground-segment development work has progressed nominally with the detailed design phase. Delivery of the first version of the control software was foreseen for March.

Integral

With all of the mission participants, the project team is actively coordinating the delivery of units and subsystems to assemble, integrate and test the first full-scale model of the satellite, the structural and thermal model (STM). The lower part of the satellite, the service module (SVM), will be reused from the XMM project. Good progress on XMM indicates that the SVM will be available on time for minor refurbishment and insertion into the satellite assembly flow. The upper part of the satellite, made up of the payload module (PLM) structure and payload instruments, is also progressing well. The strong but lightweight structure is undergoing its final tests before delivery to the Prime Contractor, Alenia (I). The payload teams are finalising their instrument models. Some delays are expected, but should be absorbed through simplifications of the unit or by re-arranging the integration flow and test logic.

Most of the equipment required to manipulate and transport the satellite on the ground has been delivered. Preparations are in progress to have



XMM reflection grating assembly under test at CSL, Liège (B)

Le réseau de réflexion de XMM aux essais au CSL à Liège (B) *suffisamment mûr pour que l'on puisse procéder à l'intégration du modèle de vol. Conformément aux choix des responsables d'XMM en matière de modèles, la qualification des derniers éléments du satellite interviendra dans le cadre du programme d'essais de son prototype de vol. Les équipements de vol sont livrés dans les délais impartis et l'intégration du modèle de vol du satellite a commencé comme prévu par le montage du système de pilotage par réaction, du câblage d'alimentation et des équipements thermiques du module de servitude chez BPD (I). Le sous-système de contrôle d'attitude et de correction d'orbite fait parallèlement l'objet d'essais menés à bien chez Matra Marconi Space (GB), avant son intégration définitive au satellite prévue dans le courant de l'année.*

Les essais entrepris sur le troisième module de vol des miroirs, sur le deuxième modèle de vol de l'ensemble à réseau de diffraction et sur le l'écran de protection contre les rayons X associé se sont poursuivis au Centre spatial de Liège (CSL). L'ensemble a ensuite été transporté à Munich où l'on procédera à des essais d'étalonnage dans l'installation rayons-X de l'Institut Max-Planck (PANTER).

Les activités d'intégration finale du modèle de réserve du module de miroirs se sont parallèlement déroulées chez Media Lario (I), en vue des essais de recette au CSL.

Les consortiums d'instruments ont accepté le nouveau calendrier de livraison des instruments scientifiques destinés au modèle de vol, qu'il a fallu réaménager à la fin de 1997. Dans le cas de l'expérience de moniteur optique, il a fallu rationaliser les choix en matière de modèles afin de tenir compte de la date de lancement. Les modifications adoptées apparaîtront dans le calendrier d'intégration du satellite, sans que cela influe sur sa date de livraison.

Les travaux de réalisation du secteur sol se poursuivent conformément à ce qui est programmé au titre de la phase de conception détaillée. La livraison de la première version du logiciel de contrôle était prévue fin mars.

Intégral

L'équipe du projet coordonne activement, avec l'ensemble des participants à la mission, la livraison des différents éléments et sous-systèmes permettant d'assembler, d'intégrer et de tester le modèle structurel et thermique (STM), premier modèle en grandeur réelle du satellite. Le module de servitude (SVM), constituant la partie inférieure du satellite, sera le même que celui utilisé pour le projet XMM. La progression satisfaisante du programme XMM laisse à penser que le SVM sera prêt à temps pour une légère remise en état avant son insertion dans la séquence d'assemblage du satellite. La réalisation de la partie supérieure, constituée par les instruments et la structure du module charge utile (PLM), progresse également de manière satisfaisante. La structure légère mais rigide subit ses derniers essais avant d'être livrée au maître d'oeuvre, Alenia (I). Les équipes responsables de la charge utile achèvent les modèles de leurs instruments. On s'attend à quelques retards qui devraient être compensés par une simplification du modèle ou par un réaménagement de la séquence d'intégration et une révision de la méthode d'essais.

La majeure partie des équipements requis par la manipulation et le transport du satellite au sol ont été livrés. La préparation des installations d'essais d'Alenia à Turin (I) et de l'ESTEC à Noordwijk (NL) suit son cours.

Dans l'ensemble, les préparatifs du STM progressent selon le calendrier établi et devraient permettre d'entreprendre, comme prévu, les essais du satellite entre les mois d'avril et d'octobre.

Les groupes chargés des éléments du secteur sol s'emploient à résoudre les questions soulevées lors de la dernière revue système du secteur sol. Les travaux se poursuivent conformément aux prévisions.

La mise en oeuvre de l'Arrangement signé en novembre dernier avec l'Agence spatiale russe, prévoyant la fourniture d'un lanceur Proton en échange de données scientifiques, avance à pas comptés. Un certain nombre d'éclaircissements sont cependant nécessaires avant qu'il puisse entrer pleinement en vigueur.

Rosetta

La responsabilité de l'assemblage, de l'intégration et de la vérification (AIV) du satellite a été confiée à Alenia (I) à l'issue de négociations contractuelles menées avec succès, ce qui complète le choix des principaux sous-traitants entrant dans le consortium Rosetta. L'attention se porte dorénavant sur le choix des équipementiers. Les premières offres industrielles reçues en réponse à l'appel d'offres et à la demande de prix récemment adressés sont en cours d'évaluation.

Le contrat relatif à l'Agence d'approvisionnement en pièces détachées a été concédé à Technologica (E).

Sur le plan technique, l'attention se porte aujourd'hui sur certains problèmes critiques de régulation thermique, de contrôle d'attitude et de correction d'orbite. La qualification des photopiles faible intensité basse température (LILT) progresse de façon satisfaisante pour les deux technologies envisagées : silicium ou arséniure de gallium. Les premiers essais sur l'efficacité des piles sont prometteurs.

D'importants efforts, entrepris en collaboration avec la communauté scientifique de Rosetta, ont par ailleurs été consacrés à modéliser de manière convaincante les jets de poussière et de gaz de la comète, ce qui est indispensable à la conception d'un satellite suffisamment robuste. Il s'agit là d'une entreprise difficile, dans la mesure où nombre des propriétés de l'environnement cométaire ne seront connus avec certitude qu'à la fin même de la mission Rosetta.

La définition du secteur sol progresse également selon le calendrier établi, avec l'affinement de la définition de l'interface satellite-sol et des aspects opérationnels du satellite. L'approvisionnement d'une nouvelle antenne espace lointain de 34 m, qui sera installée à Perth, en Australie occidentale, se déroule conformément aux prévisions.

Artémis

Le terminal de télécommunications optiques Silex a été lancé à bord de Spot-4 au cours de la nuit du 23 au 24 facilities at Alenia in Turin (I) and at ESTEC in Noordwijk (NL) ready for the tests.

Overall, STM preparations are proceeding on schedule and should allow the satellite tests to be run as planned in the April to October period.

The ground-segment-element groups are closing off the issues raised at the earlier Ground Segment System Review. The development effort is progressing according to plan.

Signed last November, the Arrangement with the Russian Space Agency for the provision of a Proton launcher in exchange for science data is slowly being implemented, but further clarifications are still required before it can become fully operational.

Rosetta

Following a successful contract negotiation, responsibility for spacecraft Assembly Integration and Verification (AIV) has been assigned to Alenia Aerospace (I), thereby completing the selection of the major subcontractors in the Rosetta industrial consortium. Attention is now focused on the selection of the equipment suppliers. The first industrial offers received in response to the earlier Invitation to Tender and Request for Quotations are under evaluation. The contract for the Parts Procurement Agency has also been placed, with Technologica (E).

On the technical side, attention is being given to critical issues in the thermal-control and attitude and orbit control areas. Qualification of the Low Intensity Low Temperature (LILT) solar cells has made good progress, for both the silicon and gallium-arsenide technologies. The first test results on the cells' efficiency are promising.

A significant effort, jointly undertaken with the Rosetta scientific community, has also been devoted to the definition of a sound cometary dust and outgassing model, which is essential to ensure a robust spacecraft design. This is not an easy task as many properties of the comet environment will only be known with certainty after the successful conclusion of the Rosetta mission itself.

Integral Spectrometer structural and thermal model (STM) developed by CNES

Modèle de structure/thermique du spectromètre d'Intégral mis au point par le CNES

Definition of the ground segment is also proceeding on schedule, with the refinement of the spacecraft-to-ground interface definition and the spacecraft operational aspects. The procurement of a new 34 m deep-space antenna, to be located in Perth, W. Australia, is progressing according to plan.

Artemis

The Silex optical communications terminal was launched onboard Spot-4 during the night of 23/24 March 1998 and its early orbit operations have been completed without problem. In-orbit commissioning will be carried out in the coming weeks, after which the terminal will be placed in a dormant mode until the launch of Artemis next year.

Integration of the Artemis flight-model satellite is now close to completion and its shipment to ESTEC for environmental testing is expected in May 1998. The environmental test programme is planned to last until February 1999.

EOPP

Future strategy
Following a comprehensive series of bilateral meetings with all Delegations, the future strategy, together with a proposal for the Earth Observation Envelope Programme, has been submitted to the Earth-Observation Programme Board (PB-EO) for discussion prior to submission of the Enabling Resolution to the Council.

Future programme
In response to the Call for Outline Earth-Watch Proposals sent to industry in November, twenty proposals have been received and accepted for evaluation. These proposals demonstrate strong support for the future strategy and the Earth Observation Envelope Programme.

Proposals have also been received for the first four Phase-A studies of candidate Earth-Explorer Missions and these are also under evaluation.

Campaigns
Preparatory activities for the CLARE 98 (Cloud Lidar And Radar Experiment) campaign are now underway. It has been designed to provide a better understanding of three-dimensional cloud structure in preparation for the possible Earth Radiation Explorer mission.

Polar Platform/Envisat

Envisat-1 system
The first satellite validation test between the ESOC Flight Operations Control Centre and the Polar Platform/Envisat service module located at Matra Marconi Space (UK) was successfully conducted in mid-February.

The Announcement of Opportunity (AO) for scientific data exploitation and pilot projects has been released, with a closing date of 31 May 1998.

The Envisat Data Policy has recently been approved by the Earth Observation Programme Board, and the High-Level Operation Plan for Envisat-1 has been submitted to Delegations for approval.

Polar Platform (PPF)
The Envisat satellite engineering model

mars 1998, et ses premières opérations en orbite se sont déroulées sans problème. Sa recette en orbite devait avoir lieu dans les semaines suivantes. Le terminal sera ensuite configuré en mode d'attente avant le lancement d'Artémis, l'année prochaine.

L'intégration du modèle de vol d'Artémis est presque achevée et sa livraison à l'ESTEC, pour des essais d'ambiance qui doivent durer jusqu'en février 1999, était prévue en mai 1998.

EOPP

Stratégie future

A la suite d'une importante série de rencontres bilatérales avec l'ensemble des délégations de l'ESA, la stratégie future en matière d'observation de la Terre a été présentée au Conseil directeur concerné, conjointement à une proposition relative au Programme-enveloppe d'observation de la Terre, afin d'être examinée avant la soumission d'une résolution habilitante au Conseil.

Programmes futurs

Vingt propositions ont été reçues et acceptées pour évaluation en réponse à l'Appel à propositions d'esquisses de projets de surveillance de la Terre adressé en novembre à l'industrie. Ces propositions témoignent d'un fort intérêt pour la future stratégie et pour le Programme-enveloppe d'observation de la Terre.

Des propositions ont été également reçues pour les quatre premières études de phase A relatives à des mission d'exploration de la Terre et sont en cours d'évaluation.

Campagnes

Les activités préparatoires à la campagne CLARE 98 (Expérience de Lidar et de Radar de nébulosité) sont en cours. Cette expérience doit permettre de mieux appréhender la structure tridimensionnelle des nuages, dans la perspective d'une possible mission d'exploration du rayonnement terrestre.

Plate-forme polaire/Envisat

Système Envisat-1

Les premiers essais de validation du satellite, réalisés entre le Centre de contrôle des opérations en vol de l'ESOC et le module de servitude Plate-forme polaire/Envisat se trouvant chez Matra Marconi Space (GB) ont été réalisés avec succès à la mi-février.

L'Appel à propositions (AO) de projets pilotes et d'exploitation des données scientifiques a été lancé, avec clôture au 31 mai 1998.

La Politique des données d'Envisat a été récemment approuvée par le Conseil directeur du programme d'observation de la Terre, et le Plan d'exploitation de haut niveau d'Envisat-1 a été soumis pour approbation aux délégations.

Plate-forme polaire (PPF)

Le programme d'assemblage, d'intégration et d'essais (AIT) du modèle d'identification du satellite Envisat s'est poursuivi avec la réalisation de plusieurs essais fonctionnels du module de charge utile intégré et avec l'intégration de l'ensemble électronique du modèle d'identification de l'ASAR (CESA). La livraison du dernier élément de la charge utile, le panneau d'antenne du modèle d'identification de l'ASAR, est attendue sous peu.

L'intégration du faisceau de câbles du modèle de vol du module de charge utile a été réalisée chez Matra Marconi Space (GB) après remise en état de la structure porte-instruments, et l'ensemble peut aujourd'hui être intégré au modèle de vol du compartiment des équipements de charge utile (PEB). On finit de préparer, chez DASA/DSS (D), les essais de recette définitive du modèle de vol du PEB, qui devraient être réalisés au cours des prochaines semaines.

La réalisation de l'enregistreur à état solide (SSR) progresse de manière satisfaisante. La première partie de la revue préliminaire de conception du SSR s'est déroulée selon les prévisions et le modèle d'identification a déjà été intégré au modèle de vol du PEB. La question de la compatibilité de l'ensemble avec le choc de séparation d'avec le lanceur Ariane-5 reste posée, et l'on réfléchit actuellement à la meilleure manière de résoudre ce problème.

Charge utile Envisat-1

La réalisation des instruments a progressé de manière importante : l'intégration des modèles de vol est presque achevée dans les installations des différents maîtres d'oeuvre, et dans certains cas les essais définitifs sont très avancés.

Le radiomètre hyperfréquences (MWR) est le premier modèle de vol d'instrument déjà livré. Il est actuellement intégré au DORIS et subit ses essais définitifs. L'ensemble DORIS/MWR doit être livré au cours des prochaines semaines. La livraison des derniers instruments s'échelonnera tout au long de l'année

Les modifications à apporter à l'électronique du MIPAS pour permettre le fonctionnement de l'appareil aux basses températures ont été validées et sont en cours de mise en oeuvre. D'autres modifications relatives à l'antenne de l'ASAR ont également été adoptées afin d'éliminer les interférences RF provenant de l'instrument RA-2.

Secteur sol Envisat-1

Des chaînes de données, représentatives de celles de la Station de traitement des données de la charge utile et du Centre d'archivage à faible débit, sont en cours d'assemblage dans la Plate-forme de référence du système de gestion des données de charge utile (PDS), située chez Datamat à Rome (I), afin de permettre la recette de la présente version du PDS, prévue à la fin de 1998. Les processeurs ASAR et MIPAS de niveau 1-b ont déjà été intégrés à la plate-forme de référence.

Les essais de compatibilité entre Envisat et le PDS seront réalisés par étapes entre mars 1998 et le début de 1999, parallèlement au programme d'assemblage, d'intégration et d'essais (AIT) du satellite.

Météosat

Exploitation Météosat

La totalité des satellites de première génération, conçus selon le modèle qui

Envisat's GOMOS engineering model undergoing solar vacuum testing at Intespace in Toulouse (F)

Le modèle technologique de l'instrument GOMOS d'Envisat aux essais de simulation solaire en chambre à ride

Assembly, Integration and Test (AIT) programme has continued with the completion of several functional tests of the integrated Payload Module and with integration of the ASAR engineering-model electronics assembly (CESA). Delivery of the last payload element, the engineering-model ASAR antenna panel, is expected shortly.

The flight-model Payload Module harness integration has been completed at Matra Marconi Space (UK) after refurbishment of the payload carrier structure, and is now ready to be integrated with the flight-model Payload Equipment Bay (PEB). The acceptance-test preparation activities for the flight-model PEB are close to completion at DASA/DSS (D), and final acceptance testing will be performed in the coming weeks.

The development of the Solid State Recorder is progressing satisfactorily. The first part of the SSR Preliminary Design Review has been held successfully and the engineering model has already been integrated into the flight-model PEB. The issue of shock compatibility with Ariane-5 remains a concern and several activities are in progress to establish the best course of action.

Envisat-1 payload
Significant progress has been made in the development of the instruments: integration of the flight models is close to completion at the various instrument prime facilities, and in a number of cases final testing is well advanced.

The MWR was the first flight-model instrument to be delivered and it is now in integration and final testing with DORIS. The DORIS/MWR composite will be delivered in the coming weeks. The deliveries of the remaining instruments will be staggered through the year.

The modification needed to the MIPAS electronics for operation at low temperatures has been validated and is currently being implemented. Modifications have also been successfully qualified on the ASAR antenna to eliminate RF interference from the RA-2 instrument.

Envisat-1 ground segment
Data chains representative of the Payload Data Handling Station and the Low Rate Archiving Centre are being assembled within the Payload Data Segment (PDS) Reference Platform located at Datamat in Rome (I) for the PDS version acceptance scheduled for the end of 1998. The complete ASAR and MIPAS level-1b processors are already integrated within the Reference Platform.

Envisat spacecraft to PDS compatibility testing will take place in several stages, from March 1998 until early 1999, in parallel with the Envisat satellite AIT activities.

Meteosat

Meteosat operations
All of the spacecraft of the first generation, which is the design currently providing the operational service, were supplied by industry under contract to ESA. The spacecraft are operated by Eumetsat from its operational control centre in Darmstadt (D). The last spacecraft launched, in September 1997, was Meteosat-7 (known before launch as MTP - Meteosat Transition Programme) and it is operating nominally. It is expected that the operational service will be provided by Meteosat-7 from Spring 1998 and, all being well, it should continue to function in that role until the launch of the Meteosat Second Generation spacecraft early in the next decade.

assure actuellement le service opérationnel, ont été livrés par l'industrie, conformément aux contrats passés avec l'ESA. Ces satellites sont exploités par Eumetsat, à partir de son centre de contrôle des opérations situé à Darmstadt (D). Le dernier satellite lancé, Météosat-7 (connu, avant son lancement, sous le nom de MTP pour 'Programme Météosat de transition') a été placé sur orbite en septembre 1997 et fonctionne normalement. On pense qu'il sera opérationnel à partir du printemps 1998 et qu'il pourrait, si tout va bien, assurer ses fonctions jusqu'au lancement du premier des satellites Météosat de deuxième génération, au début de la prochaine décennie.

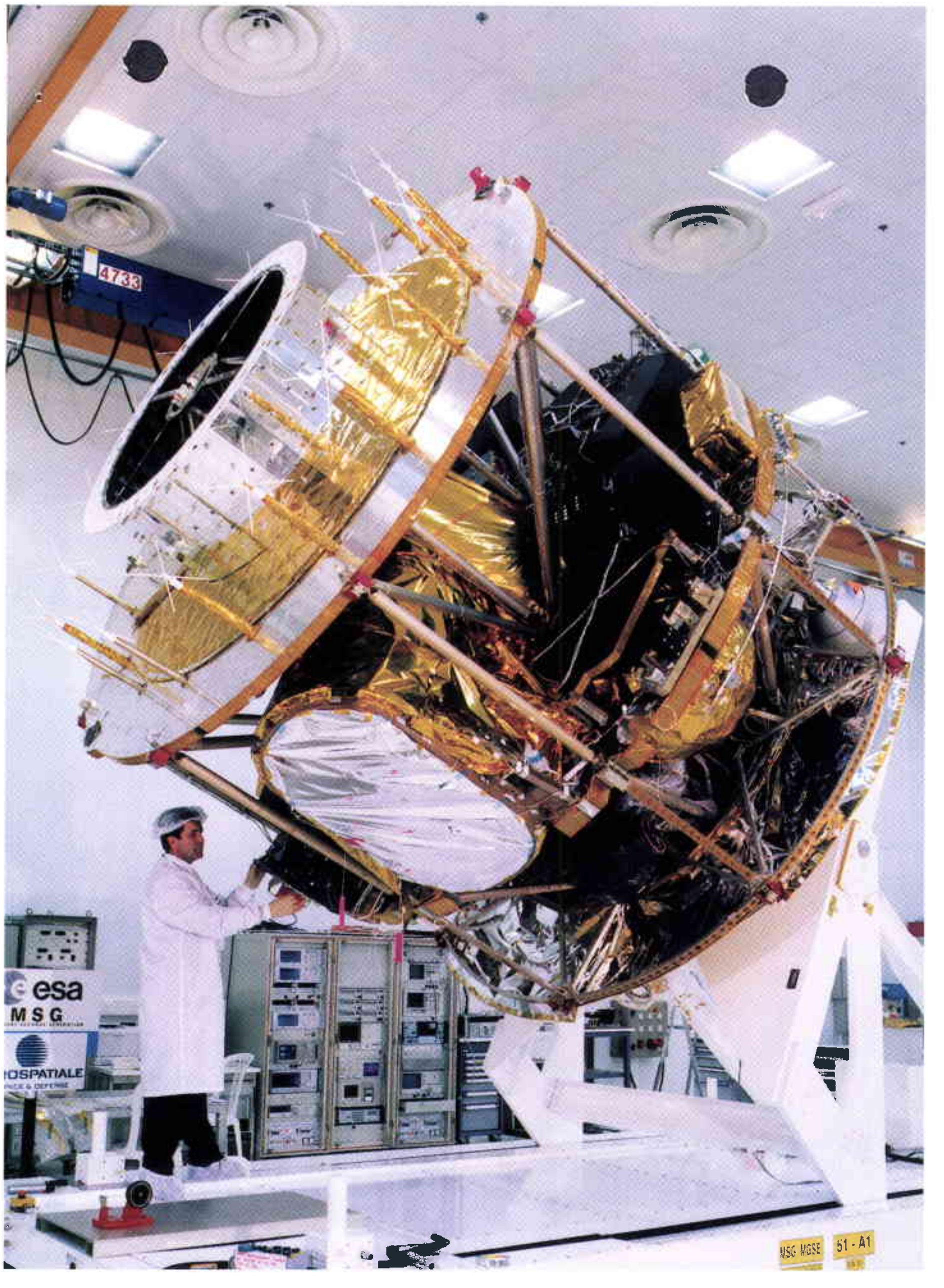
Météosat de deuxième génération (MSG)

La revue préliminaire de conception du SEVIRI (l'imageur visible et infrarouge amélioré) et de ses sous-ensembles est terminée, mais la réalisation de la première unité de vol de cet instrument demeure, comme prévu, sur le chemin critique.

Le modèle structurel et thermique du satellite est arrivé à l'ESTEC (NL) pour y subir ses essais thermiques dans le grand simulateur spatial.

Les revues critiques de conception (CDR) se poursuivent au niveau des équipements et des sous-systèmes, permettant d'accroître à ce niveau la fabrication des matériels de vol. La prochaine CDR au niveau des sous-systèmes est prévue en octobre 1998.

Le développement du satellite MSG-1 et l'approvisionnement des exemplaires MSG-2 et 3 se déroulent selon les prévisions, les travaux d'ingénierie et la production des modèles thermiques/mécaniques progressant au niveau des équipements et des sous-systèmes. Le lancement de MSG-1 est toujours prévu pour le mois d'octobre 2000 et celui de MSG-2 en 2002. La mise en stockage de MSG-3 doit avoir lieu en 2003.



The Meteosat Second Generation (MSG) spacecraft

Véhicule spatial Météosat seconde génération

Métop

Après la décision d'Eumetsat, prise le 28 janvier au cours d'une session spéciale de son Conseil organisée à Darmstadt (D), de contribuer au projet à hauteur de 26 MECU, les participants potentiels se sont réunis le 30 janvier et ont décidé d'attribuer 90 MECU au programme, franchissant ainsi une étape importante. L'autorisation d'entamer les activités de phase C/D de Métop pourrait être lancée avec effet immédiat, et validité jusqu'au 30 septembre, afin de couvrir la période précédant l'approbation définitive du programme EPS, prévue lors du Conseil d'Eumetsat en juin.

Sur la base de ces résolutions, de l'approbation antérieure de la proposition de contrat par l'Agence et du franchissement du niveau de souscription nécessaire, le coup d'envoi du projet Métop a été donné en février, dans les installations du maître d'oeuvre Matra Marconi Space, à Toulouse (F).

Une série de réunions de lancement a rassemblé, comme prévu, la majorité des sous-traitants concernés par les éléments du module de servitude et de charge utile qui ont un caractère critique pour le calendrier. Fin mars, la plupart de ces réunions avaient été couronnées de succès, ce qui a permis aux sous-traitants de s'engager pleinement dans le projet afin de respecter son calendrier très serré. Les quelques réunions restantes devaient avoir lieu avant la mi-avril.

Meteosat Second Generation

The Preliminary Design Review for SEVIRI (Scanning Enhanced Visible and Infrared Imager) and its subassemblies has been closed out, with the instrument remaining, as expected, on a critical path for the first flight unit.

The structural and thermal model satellite has arrived at ESTEC (NL) for thermal testing in the Large Space Simulator.

Critical Design Reviews (CDRs) at equipment and subsystem level continue, authorising more flight hardware satellite manufacturing at this level. A CDR at subsystem level is planned for October 1998.

The development of the MSG-1 spacecraft and the procurement of MSG-2 and -3 are on schedule, with engineering and thermal/mechanical-model production in progress at equipment and subsystem level. The launch of MSG-1 remains on schedule for October 2000, with MSG-2 to be launched in 2002 and MSG-3 to go into storage in 2003.

Metop

A major step forward was achieved with a Potential Participants Meeting on 30 January granting 90 MECU for the project, following the Eumetsat decision at its special Council Meeting in Darmstadt (D) on 28 January to contribute 26 MECU. An Authorisation to Proceed with Metop Phase-C/D activities could therefore be issued with immediate effect, valid until 30 September, to bridge the period until the full approval of the EPS programme, expected at a Eumetsat Council meeting in June.

On the basis of these resolutions and the previous approval of the Contract Proposal by the Agency, and the necessary level of subscription achieved so far, kick-off of the Metop project took place in February at the premises of the main contractor Matra Marconi Space, in Toulouse (F).

A series of pre-negotiated kick-off meetings involving the majority of the sub-contractors then took place for the time-critical Service and Payload Module elements. By the end of March, most of them could be declared successful, allowing the sub-contractors to be fully engaged in order to meet the tight project schedule. The few remaining kick-offs should take place before mid-April.

ERS

Following the United Kingdom's decision to subscribe to the whole of Phase-E1, the level of subscriptions for the years 1998 and 1999 has reached 89.79%.

The technical performance of ERS-2 remains excellent, combining the provision of high-quality data with very good availability. The gain of the amplification module of the Active Microwave Instrument will be increased to compensate for the slow but continuous Travelling Wave Tube degradation. The product quality is therefore expected to remain the same until the end of the mission.

ERS-1 is in hibernation and the periodic checkouts show that payload performance is being maintained. On 29 December 1997, however, the power output of the spacecraft's solar array suddenly fell by 38%, probably due to the thermo-electrical degradation of an isolator provoking a short-circuit between conductor strips. As a result, ERS-1 will no longer be able to provide 'full' mission back-up in that not all instruments can now be operated at the same time. However, individual instruments like the Radar Altimeter, Global Wind or SAR imaging are still operable and can serve as back-ups to ERS-2.

International Space Station Programme

The highlight of the present reporting period was without doubt the signature of the principal governing documents for the International Space Station, namely the Inter-Governmental Agreement (IGA) and the corresponding Memoranda of Understanding (MOUs). The signing ceremony, on 29 January in Washington DC, marked the successful completion of a lengthy period of effort for many people, both in the Delegations and the Executive.

ISS overall assembly sequence

A General Designers Review (GDR) was held in Moscow at the end of January to review the status of the Russian Segment, in particular the Functional Cargo Block (FGB) and the Service Module. This review showed the FGB to be on schedule for launch in June 1998, and the flight unit was subsequently transported to Baikonur. The Service Module was shown to be 2-3 months behind schedule, due primarily to additional work on tubing and harness replacement, and delays in the deliveries of sub-system hardware. The next GDR is planned for March, after which a decision will be taken on a revised Assembly Sequence.

Columbus Orbital Facility (COF)

The COF System Preliminary Design Review (PDR) and NASA Safety Review No. 1 have been successfully completed on schedule, following an in-depth review of the industrial documentation by ESA and the various NASA centres involved. The main purpose of the PDR was to evaluate the system design to the point at which formal release for the manufacture of the Electrical Test Model (ETM) could be sanctioned. Equipment and subsystem CDRs have been initiated.

The Bilateral Integration and Verification Plan, the Hardware/Software Exchange Agreement and the Documentation Exchange Agreement have all now been signed by NASA and ESA.

A final round of interface meetings has resulted in a completed and frozen definition of the COF to Common Berthing Mechanism (CBM) and Hatch interfaces. A meeting with the Shuttle Programme team has advanced the definition of the COF-to-Shuttle interfaces.

COF launch barter

(i) Nodes 2 and 3

Initial system-configuration and primary-structure design activities have been completed to enable the release of primary structure jig manufacturing and base metal ordering. The evaluation of the industrial proposals for the European items of the Nodes 2 and 3 procurement has been completed, with the exception of the ECLSS components, which await the final definition of items to be made available from NASA.

ERS

La décision prise par le Royaume-Uni de souscrire à l'ensemble de la phase E1 a permis d'atteindre un niveau de souscriptions de 89,79% pour les années 1998 et 1999.

Les performances techniques d'ERS-2 sont toujours excellentes, permettant d'allier une très grande disponibilité à des données de très haute qualité. Le gain du module d'amplification du détecteur actif à hyperfréquence sera augmenté afin de compenser la dégradation lente mais continue du tube à ondes progressives.

La qualité de la production devrait être ainsi préservée jusqu'à la fin de la mission.

ERS-1 est en hibernation et les vérifications périodiques montrent que les performances de la charge utile sont préservées. Une chute soudaine de 38% de la production électrique du générateur solaire du satellite s'est cependant produite le 29 décembre 1997, provoquée probablement par un court-circuit entre rubans conducteurs due à la dégradation thermoélectrique d'un isolant. Depuis lors, ERS-1 n'est plus en mesure d'assurer pleinement sa mission de réserve du fait que ses instruments ne peuvent fonctionner tous en même temps. Certains instruments, comme l'altimètre Radar, le SAR ou le lidar vents demeurent cependant individuellement opérationnels et peuvent servir de secours à ERS-2.

Programme de Station spatiale internationale

La signature des principaux documents régissant la Station spatiale internationale, à savoir l'Accord intergouvernemental (IGA) et les Mémorandums d'accord (MOU) correspondants, constitue, à n'en pas douter, le moment fort de ces derniers mois. La cérémonie de signature, organisée le 29 janvier à Washington DC, est venue couronner une longue période d'efforts, consentis tant par les Délégations que par l'Exécutif.

Séquence d'assemblage de l'ISS

L'état d'avancement de la composante russe, et notamment du module Energie (FGB) et du module de service, a été examiné lors d'une revue générale de conception (GDR) qui s'est déroulée à Moscou à la fin du mois de janvier. Cette revue a montré que le FGB serait prêt à temps pour le lancement prévu en juin 1998. L'unité de vol a par la suite été transportée à Baïkonour. La réalisation du module de service a, par contre, pris deux à trois mois de retard, en raison notamment de travaux supplémentaires de remplacement de câbles et de canalisations et de retards dans la livraison de matériels destinés à certains sous-systèmes. La revue générale de conception suivante, prévue en mars, devait conduire à une décision sur une séquence d'assemblage révisée.

Elément orbital Columbus (COF)

La revue préliminaire de conception système (PDR) du COF et la revue de sécurité n°1 de la NASA ont été réalisées dans les délais prévus, après que l'ESA et les différents centres de la NASA associés au projet eurent effectué une étude approfondie de la documentation industrielle fournie. L'objectif principal de cette PDR a été d'évaluer la conception système à un niveau permettant de lancer officiellement la fabrication du modèle d'essais électriques (ETM). Les revues critiques de conception (CDR) des équipements et des sous-systèmes ont été lancées.

Le plan bilatéral d'intégration et de vérification, l'accord d'échange matériels/logiciels et l'accord d'échange de documentation ont tous été signés par la NASA et l'ESA.

La dernière série de réunions sur les interfaces a permis de compléter et d'arrêter définitivement la définition des interfaces COF/ Mécanisme commun d'accostage (CBM) - écoutille. Une réunion avec l'équipe du programme de Navette spatiale a permis de faire progresser la définition des interfaces COF/Navette.

Compensation du lancement du COF

(i) Eléments de jonction 2 et 3

L'achèvement des premières activités liées à la configuration système et à la conception de la structure primaire permet désormais de lancer la fabrication du gabarit de la structure primaire et de commander les matières premières. L'évaluation des propositions industrielles relatives à l'approvisionnement des équipements européens destinés aux éléments de jonction 2 et 3 a été menée à bien, sauf en ce qui concerne les composants de l'ECLSS (Sous-système de régulation d'ambiance et de soutien-vie) pour lesquels on attend le choix définitif des éléments susceptibles d'être fournis par la NASA.

(ii) Fourniture de logiciels / composants du DMS-R / Soutien technique à la NASA

Le personnel de soutien technique en poste à Houston a continué d'apporter directement son aide à la NASA. Une deuxième livraison de matériel à l'Agence spatiale américaine a eu lieu en décembre 1997.

(iii) Bâti réfrigérateur/congélateur pour l'équipage

La proposition d'approvisionnement des phases B et C/D du Bâti réfrigérateur/congélateur (RFR) ont été approuvées par le Comité de la politique industrielle (IPC) de l'ESA en mars 1998. Les activités de phase B seront basées sur les résultats de la phase A, actuellement conduite par DASA/Dornier (D).

(iv) Bâti congélateur cryogénique

Deux études de phase A concurrentielles sont en cours pour le congélateur cryogénique – 180°C et doivent être achevées d'ici la mi-1998. Une procédure d'appel d'offres ouvert pour les phases suivantes doit être prochainement entamée.

Sous-système de régulation d'ambiance et de soutien vie du MPLM (ECLSS)

Les revues de qualification des équipements, dont les essais se sont poursuivis, devaient être achevées en avril. Les activités relatives à la recette des unités de vol se poursuivent. Environ 80% des pièces destinées au premier modèle de vol et des pièces de rechange ont été livrées.

Véhicule de transfert automatique (ATV)

Les activités de revalidation de la proposition se sont déroulées comme

(ii) Software Deliveries/ DMS-R items/ Associated Sustaining Engineering for NASA
Engineering support personnel have continued to provide direct support to NASA in Houston. The second set of hardware deliveries was made to NASA in December 1997.

(iii) Crew Refrigerator/Freezer Racks
The Phase-B and Phase-C/D procurement proposal for the Refrigerator Freezer Rack (RFR) was approved by ESA's Industrial Policy Committee (IPC) in March 1998. Phase-B will be based on the results of Phase-A, which is presently being carried out by DASA/Dornier (D).

(iv) Cryogenic Freezer Racks
For the -180° C Cryo-Freezer, two competitive Phase-A studies are ongoing and will be completed by mid-1998. A competitive Invitation to Tender (ITT) process for the next phases will be initiated shortly.

MPLM Environmental Control and Life Support System (ECLSS)
Equipment testing is underway and Equipment Qualification Reviews should be completed in April. Flight-unit acceptance activities are continuing, with about 80% of the FM1 and FM spares deliveries now complete.

Automated Transfer Vehicle (ATV)
Proposal revalidation activities have been running as planned. The Phase-C/D schedule has been reassessed and the reference launch date for the first flight is now end-March 2003. Industry gave a commitment in mid-March such that it is now expected that the ATV contract proposal will be submitted to the Agency's Industrial Policy Committee (IPC) in June 1998, following evaluation of an updated industrial proposal.

Crew Transport Vehicle (CTV)
Following the approval of the proposal for the extension of ESA/NASA cooperation in the X-38/CRV Programme by the ESA Manned Space Programme Board (PB-MS) in December, a Declaration for an additional slice of the European Participation in the ISS Development Programme was opened for subscription until end-February. By mid-February subscriptions had been made by three countries, up to a contribution level which permitted the start of the industrial work.

Step-1 extension activities have been further reoriented towards X-38 cooperation, and the European team in Houston has been reinforced accordingly.

The overall aerothermoynamics database work was essentially agreed by end-January and that effort has now started. The detailed design of the complete aft structure is on schedule and preparations for manufacturing essential elements of the aft structure frames and panels are proceeding.

The design work for the complete nose of the vehicle is proceeding with manufacturing capabilities identified which support the V-201 schedule.

Atmospheric Reentry Demonstrator (ARD)
Activities have proceeded as planned in order to meet the expected Ariane-503 mid-July launch date.

Operations and Ground Segment
A major effort to update the Space Station Implementation Plans involving all International Partners culminated in their baselining at the Fourth Multilateral Operations and Utilization Control Board (MO&UCB) meeting held at NASA/JSC in December 1997.The MO&UCB also approved the Operations Summary (OS) for the first six planning periods corresponding to the Revision-C Assembly Sequence.

Following the successful completion of the definition study for the COF/ATV Operations Control Functions and Facilities, and of the study related to the Implementation Definition of the associated Ground Communications Infrastructure, the results were presented at ESTEC on 29 and 30 January.

The definition study for the COF/ATV Operations Support Functions and Facilities is experiencing delays. The Implementation Review is now planned for end-March.

The PLASMATRON facility was officially inaugurated on 8 December 1997 in the presence of Minister Ylieff of Belgium.

Utilisation
Utilisation promotion
The selection of Express Pallet Payloads to be flown within the framework of the Early Utilisation Agreement with NASA has been finalised. It is intended to fly up to six completely outfitted payload adapters during a three-year period starting in 2002. The following payloads were selected for these opportunities:
- TEF
- ACES
- EXPORT (EXPOSE + SPORT)
- SOLAR PACKAGE
- FOCUS.

Integration of the ARD at Aérospatiale

Intégration de l'ARD à l'Aérospatiale

prévu. Le calendrier de la phase C/D a été revu et la date de référence du premier vol a été fixée à la fin-mars 2003. Les engagements pris par l'industrie à la mi-mars permettent de penser que la proposition de contrat relative à l'ATV sera soumise au Comité de la politique industrielle de l'Agence (IPC) en juin 1998, après évaluation d'une proposition industrielle remise à jour.

Véhicule de transport d'équipage (CTV)

A la suite de l'approbation, par le Conseil directeur des programmes spatiaux habités (PB-MS) de l'ESA, réuni en décembre, de la proposition de poursuite de la coopération ESA/NASA au programme X-38/CTV, une Déclaration relative à une tranche additionnelle du programme de participation de l'Europe au développement de l'ISS a été ouverte à la souscription jusqu'à la fin du mois de février. A la mi-février, trois pays avaient souscrit à cette tranche additionnelle, à un niveau de contribution qui a permis de lancer les activités industrielles. Les activités entrant dans le cadre de la première étape de cette tranche additionnelle ont été ensuite réorientées au profit de la coopération au projet X-38, et l'équipe européenne basée à Houston a été renforcée en conséquence.

Les travaux portant sur la base de données aérothermodynamiques ont été approuvés dans leur principe à la fin du mois de janvier et ont pu débuter. Les travaux de conception détaillée de l'ensemble de la structure arrière se déroulent selon le calendrier prévu et l'on prépare la fabrication des éléments essentiels des bâtis et des panneaux de cette structure.

La conception du nez du véhicule progresse également, avec la définition des capacités de fabrication respectant le calendrier prévu pour le vol V-201.

Démonstrateur de rentrée atmosphérique (ARD)

Les activités se sont déroulées selon le calendrier établi, afin de respecter la date de lancement du vol Ariane 503, prévue à la mi juillet.

Activités opérationnelles et secteur sol

Les travaux de mise à jour des plans de mise en oeuvre de la Station spatiale, associant l'ensemble des partenaires internationaux, ont permis d'officialiser ces documents au cours de la quatrième réunion de la Commission multilatérale de contrôle des opérations et de l'utilisation (MO&UCB) qui s'est tenue au JSC de la NASA, en décembre 1997. Le MO&UCB a également approuvé la Synthèse des opérations (OS) prévues pour les six premières périodes de planification, correspondant à la Révision C de la séquence d'assemblage.

L'étude de définition des installations et fonctions de contrôle des opérations du COF/ATV et l'étude relative à définition de la mise en oeuvre de l'infrastructure de communications au sol associée ont été menées à bien. Leurs résultats ont été présentés à l'ESTEC les 29 et 30 janvier.

L'étude de définition des installations et fonctions de soutien des opérations du COF/ATV a pris du retard. La revue de mise en oeuvre a été reportée à la fin mars.

L'installation PLASMATRON a été officiellement inaugurée le 8 décembre 1997, en présence du ministre belge, M. Yvan Ylieff.

Utilisation

Promotion de l'utilisation

Le choix définitif des charges utiles à installer sur des palettes express dans le cadre de l'accord ESA/NASA sur l'utilisation initiale de la Station a été arrêté. Il est prévu d'emporter jusqu'à six adaptateurs de charges utiles entièrement équipés pendant une période de trois ans débutant en 2002. Les charges utiles suivantes ont été sélectionnées pour ces occasions de vol :

- TEF
- ACES
- EXPORT (EXPOSE + SPORT)
- SOLAR PACKAGE
- FOCUS

Un accord de compensation, en cours de négociation avec la NASA, prévoit que l'ESA fournira deux coupoles à l'Agence américaine en échange du lancement de la majorité de ces charges utiles.

Le deuxième symposium sur l'utilisation de la Station spatiale doit se tenir fin 1998 à l'ESTEC (NL). Il permettra de présenter en détails les différentes installations à utilisateurs multiples en cours de développement pour l'ISS et d'examiner les différents projets de recherche susceptibles d'y être entrepris.

Préparation de l'utilisation

La première phase des activités prévues par le contrat d'intégration des charges utiles extérieures devait être achevée fin avril. Une analyse approfondie de l'installation des six ensembles de charges utiles confirmés est en cours de réalisation. Une phase de consolidation est prévue jusqu'à la fin de 1998, avant le lancement de la phase C/D, début 1999.

La production des documents de contrôle des interfaces des deux premières installations de recherche en microgravité pour Columbus (MFC) (Biolab et Laboratoire de science des fluides) est actuellement en cours. Des efforts supplémentaires doivent être consentis dans le domaine de la documentation, avec le lancement de l'étude d'intégration d'ici la mi-98, afin de respecter le calendrier d'intégration des charges utiles du COF. On prépare actuellement le cahier des charges du contrat d'intégration des charges utiles du COF et une proposition d'approvisionnement doit être soumise en mai au Comité de la politique industrielle (IPC) de l'ESA.

Deux appels d'offres, portant sur les études d'installation d'équipements complexes (ALADIN et XEUS) à bord de l'ISS, ont été lancés. Les projets ALADIN – l'installation Lidar vent – et XEUS – une grande installation dans le rayonnement X qui doit être assemblée à bord de l'ISS – sont respectivement menés en coopération avec la Direction des télécommunications et la Direction des programmes scientifiques de l'Agence. Les propositions industrielles relatives à ces deux activités devaient être soumises à la mi-mars 1998.

Réalisation des matériels destinés à l'utilisation

Les revues critiques de conception de la boîte à gants et du congélateur –80° C progressent et devraient être terminées en mai. La phase de développement principale (phase C/D) de l'Hexapod a commencé. La phase C/D du système de pré-pointage a été repoussée de trois mois, afin que l'on puisse intégrer, pendant une phase-relais, les résultats de la sélection des charges utiles extérieures.

A barter agreement with NASA is under negotiation whereby the cost of the launch for the majority of these payloads would be offset by ESA providing two Cupolas to NASA.

The second Space Station Utilisation Symposium is planned to be held late in 1998 at ESTEC (NL). It will include detailed presentations on the various Multi-User Facilities under development for Space Station and discussions on the research ideas to be realised with these facilities.

Utilisation preparation
Phase-1 of the External Payload Integration contract will be completed by the end of April. An in-depth accommodation analysis of the six confirmed payload complements is presently being carried out. A consolidation phase, lasting until the end of 1998, will be introduced prior to starting Phase-C/D in early 1999.

The generation of Interface Control Documents for the first two MFC facilities (Biolab and Fluid-Science Lab) is in progress. In order to maintain the payload-integration schedule for the COF, further documentation efforts and in particular the analytical integration must be started by mid-1998. The Statement of Work for the COF payload-integration contract is in preparation and a procurement proposal will be submitted to ESA's Industrial Policy Committee (IPC) in May.

The Invitation to Tender (ITT) for two ISS accommodation studies of complex facilities (ALADIN and XEUS) have been issued. ALADIN - the Wind Lidar Facility - is being carried out jointly with ESA's Directorate for Telecommunications, and XEUS - a large X-Ray Facility assembled at the ISS - is being studied in cooperation with the Directorate for Scientific Programmes. Industrial proposals for these two activities will be submitted in mid-March 1998.

Utilisation hardware development
The Critical Design Reviews for the Glovebox and -80° C Freezer facilities are in progress and should be completed in May. The main development phase (Phase-C/D) for the Hexapod has started. Phase-C/D for the Coarse Pointing System has been postponed by three months to allow for a bridging phase, which is necessary to introduce the results of the external payload selection.

In January, five International Standard Payload Racks (ISPRs) were delivered to ESA by NASDA. They are being prepared for delivery to the industries developing the - 80 degC Freezer and the Glovebox.

The development of the Standard Payload Outfitting Equipment SPLC, RPDA and AAA is progressing. Engineering models will be available in the second half of 1998. Qualification will be completed by the end of 1998 and delivery of recurring flight models for a large number of payloads will start in early 1999.

The industrial proposal for the development of the European Drawer Rack (EDR) was received in February and is under evaluation.

Astronaut Activities
A European Astronaut Policy Working Group was established in January. A series of meetings resulted in a report which presents an analysis of the number of future flight opportunities and, accordingly, the necessary size of the future European Astronaut Corps. The ESA Council decided in March to integrate national astronauts into a single European Corps in order to optimise the use of existing resources (see 'In Brief').

Early Deliveries
Data Management System for the Russian Service Module (DMS-R)
Following delivery of the Fault Tolerant Computers (FTCs) at the end of October, some minor problems were encountered and these units were returned in December for reworking. The units were returned to RSC-Energia in the third week of January, with no impact on the Service Module Schedule.

The Control Post Computers (CPC), which were originally planned to be delivered to Russia in December, experienced some failures during final acceptance testing and revised delivery dates were agreed with RSC-Energia. The revised hardware and software delivery schedule does not affect the Service Module integration and test planning.

European Robotic Arm (ERA)
The ERA schedule indicates a slippage of one to two months, principally due to delays in the On-Board Computer, End Effector, and Main Joint subsystems. Efforts to relieve these slippages are continuing, but the overall schedule is considered critical and the delivery date of July 1999 for the ERA flight model is threatened.

Flight End Effector Basepoints and the GEO model have been shipped to RSC-Energia. Final acceptance of the Basepoints is held up, however, pending the resolution of some non-conformances. The Acceptance Review of the WET (Weightless Environmental Test) model was held in March, with the participation of representatives from the Gagarin Cosmonaut Training Centre and RSC-Energia. Shipment to Russia is planned for April.

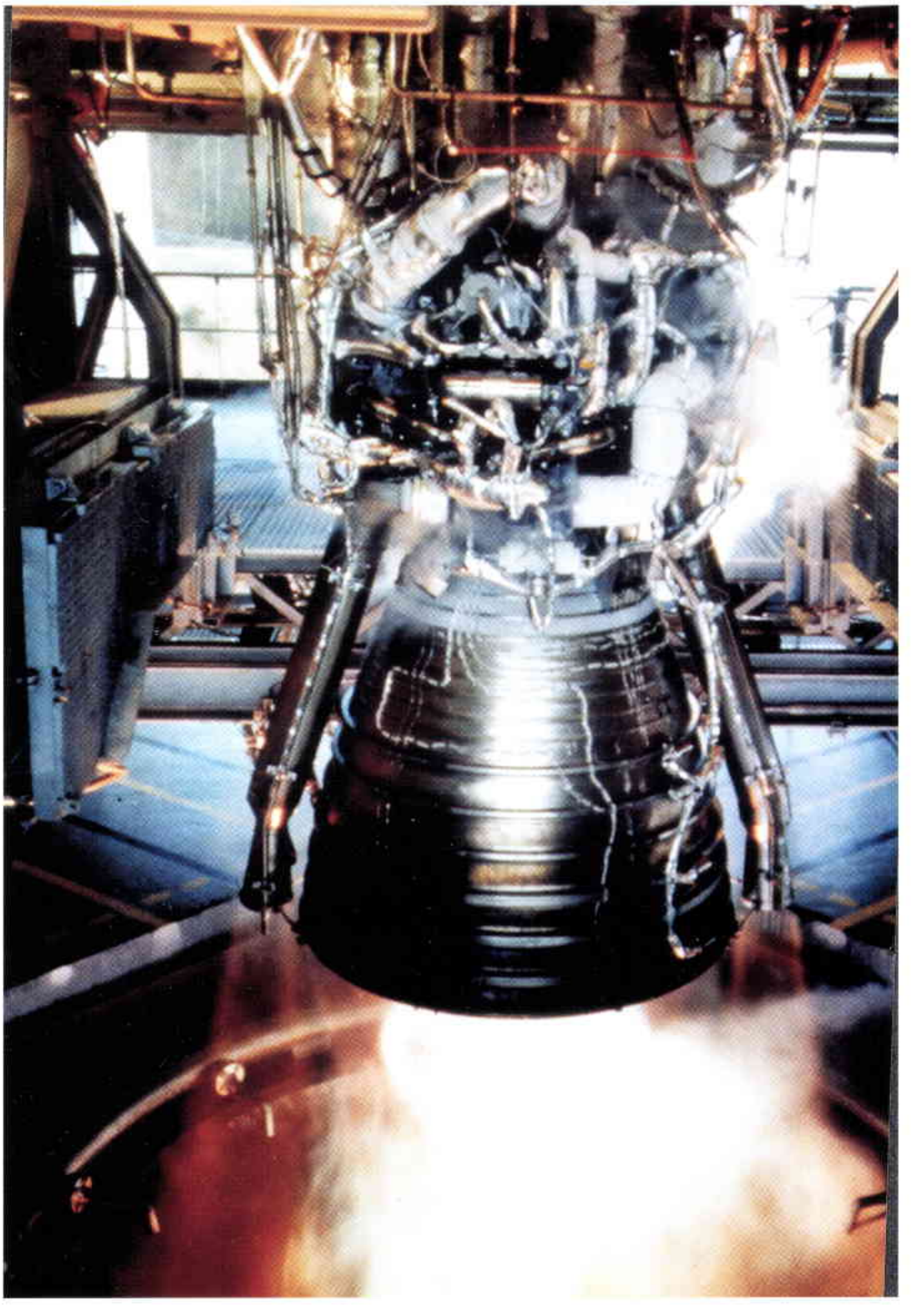
The Ground Segment and Operations interfaces are partly defined, but the process of integrating ERA into the Science and Power Platform of the Russian Segment still requires clarification from the Russian side.

Microgravity

EMIR-1 and EMIR-2
Under the EMIR-1 and EMIR-2 programmes, two sounding rockets were launched from ESRANGE in Sweden. The Maser Technology flight with the new Maser service module was launched on 26 January. However, neither in-flight telemetry nor video signals were received and it proved impossible to locate and recover the payload. The Mini-Texus 5 was flown on 11 February, and all experiment results were successfully received by telemetry.

MFC
The Biolab Phase-C/D contract was awarded in December and contracts with most of the subcontractors were signed in February. The Preliminary Design Review (PDR) is scheduled for October 1998. Technical Interchange Meetings with NASA to discuss the fire-detection and contamination issues are planned in March. The first meeting of the Science Team, to discuss the Experiment Processing Unit (EPU) test results and schedule experiment preparation, is planned for April.

The Phase-C/D proposal for the Fluid-Science Laboratory (FSL) is expected in



An Ariane-5 Vulcain engine test firing in progress

Essai de mise à feu du moteur Vulcain d'Ariane-5

Cinq bâtis internationaux de charge utile normalisés (ISPR) ont été livrés en janvier à l'ESA par la NASDA. Ils subissent actuellement les préparatifs nécessaires à leur livraison aux entreprises qui réalisent la boîte à gants et le congélateur –80° C.

Les travaux de développement du SPLC des équipements de charges utiles standard, du RPDA et de l'AAA d'équipement de la charge utile standard progressent. Les modèles d'identification devraient être disponibles dans le courant du second semestre de 1998. La qualification sera achevée fin 1998 et la livraison des modèles de vol récurrents d'un grand nombre de charges utiles commencera début 1999.

La proposition industrielle de développement du bâti à tiroirs européen (EDR), reçue en février, est en cours d'évaluation.

Activités des astronautes

Un Groupe de travail relatif à la politique des astronautes européens a été créé en janvier. Il s'en est suivi une série de réunions et un rapport qui présente une analyse des futures occasions de vol et, en conséquence, des effectifs du futur corps d'astronautes européens. En mars le Conseil de l'ESA a décidé d'intégrer des astronautes nationaux dans un corps européen unique afin d'optimiser l'utilisation des ressources existantes.

Livraisons à court terme
Système de gestion de données pour le module de service russe (DMS-R)

Les ordinateurs à tolérance de panne (FTC) livrés fin octobre ont connu quelques défaillances mineures. Ils ont été renvoyés au fabricant en décembre pour réparation et sont rentrés chez RSC-Energia dans le courant de la troisième semaine de janvier, sans que cela ait d'incidence sur le calendrier du module de service.

Les ordinateurs du poste central (CPC), qui auraient du être fournis à la Russie en décembre, ont subi quelques dégâts au cours des derniers tests de recette et les dates de livraison ont été revues en accord avec RSC-Energia. Le nouveau calendrier de livraison du matériel et du logiciel n'a pas d'incidence sur le planning de l'intégration et des tests du module de service.

Bras télémanipulateur européen (ERA)

Le calendrier de l'ERA fait apparaître un glissement de un à deux mois dû, pour l'essentiel, à des retards affectant le calculateur de bord, l'organe terminal et l'articulation principale. Toutes les actions décidées pour pallier ce glissement se poursuivent mais le calendrier d'ensemble est jugé critique et la date de livraison du modèle de vol de l'ERA fixée à juillet 1999 est incertaine.

Les points d'attache de l'organe terminal de vol et de modèle géométrique (GEO) ont été expédiés à RSC-Energia. La recette définitive des points d'attache est toutefois arrêtée dans l'attente de la résolution de quelques non-conformités. La revue de recette du modèle de WET a eu lieu en mars avec la participation des représentants du Centre de formation des cosmonautes Gagarin et de RSC-Energia. L'expédition en Russie est prévue pour avril.

Les interfaces secteur sol et opérations sont définies en partie mais il reste à éclaircir, du côté russe, la procédure d'intégration de l'ERA à la Plate-forme Science et Energie.

March 1998, with the objective of placing the contract soon afterwards.

The final presentation of Phase-B of the Material Science Laboratory (MSL) will be held in March, and a procurement proposal for Phase-C/D for MSL in the US Module will be submitted. The main contract will include the Low-Gradient Furnace (LGF) module, while an option, to be placed at a later date, will develop the Solidification and Quenching Furnace (SQF) module. The Phase-C/D contract is planned to start in June 1998. The Material Science Laboratory has been introduced into the NASA launch manifest for flight on UF-3 in September 2001.

Two parallel Phase-A contracts were initiated in November 1997 for the European Physiology Modules (EPM) Laboratory. The mid-term reviews are planned in March 1998, while the Phase-A final presentations are foreseen in July 1998. Discussions have been initiated with NASA on the harmonisation of the payload composition between the Human Research Facility (HRF) and the EPM.

Launchers

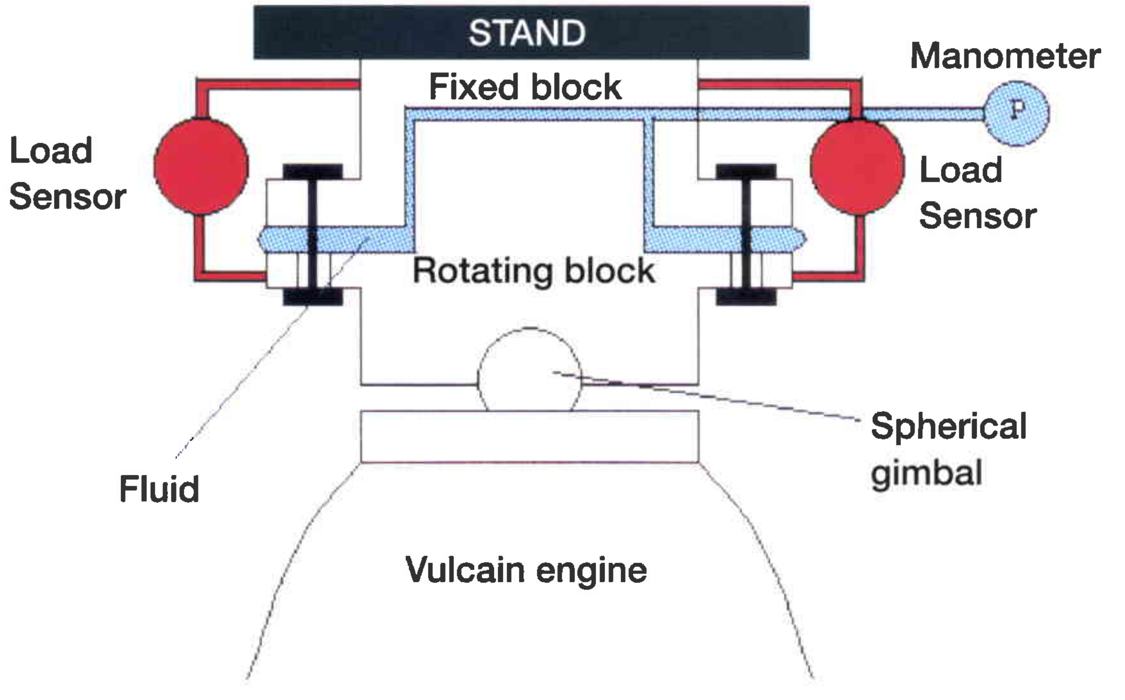
Ariane-4

Between December and March, five Ariane-4 launchers (Arianespace flights V103 to V107) successfully placed in orbit: five commercial communications satellites (JCSAT -5, Intelsat -804, Brasilsat -B3, Inmarsat-3F5, and Hotbird-4), one scientific mission (Equator-S) and one Earth-observation satellite (Spot-4). The latter carried an ESA payload for optical inter-satellite communications, as part of the SILEX Programme.

Ariane-5

Preparation of the third qualification flight has been the major activity, and has included the correction of flight-502 anomalies, primarily:

FINDING THE CAUSE OF THE ARIANE-502 ROLL TORQUE



One of the activities to determine the actual cause of the roll disturbance torque detected during the Ariane-502 flight was to measure the effect of the boundary layer of the Vulcain engine main jet. A 'roll-meter' device has been developed, which is based on the following principle:

Description

The device is placed between the test stand and the engine. It consists of a rotating block housed within a fixed block, separated by a highly viscous pressurised fluid. The bolts are housed in oblong holes in the rotating block, allowing rotation while also supporting the engine when not running. The two load sensors are connected to the stand-integrated fixed block and to the engine-integrated rotating block via a spherical gimbal.

Operation

On firing the Vulcain engine, under the effect of the thrust the rotating block is released from contact with the bolts, compressing the fluid separating it from the fixed block. In the absence of friction, the load sensors can measure the roll torque specific to the Vulcain engine.

The device was used for the first time on the M18R2-07 test on 3 March. It measured a torque of 810 Nm, compared to the 900 Nm on the 502 flight. Further tests are planned and will be executed while varying the parameters – replacing divergent, repositioning turbine exhausts, replacing engine, etc. – in order to analyse the effect of each in more detail.

Microgravité

EMIR-1 et EMIR-2

Deux fusées-sondes ont été lancées de l'Esrange, en Suède, dans le cadre des programmes EMIR-1 et EMIR-2. Le vol d'essai de la technologie Maser, emportant le nouveau module de service Maser, a eu lieu le 26 janvier. Toutefois, aucun signal de télémesure en vol ou signal vidéo n'a pu être reçu et il a été impossible de localiser et de récupérer la charge utile. Le vol Mini-Texus 5 a eu lieu le 11 février, et l'ensemble des résultats expérimentaux ont été normalement transmis par télémesure.

MFC

Le contrat de phase C/D du Biolab a été attribué en décembre et la plupart des contrats de sous-traitance ont été signés en février. La revue de définition préliminaire doit se dérouler en octobre 1998. Des réunions d'échanges techniques devaient avoir lieu en mars avec la NASA pour examiner la question de la détection d'incendie et de la contamination. La première réunion de l'équipe scientifique devait avoir lieu en avril pour examiner les résultats des essais de l'unité de conduite des expériences (EPU) et discuter du calendrier de préparation des expériences.

La proposition de phase C/D du laboratoire de science des fluides (FSL) était attendue en mars 1998, les contrats devant être placés dans la foulée.

La présentation définitive des résultats de la phase B du laboratoire de science des matériaux (MSL) devait avoir lieu en mars. Une proposition d'approvisionnement relative à la phase C/D du MSL destiné au module américain doit être soumise par la suite. Le contrat principal concernera notamment la réalisation du Four à faible gradient (LGF), avec possibilité d'attribuer ultérieurement un contrat de développement du module Four de solidification avec trempe (SQF). Le contrat de phase C/D devrait entrer en vigueur en juin 1998. Le Laboratoire de science des matériaux a été inclus dans le manifeste de la NASA, sa mise sur orbite devant intervenir en septembre 2001, lors du vol UF-3.

La mise en oeuvre de deux contrats parallèles de phase A relatifs aux modules de physiologie européens (EPM) a débuté en novembre 1997. Les revues à mi-parcours étaient prévues en mars 1998, et les présentations finales en juillet 1998. Des discussions ont été entreprises avec la NASA pour harmoniser la répartition de la charge utile entre l'Installation de recherche sur l'Homme (HRF) et les EPM.

Lanceurs

Ariane-4

Entre décembre 1997 et mars 1998, cinq lanceurs Ariane-4 (vols Arianespace V103 à V107) ont permis de placer sur orbite cinq satellites de télécommunications commerciaux (JCSAT-5, Intelsat-804, Brasilsat-B3, Inmarsat-3F5 et Hotbird-4), un satellite scientifique (Equator-S) et un satellite d'observation de la Terre (Spot-4). Ce dernier transporte avec lui une charge-utile de l'ESA destinée aux liaisons optiques intersatellites, dans le cadre du programme SILEX.

Ariane-5

La majeure partie des activités a été consacrée à la préparation du troisième vol de qualification et à la correction des anomalies constatées pendant le vol 502, à savoir essentiellement :

- *le non-déploiement des parachutes de récupération des étages d'accélération à poudre. Le cône avant des accélérateurs a été renforcé afin de répondre aux contraintes de rentrée.*
- *la présence d'un couple de roulis relativement constant de 900 Nm lors de la phase de propulsion de l'étage principal, et l'arrêt de celui-ci 5,8 secondes plus tôt que prévu.*

Le mouvement de roulis a été attribué, en février, à deux causes possibles, après analyse de niveau 1 des données de vol et recherches spécifiques :

- *Un mouvement en spirale des gaz d'échappement provoqué par la rugosité de la surface interne de la tuyère du moteur Vulcain. Après modélisation informatique, on estime que la valeur du couple provoqué par ce phénomène est comprise entre 250 et 950 Nm.*
- *La rupture, pendant le vol, d'une des biellettes de fixation sur la ligne d'échappement d'une turbopompe. La déviation du jet d'échappement pourrait avoir produit un couple de roulis de 600 à 950 Nm.*

L'arrêt prématuré de l'étage principal est attribué au ballottement du propergol liquide à l'intérieur du réservoir d'oxygène, généré par le mouvement de roulis du lanceur. Il a été décidé, en conséquence, d'installer un système de contrôle d'attitude supplémentaire sur le lanceur Ariane-503 afin de doubler les capacités de correction du roulis.

Une mesure du couple en roulis a été réalisée lors d'un premier essai statique de mise à feu du moteur Vulcain, effectué le 3 mars à Vernon (F) sur un exemplaire munis de fixations modifiées. Les résultats de cet essai ont révélé l'existence d'un couple en roulis quasi constant de 810 Nm ± 2% au cours des 800 secondes de la mise à feu. Ce résultat, qui doit encore être confirmé lors de nouveau essais, est très encourageant et tend à confirmer que le couple constaté au cours du vol A502 est entièrement imputable à la conception de la tuyère du moteur Vulcain, et peut être, de ce fait, facilement compensé par la préorientation adéquate des deux lignes d'échappement des turbopompes.

Le système supplémentaire de contrôle d'attitude a été maintenu à titre de précaution pour le vol A503, mais pourrait s'avérer inutile lors des lancements suivants si les résultats obtenus lors de ce premier essai sont confirmés par d'autres essais et par les résultats obtenus lors du vol A 503 lui-même.

Le calendrier actuel prévoit que le lanceur Ariane-503 sera prêt à la mi-juillet. Le choix de la date exacte du lancement dépendra de la disponibilité du passager auxiliaire commercial embarqué avec la capsule ARD de l'ESA. Des négociations se poursuivent avec les propriétaires de plusieurs satellites de télécommunications.

Ariane-5 Evolution

Plusieurs études et essais au niveau des composants ont été réalisés sur l'étage cryotechnique et sur le moteur Vulcain-2. Ces travaux ont porté principalement sur le débit d'oxygène et les systèmes de pressurisation, sur le bâti-moteur et les turbopompes oxygène et hydrogène.

La fabrication des modèles au sol et de qualification en vol du support de charge utile Sylda-5 a été achevée.

Futurs lanceurs

Le Programme européen de recherche appliquée sur les futurs systèmes de

- The solid-booster recovery parachutes did not deploy: the booster's forward cone is being reinforced to cope with re-entry loads.
- A relatively constant roll torque of 900 Nm was present during main stage propulsion. The main-stage cut-off occurred 5.8 s earlier than foreseen.

Two possible causes of the roll movement were retained in February, as a result of the level-one flight-data analysis plus specific investigations:
- Spiral movement of the exhaust gases caused by roughness of the internal surface of the Vulcain's nozzle. The torque level due to this phenomenon was estimated via computer modelling to be between 250 and 950 Nm .
- An attachment rod on a turbopump exhaust duct could have broken during flight. The deviated exhaust jet could have generated a torque of between 600 and 950 Nm.

The early main-stage cut-off is attributed to sloshing of the liquid propellant inside the oxygen tank, generated by the launcher's roll movement. It was therefore decided to install an additional attitude-control system on the Ariane-503 vehicle to double the roll counteracting performance.

A first static firing test of a Vulcain engine was performed on 3 March in Vernon (F), with a modified engine fixture to measure the roll torque generated during the test. The results showed a quasi-constant roll torque of 810 Nm ± 2% during the 800 s of firing. This finding, to be checked in further tests, is very encouraging and should confirm that the torque encountered during the Ariane-502 flight can be totally attributed to the Vulcain nozzle design, and is therefore easily counteracted by properly pre-orienting the two turbopump exhaust ducts.

As a conservative measure, the additional attitude-control system is being maintained on the 503 launcher. This will probably be unnecessary on future launches, if the results of this first test are confirmed by the further tests and by the Ariane-503 flight results.

Present planning foresees that Ariane-503 will be ready for launch in July. The exact date will depend on the availability of the commercial co-passenger for ESA's ARD capsule. Negotiations are still in progress with the owners of several candidate telecommunication satellites.

Ariane-5 Evolution

Several studies and component-level tests have been carried out on the cryogenic stage and Vulcain-2 engine. They concerned mainly the oxygen flow and pressurisation systems, the engine's thrust frame and the oxygen and hydrogen turbopumps.

Manufacture of the on-ground and in-flight qualification models of the Sylda-5 payload structure has been completed.

Future launchers

Future launchers with reusability features to reduce the cost of access to space are being defined in the Future European Space Transportation Investigations Programme (FESTIP) and the corresponding technologies are being developed.

The most promising concepts will be selected in mid-1998 in order to define the technology work to be conducted in the context of the follow-up to FESTIP, namely the Future Launchers Technologies Programme (FLTP).

In-Orbit Technology Demonstration Programme

JERICO (Joint European Robotics Interactive and Calibrated Operations)

A robotic system to be flown on the Russian Segment of the International Space Station in 1999, JERICO is a cooperative effort by ESA (Belgian industry), ASI (I) and RSC-Energia.
The first contract for the development of launcher-independent items – mostly ground-segment building blocks – is almost finalised. Belgian industry is currently preparing the proposal for the continuation of the JERICO system-development phase, which is expected to be presented to ESTEC in mid-April.

RSC-Energia has provided valuable input concerning the configuration of the Russian Segment, although major obstacles for the communication interfaces have been identified. The cooperation agreement with RSC-Energia is expected to be signed in March 1998.

ASI is progressing well with its developments for the JERICO manipulation system.

PROBA (Project for On-Board Autonomy)

Evaluation of the industrial proposal for the PROBA mission has been completed and the project's system design phase commenced in February. The outcome of this phase will be submitted to an ESA review in June 1998 before release of the main development phase. The parallel developments of the instruments — SREM (Standard Radiation Environment Monitor), DEBIE (Debris In-orbit Evaluator), and CHRIS (Compact High Resolution Spectrometer) — are proceeding well. Launch is planned for mid-2000, to be followed by three months of commissioning, one year of nominal operations and a year of in-flight experiments.

transport spatial (FESTIP) définit les caractéristiques des futurs lanceurs à éléments réutilisables permettant de réduire le coût de l'accès à l'espace. Les différentes technologies en rapport sont en cours de développement. Les concepts les plus prometteurs seront sélectionnés à la mi-1998 afin de définir les activités technologiques à entreprendre dans le cadre du programme qui doit prendre la suite du FESTIP, à savoir le Programme de technologie pour les futurs lanceurs (FLTP).

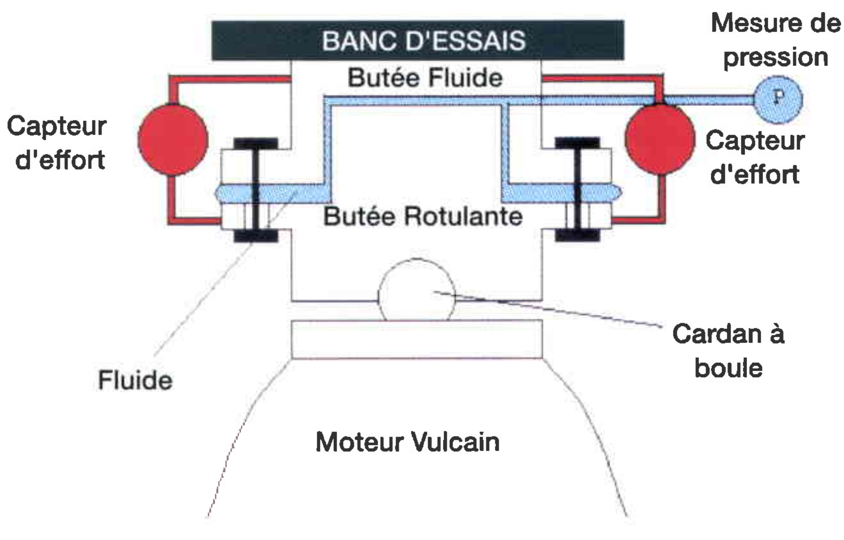
Programme de démonstration technologique en orbite

JERICO (Projet commun européen d'étalonnage interactif de robotique)
JERICO est un système de robotique destiné à la composante russe de la Station spatiale internationale, vers laquelle il sera lancé en 1999. Il est réalisé en coopération par l'ESA (Industrie belge), l'ASI (I) et RSC-Energia.
La préparation du premier contrat de développement d'éléments non liés à un lancement – essentiellement des modules du secteur sol – est presque achevée. L'industrie belge a préparé une proposition de poursuite de la phase de développement de JERICO au niveau système qui devait être présentée à l'ESTEC à la mi-avril. RSC-Energia a fourni d'importantes données sur la configuration de la composante russe, mais ils subsiste des obstacles majeurs en ce qui concerne les interfaces de communication. L'accord de coopération avec RSC-Energia devait être signé en mars 1998.

Les travaux de développement de l'ASI destinés au système manipulateur de JERICO progressent de manière satisfaisante.

PROBA
L'évaluation de la proposition industrielle relative à la mission PROBA a été achevée et la phase de conception système du projet a débuté en février. Les résultats de cette phase seront examinés par l'ESA en juin 1998, avant lancement de la phase principale de développement. Le développement parallèle des instruments SREM (Système normalisé de surveillance du rayonnement ambiant), DEBIE (Evaluateur de débris en orbite) et CHRIS (Spectromètre imageur compact de haute résolution) se déroule normalement. Le lancement, prévu pour la mi-2000, sera suivi d'une phase de recette de trois mois, d'une année d'exploitation nominale et d'une année d'expériences en vol. esa

RECHERCHE DE LA CAUSE DU COUPLE DE ROULIS D'ARIANE-502



L'une des actions entreprises pour déterminer l'origine exacte du couple de roulis qui a affecté le déroulement normal du vol Ariane-502 a consisté à mesurer les effets de la couche limite du jet principal du moteur Vulcain. On a réalisé pour ce faire un dispositif de mesure de roulis, dont voici les principales caractéristiques:

Description
Le dispositif est placé entre le banc d'essai et le moteur. Il est constitué d'une butée fixe, les deux éléments étant séparés par un fluide pressurisé à haute viscosité. Les boulons sont logés dans des trous oblongs situés sur la butée rotulante, ce qui permet tout à la fois la rotation et le soutien du moteur lorsque celui-ci ne fonctionne pas. Les deux capteurs d'efforts sont branchés sur la butée fixe solidaire du banc d'essai et sur la butée rotulante reliée au moteur, via un cardan à boule.

Fonctionnement
Lorsque l'on allume le moteur Vulcain, la butée rotulante n'est plus en contact avec les boulons sous l'effet de la poussée, compressant le fluide qui le sépare de la butée fixe. En l'absence de friction, les capteurs d'effort peuvent alors mesurer le couple en roulis spécifique du moteur Vulcain.

Ce dispositif a été utilisé pour la première fois le 3 mars, lors de l'essai M18R2-07. Il a enregistré un couple de 810 Nm, à comparer avec les 900 Nm constatés lors du vol 502. D'autres essais sont prévus et seront réalisés en faisant varier les différents paramètres — remplacement du divergent, repositionnement des échappements de turbine, remplacement du moteur, etc. — afin d'analyser l'influence de chaque élément de manière plus détaillée.

In Brief

New Discoveries Complete ISO's Observations

Water vapour detected on Saturn's largest moon, Titan, and infrared galaxies identified at immense distances are among the latest results from the European Space Agency's Infrared Space Observatory (ISO). At a press briefing in London on 7 April, ESA's Director of Scientific Programmes, Roger Bonnet, said "ISO is one of the most successful space observatories, and in the infrared it has had no rival."

On 8 April, ISO's operational teams at ESA's ground station at Villafranca, near Madrid, reported that ISO's observational phase had come to an end when the temperature of the instruments had risen above -269°C. They had been hurrying to provide the world's astronomers with as many observations as possible due to the long anticipated exhaustion of ISO's vital supply of liquid helium, which cooled the infrared telescope and its instruments to their operating temperatures close to absolute zero.

The famous Horsehead nebula region imaged by ISOCAM at wavelengths of 7 and 15 microns. Clearly visible in the insets are 3 bright reddish dots, which are recently-born stars

Thanks to superb engineering by European industry, which built the spacecraft and its super-cool telescope, ISO has given astronomers almost a year longer than the originally foreseen 18 month liftetime. During this extra time, the count of ISO's observations of cosmic objects has risen from 16 000 to about 26 000. Among the benefits of ISO's longevity has been the chance to examine an important region of the sky in and around the constellation of Orion. This was not accessible in the nominal mission but has now been observed in two periods.

Four international teams, supported by national funding agencies, supplied the instruments to analyse the infrared rays received by ISO's telescope. The Principal Investigators leading the teams are Dietrich Lemke (Heidelberg, Germany) for the versatile photometer ISOPHOT, Catherine Cesarsky (Saclay, France) for the camera ISOCAM, Thijs de Graauw (Groningen, The Netherlands) for the Short Wavelength Spectrometer (SWS), and Peter Clegg (London, UK) for the Long Wavelength Spectrometer (LWS).

Water vapour on Titan

A big difference between ISO and the only previous infrared astronomy satellite IRAS (1983) has been its ability to examine individual objects across a wide range of accurately defined infrared wavelengths. Many spectra showing patterns of intensities at the different wavelengths have enabled astronomers to deduce the presence of diverse materials in interstellar space, in the surroundings of stars and in other galaxies.

As previously reported, ISO has identified stony materials, tarry compounds of carbon and vapours, and ices like water and carbon monoxide. Together they give the first clear picture of how Mother Nature prepares, from elements manufactured in stars, the ingredients needed for planets and for life itself.

Particularly striking for the human imagination are ISO's repeated discoveries of water in the deserts of space. They encourage expectations of life elsewhere in the Universe. Water has turned up around dying stars, new-born stars, in the general interstellar medium, in the atmospheres of the outer planets and in other galaxies too. A link to the Earth's oceans and the water we live by comes in the water-ice long known to be a major ingredient of comets, which are relics from the era of planet-building.

A further link to the investigation of the origin of life is the detection of water vapour in the mysterious atmosphere of Saturn's largest moon, Titan. A preliminary announcement comes from an international team headed by Athena Coustenis of Paris Observatory and Alberto Salama of the ISO Science Operations Centre at Villafranca.

The team used ISO's Short Wavelength Spectrometer during several hours of observations last December, when Titan was at its farthest from Saturn as seen by ISO. Emissions at wavelengths of 39 and 44 microns showed up, as an expected signature of water vapour. The news will excite the scientists involved in ESA's probe Huygens, launched last year aboard NASA's Cassini spacecraft. It will parachute into Titan's atmosphere to see what the chemistry of the Earth may have been like before life began.

"Water vapour makes Titan much richer," comments Athena Coustenis. "We knew there was carbon monoxide and carbon dioxide in Titan's atmosphere, so we expected water vapour too. Now that we believe we've found it, we can expect to better understand the organic chemistry taking place on Titan and also the sources of oxygen in the Saturnian System. After ISO, the Huygens probe will reveal the actual degree of complexity in a mixture of elaborate organic molecules closely resembling the chemical soup on the young Earth."

Colliding galaxies

Some galaxies are unusually bright in the infrared because of cosmic traffic accidents that bring them into collision with other galaxies. The result is a frenzy of star formation called a starburst. The explosion of short-lived stars then creates a pall of warm dust, which ISO observed in the infrared. The relative intensities of different wavelengths enable astronomers to distinguish starburst events from other sources of strong infrared rays, such as the environment of a black hole in the nucleus of a galaxy. Collisions and starbursts play an important part in the evolution of galaxies.

A famous pair of colliding galaxies called the Antennae was one of the first objects to be examined by ISO. Continuing study of the Antennae over the past two years has revealed a clear picture of a starburst occurring exactly where the dense discs of the galaxies intersect. The nuclei of the two galaxies are also plainly distinguished.

Centaurus A is a galaxy that first attracted the attention of astronomers by its strong radio emissions. In its visible appearance, a large round (elliptical) galaxy has a dark band across its face. This turns out to be the result of a galactic collision as well. The dark band is a flat, disc-shaped galaxy seen almost edge-on. Centaurus A is the nearest case of a phenomenon seen elsewhere by ISO in which a flat galaxy has merged with an elliptical galaxy while preserving its flat configuration.

ISOCAM gives an image of Centaurus A in which the disc galaxy is the more conspicuous object. The disc is oriented at right angles to the axis of the radio-emitting regions, which are powered by jets of electrons driven by a black hole in the centre of the galaxy. Excited emissions detected by ISO's Short Wavelength Spectrometer also indicate the presence of an active black hole.

"Centaurus A is an example of ISO's magic," says Catherine Cesarsky of CEA Saclay in France, leader of the ISOCAM instrument team. "It transforms opaque clouds seen by visible light into glowing scenes in the infrared. The same thing happens in dust clouds hiding new-born stars, and on a huge scale in dusty starburst galaxies, which become infrared beacons lighting our way deep into the Universe."

Distant galaxies seen through the holes in the sky

When ISO was launched, one of the hopes for the space observatory was that it would detect galaxies made luminous by starburst events, or by black-hole activity, very far away in space and, therefore, far back in time. Dust in our own Milky Way Galaxy usually obscures the remotest and faintest galaxies. But when they look northwards and southwards, at right-angles to the disc of the Milky Way, astronomers find holes in the dust clouds through which distant galaxies are discernible.

Both for ISO and the Hubble Space Telescope (HST) these holes have been special targets for observations with long exposures, to reveal faint galaxies. ISOCAM results through the northern hole, by a Japanese-led team, were reported last year. They revealed many infrared-luminous galaxies billions of light-years away, from an era corresponding with about half the present age of the Universe. Even more distant and earlier galaxies may be present in ISO's observations, including some objects not yet seen by visible light.

Results released at the London press briefing on ISO include 'deep field' examinations by groups of astronomers led by Catherine Cesarsky of CEA Saclay and Michael Rowan Robinson of Imperial College, London, analysing the northern and southern images, respectively. In the northern deep field, when ISOCAM observations are superimposed on an HST picture of the same region, they pick out spiral galaxies experiencing starbursts. A different signature comes from large elliptical galaxies whose visible light has been shifted into the infrared by the expansion of the Universe. The astronomers estimate that some of the objects seen by ISOCAM are so far away that the Universe was only one-third of its present age when they emitted the radiation seen today.

The first ISO images from the opposite direction in the sky, in the southern deep field, show similar objects, again at great distances. A preliminary analysis indicates the presence of 30-40 remote galaxies seen at a wavelength of 7 microns and 22-30 at 15 microns. One interesting source, bright in the infrared, is not seen by visible light even in a prolonged examination by the CTIO 4-metre telescope in Chile. Astronomers suspect that this object is undergoing an especially violent period of star formation. The interpretation can be checked when HST and other telescopes have had a chance to examine this scene.

Besides illuminating the evolution of the galaxies, ISO's deep field results are encouraging for scientists planning another of ESA's astronomical space projects, FIRST. Its longer wavelengths will penetrate even deeper into the unknown.

Non-stop discoveries

The extended life was not the only outcome that made ISO such a triumph for ESA, European industry and those responsible for its operations. The pointing accuracy of the telescope turned out to be ten times better than required in the specification and its jitter was one-fifth of what was considered tolerable. Stray light in the optical system was too small to measure. The scheduling systems achieved science observations for 90-95 per cent of the available time. Much of the rest of the time, when ISO was turning to new targets, was spent in mapping parts of the sky at a wavelength of 200 microns.

Activity concerning ISO will continue at the Villafranca ground station until the year 2001, long after the completion of the observational phase of the mission. During the space operations, the main objective was to make as many observations as possible. Thorough analysis and interpretation of the results will take several years.

"We still have plenty to do," says Martin Kessler, ESA's project scientist for ISO. "Our team at Villafranca is preparing a complete archive of ISO data on 500-1000 compact disks, after reprocessing with improved software. We'll release part of this archive to the world-wide astronomical community in the autumn of this year, and the rest in 1999. We shall also advise the astronomers who have used ISO about the particular requirements for handling the data from each instrument, and we'll be doing some astronomy ourselves. There are far more results still to come from ISO."

Meanwhile, Europe's space astronomy programme continues in other directions. ESA's participation in the Hubble Space Telescope and its eventual successor assures access to important instruments for Europe's astronomers. The release, in1997, of the Catalogues from ESA's unique star-mapping mission*, Hipparcos, provided astronomers with amazingly precise data for sizing up the stars and the wider Universe. Next year will see the launch of ESA's XMM satellite to observe X-rays from the Universe with the most ingenious and sensitive X-ray telescopes ever made. It will be followed by Integral in 2001, which will investigate cosmic gamma-rays with clever imaging devices called coded masks, and ultra-sensitive detectors.

"Our aim in space astronomy is that every ESA mission should be the best in the world at the time of its launch," says Roger Bonnet, ESA's Director of Scientific Programmes. "ISO has been a shining example. It has revolutionised infrared astronomy. It has given us wonderful insights into cool and hidden places in the Universe, and into the origins of water and other materials to which we owe our very existence. A mission of this scale and complexity was feasible for Europe only through the multinational collaboration coordinated by ESA."

Further information about ISO and its results, including a picture gallery, is available via the Internet: http://isowww.estec.esa.nl

* Available from ESA Publications Division

Signing for the Fluid Science Laboratory (FSL) for the ISS on 7 April are J. Feustel-Büechl, ESA Director for Manned Spaceflight and Microgravity (right), and G. Viriglio, Head of the Divisione Spazio for Alenia Aerospazio

ESA Signs Fluid Science Laboratory Contract

The contract for the development and delivery of ESA's Fluid Science Laboratory (FSL) for Columbus was signed on 7 April 1998 at ESTEC by Mr J. Feustel-Büechl, ESA Director of Manned Spaceflight and Microgravity, and Mr G Viriglio, Head of prime contractor Alenia Aerospazio's Divisione Spazio. The ceremony took place in the High Bay area of ESTEC's Erasmus building.

FSL is one of the large multi-user facilities being developed under ESA's Microgravity Facilities for Columbus (MFC) Programme. Extending ESA's earlier fluid science research programmes, FSL will investigate areas such as flows and induced instabilities, double diffusive instabilities, interfacial tension and adsorption, mechanisms of boiling, critical point phenomena, crystal growth and directional solidification. Owing to its modular and adaptable experiment equipment, complementary science areas such as colloid and aerosol physics, particle agglomeration and plasma crystal physics are envisaged.

FSL's most important diagnostics equipment are four different, convertible interferometers, a 'first' in the history of microgravity facilities. Compared with earlier facilities, such as the Bubble, Drop and Particle Unit (BPDU) flown on Spacelab, FSL offers a greatly enhanced observation bandwidth for refractive index resolution, improved control and support capabilities, extended experiment processing and research autonomy (telescience), and enhanced Experiment Container features, such as doubling the useful volume.

The industrial consortium led by Alenia comprises seven subcontractors: Verhaert DD (B), OHB System (D), DASA/Dornier (D), Laben SpA (I), MARS (I), Officine Galileo (I) and Sener (E). The Authorisation To Proceed with the Phase-C/D activities was issued to the consortium on 15 April 1998, and the Final Acceptance is planned for December 2001 (end of the Phase-C/D contract). This will be followed by related mission preparation activities aimed at a launch date in October 2002 aboard ESA's Columbus Orbital Facility (COF).

Hipparcos Reveals Milky Way is Changing Shape

Hipparcos data has revealed that distant stars are moving in unexpected directions. Their strange behaviour could mean that the shape of the Milky Way Galaxy is changing. A team of astronomers from Turin Observatory and Oxford University announced the discovery in the 2 April issue of *Nature**.

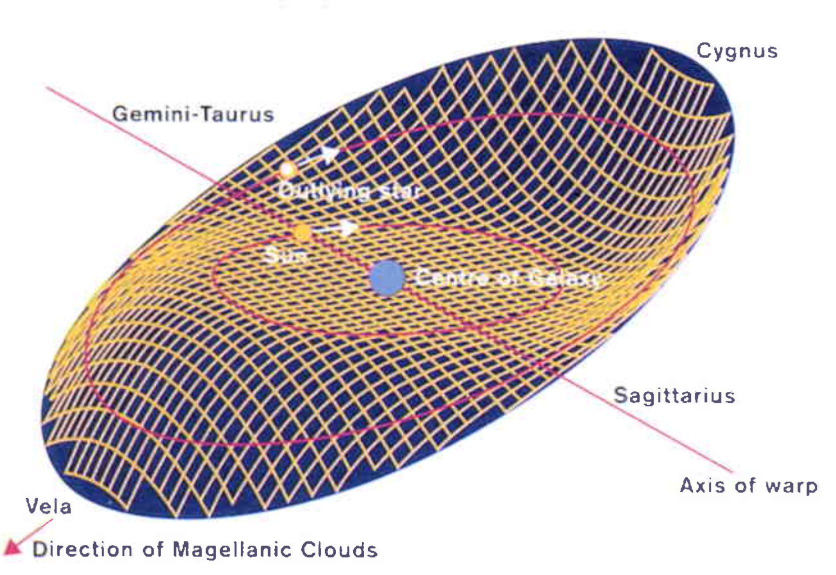
Our home galaxy, the Milky Way, is roughly flat, with a bulge in the middle. As inhabitants of the disc we see it edge-on, as the band of light across the night sky from billions of distant stars, which gives the Milky Way Galaxy its name. Astronomers have known for many years that the disc is slightly warped. What surprises them now is that distant stars are travelling in directions that, if continued, will change the warped shape.

Richard Smart of Turin Observatory, the lead author of the *Nature* article, recounted, "Our results surprised us, but the extraordinary accuracy of Hipparos convinces us that distant stars have altered course. If we knew why, we'd be a lot wiser about the unseen hand of gravity at work in our Galaxy and others."

The Hipparcos satellite measured the positions and motions of stars far more precisely than ever before. Even before ESA's publication last year of the Hipparcos and Tycho Catalogues, of 118 000 and a million stars, respectively, the Turin-Oxford group of astronomers had privileged access to some of the more exact Hipparcos Catalogue data. They obtained positions and motions of 2422 very luminous blue stars spread half-way around the sky, selecting stars that turned out to be lying more than 1600 light-years away, towards the outskirts of the Galaxy.

Like the billions of other stars inhabiting the disc of the Milky Way, the Sun slowly orbits around the centre of the Galaxy, taking 220 million years to make one circuit. Inside the Sun's orbit, astronomers see no warp in the disc of the Milky Way. But outlying stars in the direction of the Cygnus constellation lie north of, or

* *Nature*, Vol. 392, pp. 471-473. The authors are R.L. Smart, R. Drimmel, M.G. Lattanzi (Osservatorio Astronomico di Torino, Italy) and J.J. Binney (Dept. of Physics, University of Oxford, UK).



Outside the Sun's orbit, stars follow tilted orbits. According to Hipparcos results, the tilts become more pronounced at increasing distances, such as in the curved shape of the disc shown here, resembling the brim of a hat (for clarity's sake, the height of the warping is exaggerated x10)

above, the plane of the Sun's orbit. Those in the opposite direction, in the Vela constellation, are displaced southward, below their expected positions if the Milky Way were truly flat.

The first use made of the Hipparcos data by the Turin-Oxford group was to check the precise shape of the warped disc of the Galaxy. Before Hipparcos, observations of stellar positions indicated that the warp started outside Sun's orbit and had general upward and downward turns. The very precise star-fixing by Hipparcos showed the warp starting inside the Sun's orbit, with the more distant outlying parts of the Galaxy slanting more than the nearer parts do. As a result, the disc has an elegantly curved shape, like the brim of a hat.

If this shape of the warped disc were long-lasting, astronomers would expect the stars to follow corresponding orbits. Thus outlying stars in the Taurus constellation, midway between Vela and Cygnus, should be climbing 'uphill' if they are to replace the stars lying high in Cygnus at present. The appropriate track for each star can be calculated, on the assumption that the warp will persist.

Before they could accurately compare the calculated motions with those detected by Hipparcos, Richard Smart and his colleagues had to take into account the Sun's own vertical motion. Like many stars, the Sun jumps and swoops like a dolphin as it proceeds in its orbit around the centre of the Galaxy. Hipparcos data show that the Sun is at present rising at 7 km/s, relative to the disc of the Milky Way.

Outlying stars also show dolphin-like behaviour, so a statistical approach is needed to gauge their average vertical motion. At a distance of 6000 light-years, in the direction of Taurus, the stars should, on average, be climbing northwards, relative to the Sun's orbit, at about 8 km/s. The amazing conclusion by the Turin-Oxford group is that stars at that distance are, on average, descending southwards at 7 km/s.

They cannot therefore replace the present stars in the Milky Way in Cygnus. Instead, they will go to positions shifted southwards in relation to the disc of the Milky Way – unless some new disturbance makes the stars change course again.

The Milky Way is not the only galaxy to show deformations of its disc. About half of all other disc galaxies are seen to have the same effect. This remarkably high proportion may mean that galaxies are so rigid that any warp, once established, lasts for billions of years. Alternatively, galaxies may be very floppy, with new warps being created all the time.

The Hipparcos result on the Milky Way may favour the latter, more dynamic interpretation. The riddle of what warps galaxies has puzzled astronomers for decades. Explanations on offer range from intergalactic winds to magnetic contortions. A popular theory blames the warp in the Milky Way on the gravitational pull of invisible dark matter in the halo of the Galaxy. This would imply that the present warp should be a long-lived phenomenon. As the warp may now be only temporary, other explanations will be favoured.

Mario Lattanzi, of the Turin group, puts it this way, "As is often the case in experimental science, better experimental data challenge our current understanding of how the Milky Way works."

Prominent among the rival proposals about the warping of galaxies is the gravitational (tidal) effect of other galaxies passing close by. In the case of the Milky Way, the Magellanic Clouds and the recently discovered Sagittarius Dwarf Galaxy are candidates as warping agents. But Smart and his colleagues confess themselves to be baffled, "We are obliged to conclude," they write, "that there is currently no convincing interpretation of the implications of Hipparcos data for the dynamics of the warp in the Galactic disc."

Hipparcos Accurately Charts Important Star Cluster in 3D

A landmark result in the science of the stars comes with a complete and accurate description of the Hyades cluster – more than 200 stars – from measurements by ESA's star-mapping Hipparcos satellite. With the distances to each star of this historically important group pinpointed, theories of the evolution of stars are, at last, much more secure. Star clusters are crucial for understanding the lives of stars because all the members of a cluster formed at the same time and from the same raw materials.

Astrophysicists can see how the evolution of each star depends on its mass and chemical composition. The heavier a star is, the more intensely it burns and the faster it consumes its thermonuclear fuel. But the accuracy of certain theories has hitherto been limited by inaccuracies in the observations.

The brightest members of Hyades are visible to the naked eye in the constellation of Taurus. As the nearest, moderately rich, star cluster, the Hyades cluster has loomed importantly in astrophysics for more than a century. Contradictory results for the distance of the star cluster left big question marks for the theorists, and recent observations with the Hubble Space Telescope (HST) seemed only to deepen the mystery.

Astronomers from ESA, Leiden Observatory, Observatoire de Paris-Meudon, University of Lausanne and Observatoire de la Côte d'Azur joined forces to analyse the data on the Hyades cluster contained in the Hipparcos Catalogue published last year (see page 40 of this issue of the ESA Bulletin for availability). Their results appeared in the March issue of the *European Journal of Astronomy & Astrophysics*.

The distance to the centre of the Hyades cluster is 151 light-years (46.34 parsecs) with an uncertainty of less than one light-year (0.27 parsec). From astrophysical theory, astronomers can date the birth of the cluster at 625 million years ago, when only the most primitive animals lived on the Earth. The cluster has done well to survive so long. The individual stars of the Hyades are bound together by the gravity of the cluster as a whole.

Their collective and individual motions have also been plotted by Hipparcos. The result is a crisp 3-D motion picture* of the cluster.

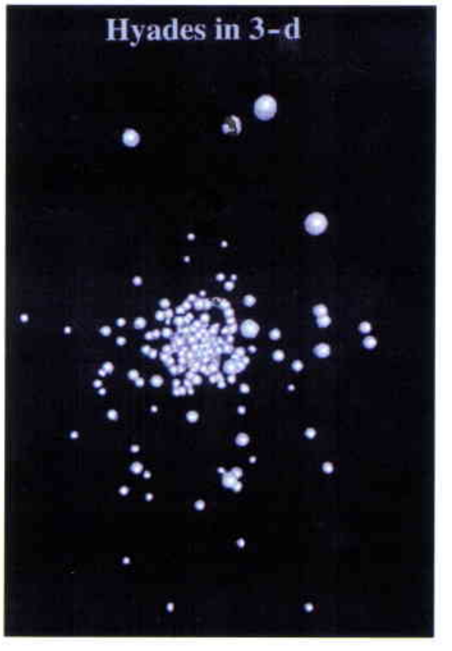
Hipparcos has also revealed almost imperceptible internal motions. Relatively massive stars have sunk towards the cluster's centre of gravity, while some others are quitting the group. They slowly 'evaporate' from the cluster's gravitational field as a result of near-collisions with other stars in the cluster or because the Hyades cluster has been stressed by gravitational encounters with other massive objects in the Milky Way Galaxy.

"The Hyades cluster has almost assumed the role of the Rosetta Stone of astronomy," comments Michael Perryman of ESA's Astrophysics Division in Noordwijk, The Netherlands, who is the lead author of the Hyades study and the Hipparcos Project Scientist. "It allows us to decipher many of the mysteries of stars. But until now, uncertainties in the observations left it muddy and hard to read with confidence. Let's say we've now cleaned this Rosetta Stone to the point of complete legibility."

The multinational research team has found out why previous measurements of the distance to the Hyades cluster gave incompatible results. Estimates relying on the motions of the cluster exaggerated the distance, because of small systematic errors in the ground-based reference system used in assessing the motions. When astronomers tried to measure the distances of the stars directly by parallax (shifts in apparent positions as the Earth orbited the Sun) small systematic differences in the ground-based determinations typically led to a smaller estimated distance. Hipparcos, from its vantage point in space, gives much better parallaxes and stellar motions, and these fit together in a perfectly consistent and comprehensive description.

The distance to the Hyades cluster is also the starting point for astronomical distance measurements, which extend throughout the Milky Way Galaxy and beyond. Its accurate measurement will therefore impact upon the overall distance scale and the age of the Universe, which have already emerged as salient areas of research in which Hipparcos results are making historic contributions.

* For details on the Hipparcos mission and its scientific results, including the Catalogues and a 3-D animation of the Hyades star cluster, see: http://astro.estec.esa.nl/Hipparcos



This image shows the 3D structure of the Hyades as seen from the position of the Sun in Galactic coordinates. Note that all spheres, representing the stars, are of the same size. Therefore, anything that appears bigger is thus physically closer to us

European Astronaut Corps

ESA will set up a single European astronaut corps by merging existing national astronaut programmes with the Agency's programme. The ESA Council approved the proposal during its meeting held in Paris on 25 March 1998.

Astronauts from national agencies, such as France (CNES), Germany (DLR) and Italy (ASI), will join ESA's astronauts J.F. Clervoy (F), P. Duque (E), C. Fuglesang (S) and C. Nicollier (CH) to form one corps. Together they will prepare for the mission opportunities available to ESA as the European partner in the International Space Station, and for other missions agreed upon between the national agencies and the United States or Russia. Moreover, a number of new astronauts will be chosen from previously selected candidates in order to maintain an appropriate representation of ESA Member States.

Integration of astronauts from the various national corps into ESA will begin this year and is to be completed by mid-2000, totalling sixteen active astronauts. After that period, the normal ESA procedure for selection will be applied, with recruitment occurring approximately every two years to make up for normal attrition and to enable ESA to continue supporting its planned missions.

The astronauts will be involved in the assembly of the International Space Station or in future operations on board. Their home base will be ESA's European Astronaut Centre in Cologne, Germany – where all new ESA astronauts will also undergo introductory training. Additionally, four of the new ESA astronauts are slated to begin training at NASA's Johnson Space Center in Houston, Texas by the autumn of this year.

The Astronaut Centre will also provide training for astronauts world-wide on the facilities that ESA is contributing to the Space Station, including the Columbus Laboratory and a resupply craft called the Automated Transfer Vehicle (ATV). esa

Ariane V106 Launches SKYPLEX

On 27 February at 19h38 Kourou time (22h38 GMT), the 106th Ariane launch (V106) – an Ariane-4 2P version – successfully lifted off from the Guiana Space Centre and placed the telecommunications satellite Hot Bird 4 into geostationary transfer orbit for the European Telecommunications Satellite Organisation (EUTELSAT).

Hot Bird 4 is carrying SKYPLEX, a new processor that allows a stream of multimedia information such as video, audio and data to be packaged, for the first time, on board a satellite. Traditionally, the various multimedia signals would need to be conveyed through standard communication networks to a ground multiplexing centre where they are combined into a single high-rate multi-programme stream and transmitted to the satellite. Thanks to SKYPLEX, the satellite can instead be accessed directly, simplifying broadcasting and reducing costs so that many more broadcasters and service providers will be able to make use of satellite systems.

Any television production facility, radio station or Internet provider can directly access the satellite: a system the size of a low-cost satellite news-gathering station (typically a 1.8 m dish and a 50 W transmitter) is sufficient to uplink to the satellite. The SKYPLEX processor on board Hot Bird 4 demodulates the incoming low-rate signals and re-combines them into a single, high-rate multi-channel digital broadcast signal which is transmitted directly to users' homes.

Transmission is fully compliant with the existing European digital television standard. Therefore, the SKYPLEX signal is indistinguishable from a conventional direct-to-home signal and can be received by any standard digital television receiver.

The SKYPLEX system is the result of a cooperative venture between ESA and EUTELSAT. The first model of the SKYPLEX payload was developed under ESA contract. The Hot Bird prime contractor Matra Marconi Space (F-UK) has been responsible for the satellite interface whilst the payload prime contractorship was awarded to Alenia Aerospazio (I), with Alcatel Espacio (E),

Mier Comunicaciones (E) and AME Space (N) as sub-contractors. The first model of the ground facilities was developed by Newtec (B).

The SKYPLEX programme is an example of how ESA, in partnership with industry and operators, aims to develop Europe's satellite multimedia market. The SKYPLEX programme is also an example of how success-oriented cooperation with industry leads to very short time-to-market initiatives (less than 20 months from contract signature to launch).

In its recently launched multimedia activities, ESA is negotiating the development of a second-generation SKYPLEX processor which will be designed to further reduce costs and to provide new Internet-ready functionality to cope with interactive multimedia communications. This next generation will be available in late 1999. esa

Ariane V107 Launches SILEX

The first civil high-data-rate optical communications system, SILEX (Semiconductor Intersatellite Link Experiment) was launched on board the French Earth observation satellite Spot-4 by Ariane flight V107. The successful launch by an Ariane-40 version (no strap-on boosters) took place on 23 March at 22h46 Kourou time (01h46 GMT on 24 March) placing Spot-4 into a Sun-synchronous orbit.

Developed by ESA, SILEX will transmit picture data from Spot-4 via the ESA Artemis satellite (scheduled for launch in late 1999/early 2000) to a data-processing centre near Toulouse, France. The advantage of the double-hop is that data can be relayed from Spot-4 for much longer periods since Artemis will be in a higher (geostationary) orbit. Present systems transmit data directly to the ground on a less frequent basis.

SILEX has both experimental and pre-operational purposes. Part of the experiment activities includes exploring the behaviour of the optical terminal; the short- and long-term stability of the various electrical, mechanical and optical elements; and the communication link quality characteristics. Also, operational procedures will be optimised.

The pre-operational part of the mission consists of transmitting (via the optical link to the ground) image data from the Spot-4 Earth observation instrument. This instrument generates data at 50 Mbps, which can be received at a ground station in southern France in real time. The SILEX service will thus eliminate the need for an extended ground station network and extends the direct visibility of the spacecraft to the central ground station. SILEX will also be used by Spot-4 to dump the content of the data memory collected during periods when the spacecraft is neither in the visibility zone of a ground station nor within reach of the Artemis terminal.

SILEX will also support an experiment between ESA's Artemis satellite and the OICETS spacecraft built by the Japanese Space Agency (NASDA).

A more detailed account of SILEX and its in-orbit commissioning will appear in the next issue of the ESA Bulletin (no. 95, August 1998). esa

ULYSSES Comes Full Circle

On 17 April, after travelling for more than seven years and covering 3.8 billion kilometres, the space probe Ulysses completed its first orbit of the Sun. This intrepid explorer has ventured into regions never before visited by any spacecraft. It has journeyed far away from the realm of the planets and gone over the poles of the Sun. From its unique perspective, Ulysses has provided scientists with the very first all-round map of the heliosphere, the huge bubble in space filled by the Sun's wind.

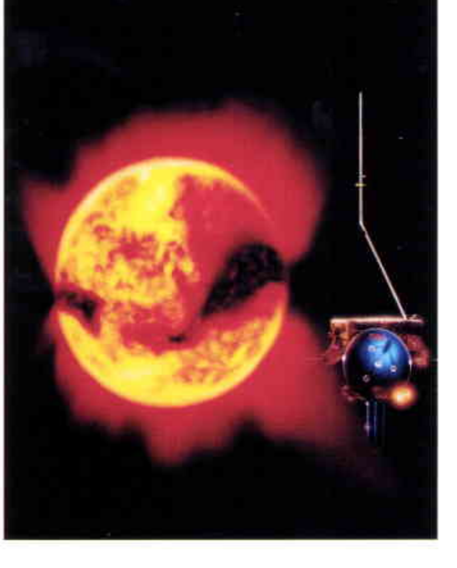
In a project of international cooperation between ESA and NASA, Ulysses was launched towards Jupiter in October 1990 by the Space Shuttle. Arriving in February 1992, Ulysses stole energy from the giant planet in a slingshot manoeuvre and was propelled back towards the Sun in an elongated orbit almost at right angles to the ecliptic plane, where the Earth and other planets circle the Sun.

"This month Ulysses returns to the point in space where its out-of-ecliptic journey began, but Jupiter isn't there," explains Richard Marsden, ESA's project scientist for Ulysses. "Following its own inexorable path around the Sun, Jupiter is far away on the opposite side of the Solar System. So Ulysses' course will not be changed a second time. The spacecraft is now in effect a man-made comet, forever bound into a 6-year polar orbit around the Sun."

Ulysses now starts its second orbit. It will travel over the poles of the Sun in 2000-2001 just as the count of dark sunspots is expected to reach a maximum. With its operational life extended for the Ulysses Solar Maximum Mission, the spacecraft will find the heliosphere much stormier than during its first orbit. Obeying a cycle of roughly eleven years, the Sun is once again becoming restless as sunspot activity builds towards the next peak around 2000.

"Gone will be the stable picture dominated by the fast solar wind," Richard Marsden predicts. "Most likely this will have been replaced by variability at all latitudes, with slow and fast wind streams jostling one another for prime position. But what exactly awaits Ulysses remains to be seen. Just like the first orbit, the second is truly a voyage into the unknown."

More details on the key results of the Ulysses mission at solar minimum can be found in the *ESA Bulletin*, no. 92, pp. 75-81, Nov. 1997 and on the WWW at: http://helio.estec.esa.nl/ulysses/ esa



Metop/EPS Given Green Light

At a meeting of the Metop-1 participants on 12 December 1997, ESA's Member States took a major decision concerning the Metop* Programme by declaring the programme started and, subject to an adequate commitment by Eumetsat, confirmed their intention to proceed with industrial activities. The relevant budgets were approved, but blocked pending the Eumetsat decision.

This was followed by the Eumetsat Council on 28 January 1998, which established very positive decisions, particulary with respect to the financial commitments for Metop-1. Consequently, the ESA Earth Observation Programme Board (PB-EO) removed the block on the 1997 and 1998 Metop-1 budgets on 30 January.

The ESA Executive together with Eumetsat released an Authorisation to Proceed to industry for a total of 115 MECU (90 MECU from ESA and 25 MECU from Eumetsat) with immediate effect. The activities covered include the procurement of long-lead-time equipment items and start of work by all contractors. These activities will run until end of September 1998 by which time a full approval of the EPS** Programme by the Eumetsat Council is anticipated and both organisations are expected to sign a Cooperation Agreement.

The industrial contract will be managed by a joint ESA-Eumetsat Single Space Segment team led by Peter Edwards, the Metop-1 Project Manager. esa

* Metop is a series of three meteorological operational polar orbiting satellites, the first of which, Metop-1, is the prototype.

** The Eumetsat Polar System, which comprises the space segment, launches and operations of the Metop satellites. It is planned to be implemented in cooperation with ESA, CNES (F) and NOAA (the US National Oceanic and Atmospheric Administration).

Space Days Cartoon Competition

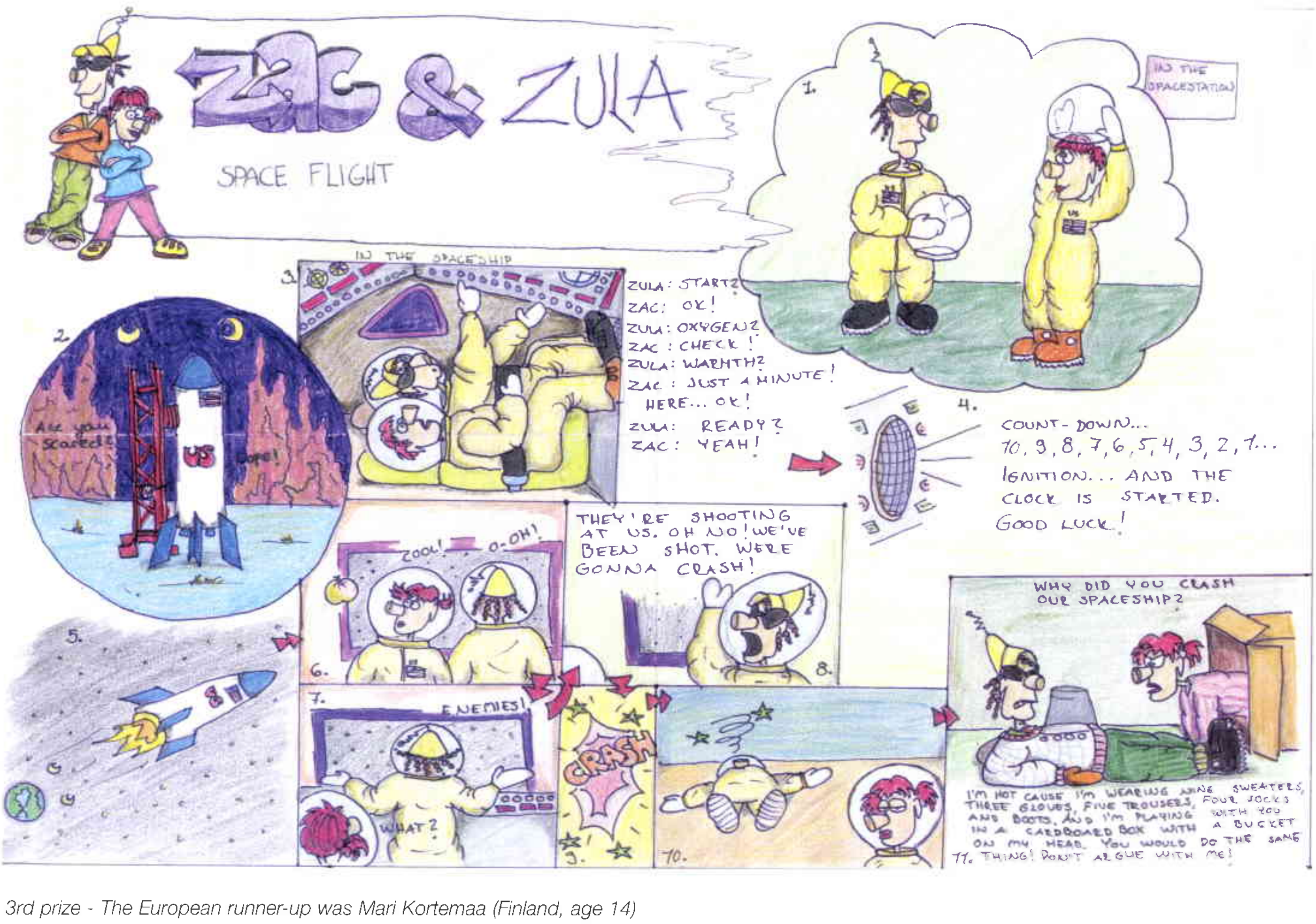
The Third Euro-Latin American Space Days, organised by ESA and COFETEL (Comisión Federal de Telecomunicaciones of Mexico) were held from 10-14 November 1997 in Mexico City. The conference programme covered Earth observation (including ground stations, data processing and applications), small satellites and technology, with a round table discussion on launchers, telecommunications (including services and providers, systems, disaster management, and satellite navigation). In addition, a special one-day session was organised on the insurance implications and financing of space projects. This special session was organised by International Space Brokers (ISB) and Arianespace Finance. As in previous years, the event also featured an industrial exhibition.

All in all, 280 people attended the conference, the majority coming from Mexican institutions. There were also representatives from all Latin American countries, some Central American countries and the Caribbean region.

ESA and COFETEL also organised a competition open to 14-16 year olds from Latin American and ESA's Member States, inviting them to draw a cartoon relating to a space theme. The two winners, Juan Carlos Alcalá Fernández (Mexico) and Stina Rükonen (Finland) have been invited to see an Ariane launch in Kourou. The five finalists from Latin America were invited to attend the Space Days in Mexico to meet ESA Astronaut Claude Nicollier. esa

2nd prize - The European winner of the competition was Stina Rükonen (Finland, age 16)

1st prize - The latin American Winner of the Space Days cartoon competition was Juan Carlos Alcalá Fernández (Mexico, age 14)



3rd prize - The European runner-up was Mari Kortemaa (Finland, age 14)

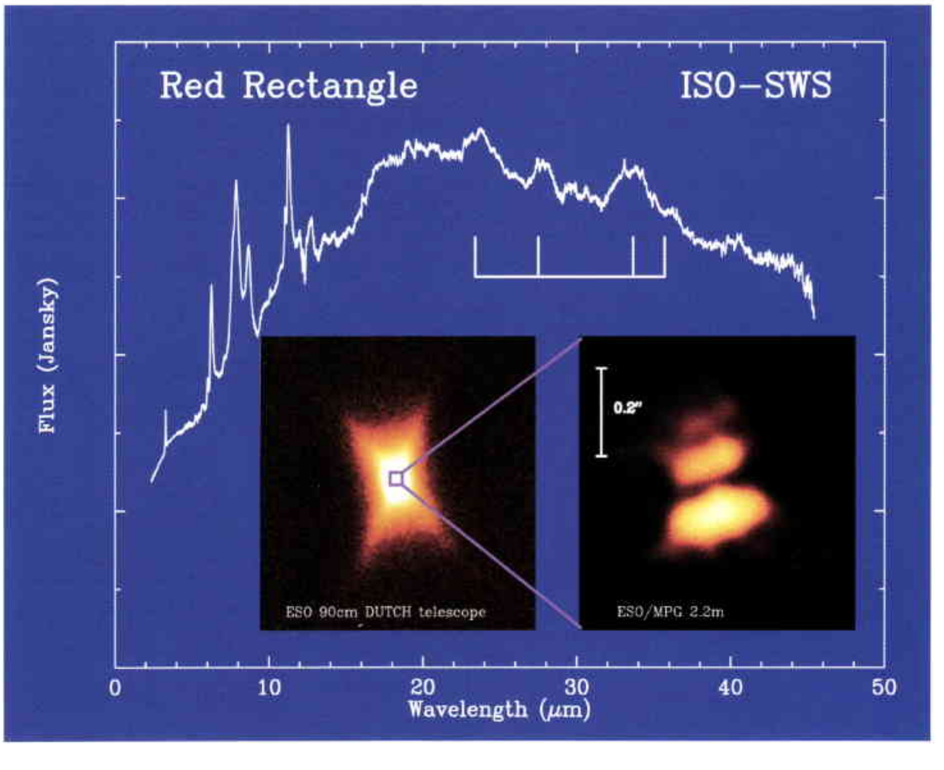
Planet Formation around Dying Stars

European astronomers at the universities of Amsterdam, Louvain, Groningen and Utrecht have found proof that planets can form around old, dying stars. In the vicinity of the Red Rectangle – old binary stars in the Monoceros constellation – they detected a ring of matter constituting the first stage of planet formation. It had previously been assumed that planets can only form around new-born stars. The results were published in *Nature* on 26 February.

Young stars are frequently surrounded by a flattened ring of gas and particles left over from the star formation process. The particles can join together to form larger and larger pieces that eventually grow to the size of planets. Observations made using the Dutch-German short wavelength spectrometer (SWS) on board ESA's Infrared Space Observatory (ISO) have shown that such rings are rich in silicates. The particular form and composition of the silicate – crystalline olivine – occurs on the Earth and in comets, which are the remnants of abortive planet formation. It thus appears to be an important constituent in the formation of planets.

From SWS observations it now appears that the ring of matter around the Red Rectangle binary contains large particles with a great deal of crystalline olivine. The Red Rectangle consists of two old neighbouring stars, one of which was a red giant and is now in the process of becoming a white dwarf. The olivine is of the same type as that found in the rings around young new-born stars, on the Earth and in comets. Towards the end of their lives, stars of the same type as our Sun swell up to form red giants and emit large quantities of gas and matter. Most of this matter escapes the star's gravity and is lost in space. But if the dying star is part of a binary system, its companion may prevent the gas and material from escaping. This will give rise to a stable, flat ring around the double star, which may remain in existence for a considerable time. In this ring, planet formation may occur. esa

This illustration shows two infrared images of the Red Rectangle. The left-hand picture shows the cloud of gas and matter emitted by the red giant (Dr H. van Wickel, Louvain). The right-hand picture shows a detail of the cloud nucleus (Prof G. Weigelt and Dr R. Osterbart, Bonn), in which the ring can be seen as a dark band. Above each picture is the spectrum made with the SWS. It exhibits a number of conspicuous peaks, which are caused by the presence of crystalline olivine.



Present and Future ESA/UK Space Activities

John Battle MP, UK Minister for Science, Energy and Industry, and ESA's Director General Antonio Rodotà held a joint Press Conference on current issues and future activities in space on Monday, 16 March in London.

The Press Conference took place immediately after Mr Battle officially opened the Science, Engineering and Technology Exhibition where Research Councils and Government Departments exhibited new technologies and demonstrated new initiatives. The exhibition marked the beginning of the UK's Science, Engineering and Technology Week.

In his opening address, Mr Battle announced a £21.2 million package of investments in three ESA programmes to "help position the British space industry on the multi-billion dollar information market of the next century". The package will be distributed as follows:

- £6.7 million over the next three years for the ARTES-3 Programme, which is developing satellite technologies providing new services for business and enabling the development of areas such as tele-medicine and tele-education
- £8.1 million over the next two years for the ERS-2 (European Remote Sensing Satellite) Programme
- £6.4 million over the next five years for EOPP (Earth Observation Preparatory Programme). esa

Publications

The documents listed here have been issued since the last publications announcement in the ESA Bulletin. Requests for copies should be made in accordance with the Table and Order Form inside the back cover.

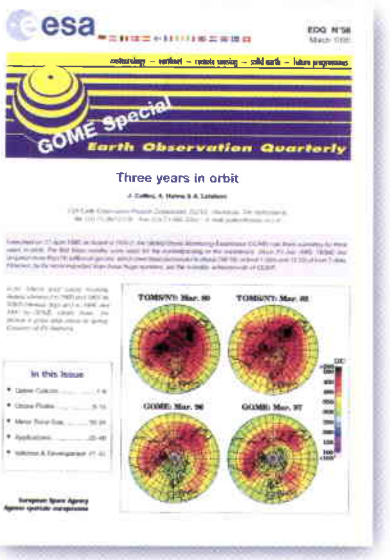
ESA Newsletters

EARTH OBSERVATION QUARTERLY
NUMBER 58, JANUARY 1998
EDS. T.D. GUYENNE & D. DANESY
NO CHARGE

PREPARING FOR THE FUTURE
VOLUME 8, NUMBER 1 (MARCH 1998)
ED. M. PERRY
NO CHARGE

MICROGRAVITY NEWS
VOLUME 11, NUMBER 1 (APRIL 1998)
ED. B. KALDEICH-SCHÜRMANN
NO CHARGE

ECSL NEWS, NUMBER 17
ED. T.D. GUYENNE
NO CHARGE



ESA Brochures

THE ATMOSPHERIC REENTRY DEMONSTRATOR (ARD) / LE DÉMONSTRATEUR DE RENTRÉE ATMOSPHÉRIQUE (MARCH 1998)
BATTRICK B. (ED.)
ESA BR-123 // 4 PAGES
NO CHARGE

Credit Card Payments for ESA Publications

It is possible to purchase the Agency's publications from the ESA Publications Division 'Bookshop' using your corporate or your personal credit card (Eurocard/Mastercard, Visa or American Express).

You can telephone or telefax your orders to the numbers given below, quoting your card's number and its expiry date.

The Bookshop (attn. Mr Frits de Zwaan)
ESA Publications Division
ESTEC
Keplerlaan 1
2200 AG Noordwijk
The Netherlands

Telephone: (31) 71 5653405
Telefax: (31) 71 5655433

Other methods of payment are also accepted. Please call or fax for details.

A list of the latest publications can be accessed via the ESA Publications Division's Home Page at the following Internet/WWW address:

http://esapub.esrin.esa.it/

THE COMPONENTS AND RADIATION EFFECTS LABORATORIES AT ESTEC (APRIL 1998)
ELLEN P. & ADAMS L. (ED. M. PERRY)
ESA BR-127 // 12 PAGES
PRICE: 15 DFL

ERS AND ITS APPLICATIONS: MARINE (APRIL 1998)
ESRIN REMOTE-SENSING EXPLOITATION DIVISION
(EDS. G. CALABRESI, A. BELLINI & B. BATTRICK)
ESA BR-128 I // 64 PAGES
PRICE: 25 DFL

ERS AND ITS APPLICATIONS: LAND (APRIL 1998)
ESRIN REMOTE-SENSING EXPLOITATION DIVISION
(EDS. G. CALABRESI, A. BELLINI & B. BATTRICK)
ESA BR-128 II // 60 PAGES
PRICE: 25 DFL

THE EUROPEAN ASTRONAUTS CENTRE (EAC), COLOGNE, GERMANY - PAST AND PRESENT ACHIEVEMENTS (JANUARY 1998)
KALDEICH-SCHÜRMANN B. (ED.)
ESA BR-130 // 51 PAGES
PRICE: 15 DFL

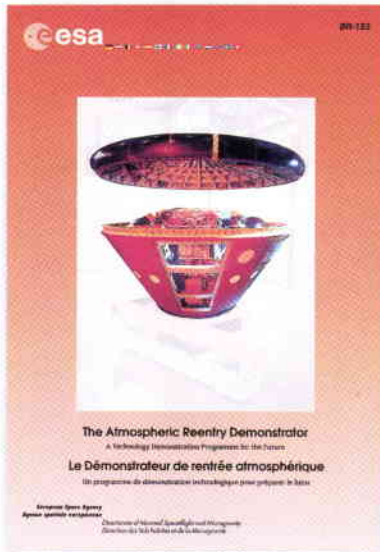
ESA Special Publications

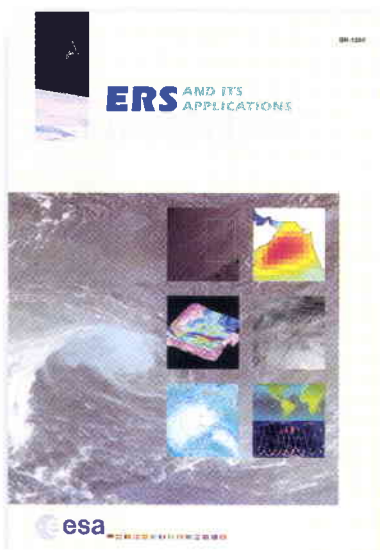
ENVISAT MISSION - OPPORTUNITIES FOR SCIENCE AND APPLICATIONS (JANUARY 1998)
ATTEMA E. ET AL. (ED. R.A. HARRIS)
ESA SP-1218 // 59 PAGES
PRICE: 35 DFL

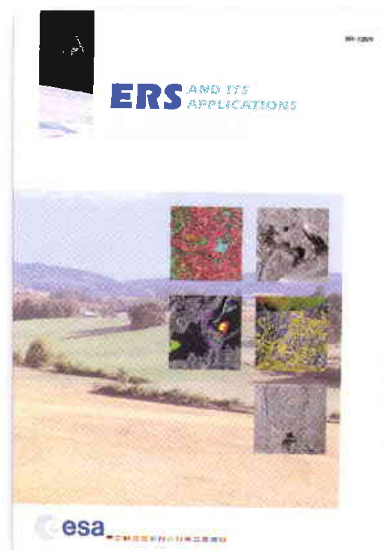
CELESTIA 2000: THE HIPPARCOS AND TYCHO CATALOGUES (APRIL 1998)
PERRYMAN M. ET AL. (ED. B. BATTRICK)
ESA SP-1220 // CD-ROM
PRICE: 80 DFL

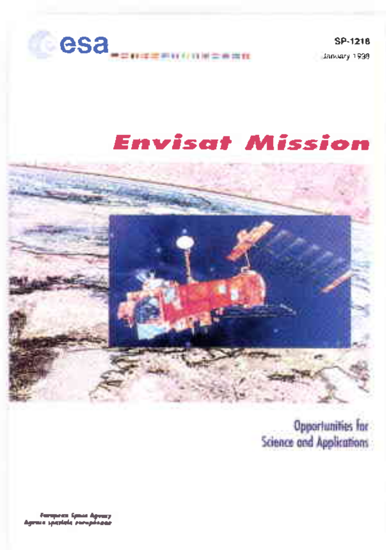
ENVISAT MISSION - PRODUCT SUMMARY OVERVIEW (MARCH 1998)
LEVRINI G. (ED. R.A. HARRIS)
ESA SP-1221 // 84 PAGES
PRICE: 50 DFL

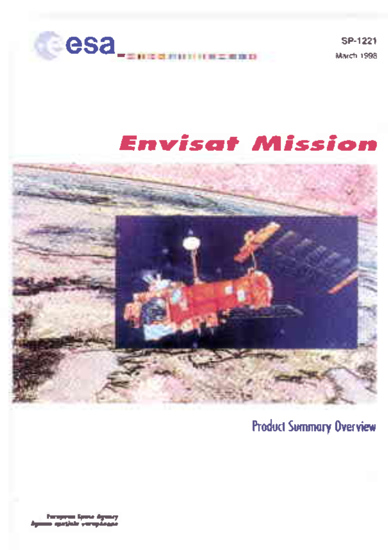
ULTRAVIOLET ASTROPHYSICS BEYOND THE IUE FINAL ARCHIVE: PROC. INTERNATIONAL CONFERENCE, SEVILLE, SPAIN, 11-14 NOVEMBER 1997 (FEBRUARY 1998)
WAMSTEKER W., GONZALEZ RIESTRA R. & HARRIS R.A. (EDS.)
ESA SP-413 // 871 PAGES
PRICE: 100 DFL









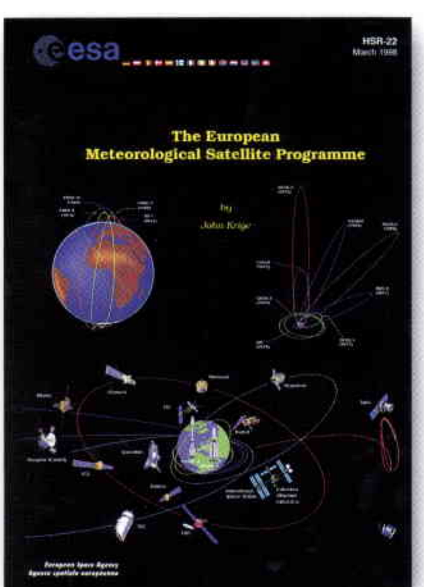


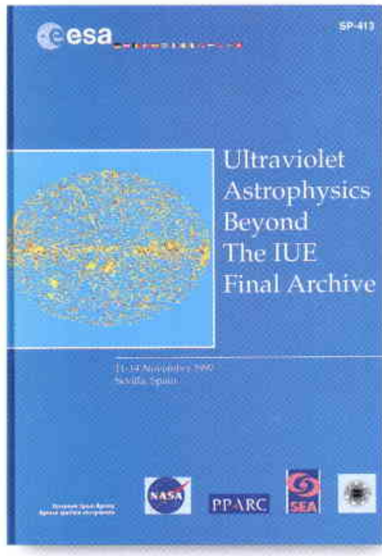
CD-ROM

CORRELATED PHENOMENA AT THE SUN, IN THE HELIOSPHERE AND IN GEOSPACE, PROC. 31ST ESLAB SYMPOSIUM, ESTEC, NOORDWIJK, THE NETHERLANDS, 22-25 SEPTEMBER 1997 (DECEMBER 1997)
FLECK B. & WILSON A. (EDS.)
ESA SP-415 // 546 PAGES
PRICE: 100 DFL

ESA Scientific & Technical Memoranda

ASSESSMENT OF HIGH-ALTITUDE LONG-ENDURANCE (HALE) PLATFORMS (MARCH 1998)
EDIN P. (ED. R.A. HARRIS)
ESA STM-257 // 72 PAGES
PRICE: 50 DFL





ESA History Reports

THE EUROPEAN METEOROLOGICAL SATELLITE PROGRAMME (MARCH 1998)
KRIGE J. (ED. R.A. HARRIS)
ESA HSR-22 // 66 PAGES
PRICE: 50 DFL

ESA Contractor Reports

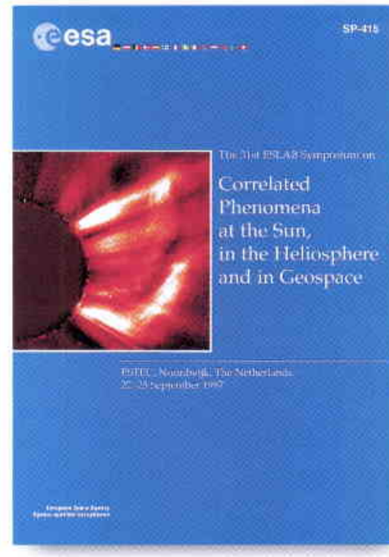
LUNAR LANDING SYSTEMS - FINAL REPORT AND EXECUTIVE SUMMARY (AUGUST 1997)
MATRA MARCONI SPACE, FRANCE
ESA CR(P)-4131 // 187 AND 31 PAGES (2 VOLS.)
PRICE: 70 DFL AND 35 DFL

FLEXIBLE THERMAL LINK - FINAL REPORT AND EXECUTIVE SUMMARY (SEPTEMBER 1997)
DAIMLER-BENZ AEROSPACE, GERMANY
ESA CR(P)-4132 // 94 AND 22 PAGES (2 VOLS.)
PRICE: 50 DFL AND 35 DFL

SMALL MISSION OPPORTUNITIES INITIATIVE STUDY (OCTOBER 1997)
MATRA MARCONI SPACE, FRANCE
ESA CR(P)-4133 // 101 PAGES
PRICE: 50 DFL

SMO PROGRAMME - EXECUTIVE SUMMARY (DECEMBER 1997)
FIAT AVIO, ITALY
ESA CR(P)-4134 // 61 PAGES
PRICE: 50 DFL

ON-BOARD SOFTWARE MAINTENANCE METHODOLOGY - FINAL REPORT (JUNE 1997)



CRI, DENMARK
ESA CR(P)-4135 // 18 PAGES
PRICE: 35 DFL

MASTER PRE-PHASE-A EXTENSION - FINAL REPORT AND EXECUTIVE SUMMARY (OCTOBER 1997)
ALENIA AEROSPAZIO, ITALY
ESA CR(P)-4136 // 67 AND 27 PAGES
PRICE: 50 DFL AND 35 DFL

A TRANSMISSION SYSTEM FOR FUTURE SATELLITE MOBILE AND PERSONAL COMMUNICATIONS - EXECUTIVE SUMMARY (MAY 1997)
SQUARE PEG COMMUNICATIONS INC., CANADA
ESA CR(P)-4137 // 36 PAGES
PRICE: 35 DFL

STUDY OF THE DIRECT ECONOMIC EFFECTS OF THE ARIANE PROGRAMMES - EXECUTIVE SUMMARY (OCTOBER 1997)
BRAMSHILL CONSULTANCY LTD., UK
ESA CR(P)-4138 // 15 PAGES
PRICE: 35 DFL

LANDER SHOCK ALLEVIATION TECHNIQUES - FINAL REPORT (AUGUST 1997)
DAIMLER-BENZ AEROSPACE, GERMANY
ESA CR(P)-4139 // 148 PAGES
PRICE: 70 DFL

COHERENT DETECTION AT LOW PHOTON NUMBER PER MEASUREMENT INTERVAL (DELPHI) - EXECUTIVE SUMMARY AND FINAL REPORT VOLUMES I AND II (MAY 1997)
TECHNISCHEN UNIVERSITÄT WIEN, AUSTRIA
ESA CR(P)-4140 // 22 , 157 AND 33 PAGES
PRICE: 35 DFL, 70 DFL AND 35 DFL

Contractor Reports

There are two types of Contractor Reports: CR(P) and CR(X) reports.

ESA CR(P) documents are available on microfiche from either of the following addresses:

British Library - Doc. Supply Centre
Customer Service
Boston Spa
Wetherby, West Yorkshire
LS23 7BQ
England

FIZ Karlsruhe
Bibliographic Service
D-76344 Eggenstein-Leopoldshafen
Germany
Tel: (49) 7247 808 135

ESA CR(X) documents have restricted distribution and are not available on microfiche. Printed copies can be requested via ESA Publications Division

APEX FEASIBILITY STUDY - FINAL REPORT (MAY 1997)
DSS-OIP, BELGIUM
ESA CR(P)-4141 // 101 PAGES
PRICE: 70 DFL

A STUDY TO INVESTIGATE LAND DEGRADATION APPLICATIONS USING A HIGH-RESOLUTION LAND SURFACE PROCESSES MISSION - FINAL REPORT (SEPTEMBER 1997)
UAM, SPAIN
ESA CR(P)-4142 // 156 PAGES
PRICE: 70 DFL

ENHANCED VIA PROCESSES FOR THE GMMT F20 FOUNDRY PROCESS - FINAL REPORT (JUNE 1997)
GEC-MARCONI MATERIALS TECHNOLOGY LTD., UK
ESA CR(P)-4143 // 16 PAGES
PRICE: 35 PAGES

DYNAMIC STABILITY STUDY OF BLUNT-BODY REENTRY VEHICLES - FINAL REPORT (APRIL 1997)
FFA, SWEDEN
ESA CR(P)-4144 // 161 PAGES
PRICE: 70 DFL

ENABLING TECHNOLOGIES FOR FUTURE SMALL MISSIONS (OCTOBER 1997)
DORNIER GMBH, GERMANY
ESA CR(P)-4145 // 126 PAGES
PRICE: 70 DFL

LOW-COST SPACE TERMINAL FOR DATA-RELAY SERVICES, PHASE 1 - FINAL REPORT (OCTOBER 1997)
ALCATEL ESPACIO, SPAIN
ESA CR(P)-4146 // 40 PAGES
PRICE: 35 DFL

MA31750 SYSTEM STUDY (OCTOBER 1997)
SAAB ERICSSON SPACE, SWEDEN
ESA CR(P)-4147 // 105 PAGES
PRICE: 70 DFL

MICROGRAVITY PAYLOAD DISTURBANCE STUDY: EXTENSION PHASE 1 - FINAL REPORT (SEPTEMBER 1997)
DAIMLER-BENZ AEROSPACE, GERMANY
ESA CR(P)-4148 // 395 PAGES
PRICE: 80 DFL

Publications Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Price	Source
Periodicals				
ESA Bulletin	4	ESA's primary magazine	Free of charge	ESA Publications Division, c/o ESTEC, 2200 AG Noordwijk, The Netherlands
Earth Observation Quarterly	4	Remote-sensing news	"	"
ECSL News	4	News from the European Centre for Space Law (under the auspices of ESA)	"	"
Reaching for the Skies	4	ESA's Space Transportation Systems news	"	"
Microgravity News	3	Microgravity Programme news	"	"
Preparing for the Future	4	Technology Programme news	"	"
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Collection of papers presented at an ESA conference	Prices vary	ESA Publications Division, c/o ESTEC, 2200 AG Noordwijk, The Netherlands
Special Publications	(SP-xxxx)	Detailed monographs on post-graduate level subjects	"	"
Brochures	(BR-xxx)	Concise summaries on specific subjects	"	"
Scientific & Technical Reports	(STR-xxx)	Graduate level — reflecting ESA's position on a given subject	"	"
Scientific & Technical Memoranda	(STM-xxx)	Graduate level — latest but not finalised thinking on a given subject	"	"
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of contracts	"	"
Training Manuals	(TM-xxx)	Series for education of users or potential users of ESA programmes, services or facilities	"	"
Public-relations material		General literature, posters, photographs, films, etc.		ESA Public Relations Service 8-10 rue Mario-Nikis 75738 Paris 15, France

All periodicals are also available via the Internet at:

http://esapub.esrin.esa.it/esapub.html

Selected public-relations material and other ESA information is available at:

http://www.esrin.esa.it

Order Form for ESA Publications

Without receipt of payment no publications are sent. All payments in Dutch Guilders (Dfl). Within Europe, mailing is free of charge. Outside Europe, airmail is free of charge for orders over Dfl. 100; smaller orders are sent sea mail.

No. of copies	ESA reference	Title	Price per copy Dfl.	Total Dfl.
			Order Subtotal:	
			Discount for orders over Dfl. 100: less 10% of subtotal:	
			Total amount:	

MAILING ADDRESS *(please print carefully):*

Name

Function Organisation

Address

Town & Postal Code Country

Date Signature

PAYMENT *please tick one box:*

❍ Cheque enclosed (made payable to ESA Publications Division)
return order form with cheque to: ESTEC - Finance Division (EFA/P)
P.O.Box 299 - 2200AG Noordwijk - The Netherlands

❍ Items ordered are all free of charge

Credit Card: ❍ Eurocard/Mastercard ❍ Visa ❍ AmEx

Card No. expires:

Name Card Holder

return form to: The Bookshop (attn. Mr. Frits de Zwaan) - ESA Publications Division - ESTEC
P.O.Box 299 - 2200AG Noordwijk - The Netherlands; FAX: +31 - (0)71 565 5433

Telephone orders (and further information) : *+31 (0)71 565 3405*

Information via e-mail: FDEZWAAN@ESTEC.ESA.NL
Internet - list of the latest publications: http://esapub.esrin.esa.it/esapub.html
Printed annual catalogues of ESA publications are available free of charge from the bookshop.

ADVERTISE YOUR SPACE-RELATED PRODUCTS/SERVICES IN

esa bulletin

Mechanical requirements — Copy dates

Printing material: 1 positive offset film (right reading, emulsion side down).

Usable material: Negative, artwork ready for reproduction. All production charges are invoiced separately.

Copy date: (in Noordwijk) Ready for printing: 30 days before publication. Any difficulty in observing these deadlines after reservation should be notified immediately fax (31) (0)71-5655433

Type area:

1/1 page	185/265 mm high
1/2 page horizontal	185/131 mm high
1/4 page vertical	91/131 mm high
1/4 page horizontal	185/ 65 mm high

Screen: 60/cm — 150/inch

Page size: 297mm × 210mm

Bleed amount: 3mm

Issue dates

ESA Bulletin: February, May, August and November

Rates in Dutch Guilders

	1×	4×	8×
1/1 page B/W	2.000.—	1.600.—	1.200.—
1/2 page B/W	1.200.—	1.000.—	800.—
1/4 page B/W	800.—	700.—	600.—

Extra charge for 4 colour processing: 1.500.— Dutch Guilders.
Loose inserts (by application only) 1/A4, Dfl. 3.000.— plus Dfl. 150.— per thousand bookbinder's handling charge

Advertising Management

Brigitte Kaldeich
ESA Publications Division
ESTEC, Keplerlaan 1
2200 AG Noordwijk, The Netherlands
Fax (31) (0) 71 5655433

Circulation

Albania
Algeria
Andorra
Argentina
Australia
Austria
Bahrain
Bangladesh
Barbados
Belgium
Belize
Benin
Bhutan
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Bulgaria
Burkina Faso (Upper Volta)
Burma
Burundi
Cameroon
Canada
Chile
China
Colombia
Commonwealth of Independent States
Congo
Costa Rica
Croatia
Cuba
Cyprus
Czech Republic
Denmark
Dominican Republic
Dubai
Ecuador
Egypt
El Salvador
Estonia
Ethiopia
Faroe Islands
Fiji
Finland
France
French Guiana
Gabon
Gambia
Germany
Ghana
Gibraltar
Greece
Guatemala
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Ivory Coast
Jamaica
Japan
Jordan
Kenya
Korea
Kuwait
Latvia
Lebanon
Liechtenstein
Libya
Lithuania
Luxembourg
Macedonia
Madagascar
Mali
Malta
Mauritania
Mauritius
Mexico
Monaco
Mongolia
Montenegro
Morocco
Mozambique
Nepal
Netherlands
Netherlands Antilles
New Caledonia
New Zealand
Nicaragua
Niger
Nigeria
NorwayPakistan
Papua New Guinea
Peru
Philippines
Poland
Portugal
Puerto Rico
Qatar
Romania
Rwanda
Sao Tome & Principe
Saudi Arabia
Senegal
Serbia
Singapore
Slovakia
Slovenia
South Africa
Spain
Sri Lanka
Sudan
Surinam
Swaziland
Sweden
Switzerland
Syria
Tahiti
Taiwan
Tanzania
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Uganda
UAE
United Kingdom
Uruguay
USA
Venezuela
Vietnam
Yemen
Zaire
Zambia
Zimbabwe

Member States

Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Italy
Netherlands
Norway
Spain
Sweden
Switzerland
United Kingdom

Etats membres

Allemagne
Autriche
Belgique
Danemark
Espagne
Finlande
France
Irlande
Italie
Norvège
Pays-Bas
Royaume-Uni
Suède
Suisse

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel (31) 71 565 3400 - Fax (31) 71 565 5433
Visit ESA Publications at: http://www.esa.int