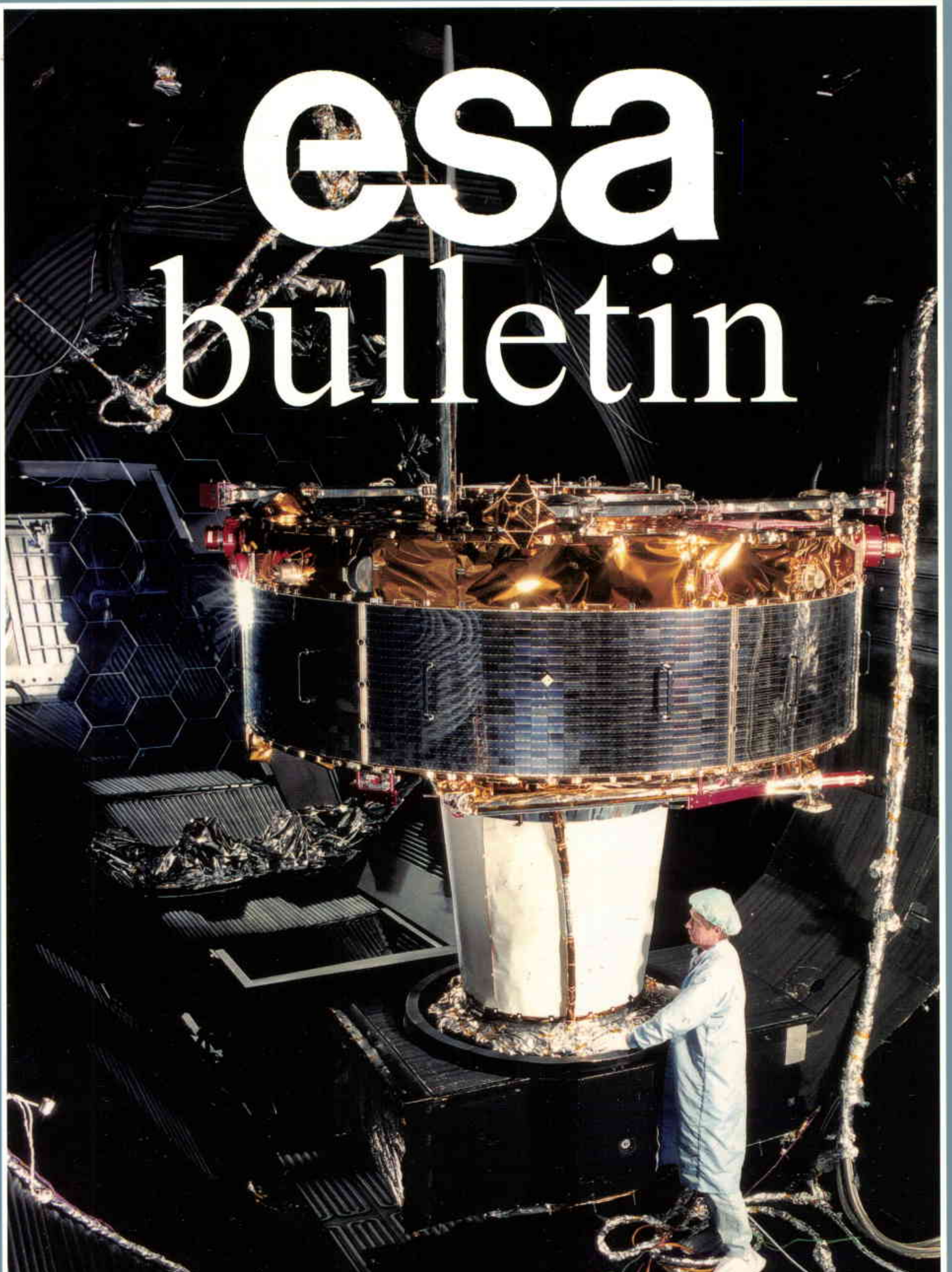

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european space agency

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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.

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

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

The ESA HEADQUARTERS are in Paris.

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agence spatiale européenne

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(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications.
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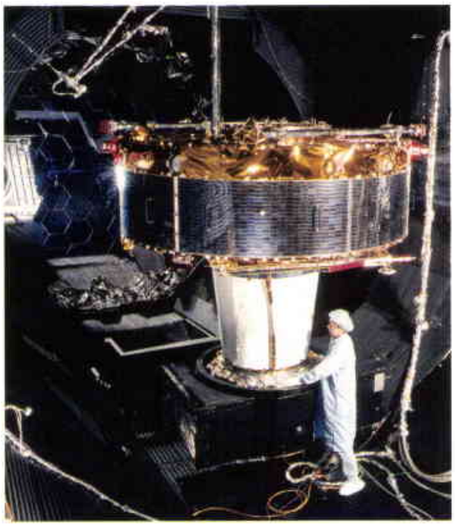

Cover: Thermal testing of one of ESA's Cluster spacecraft at IABG, Munich (D)

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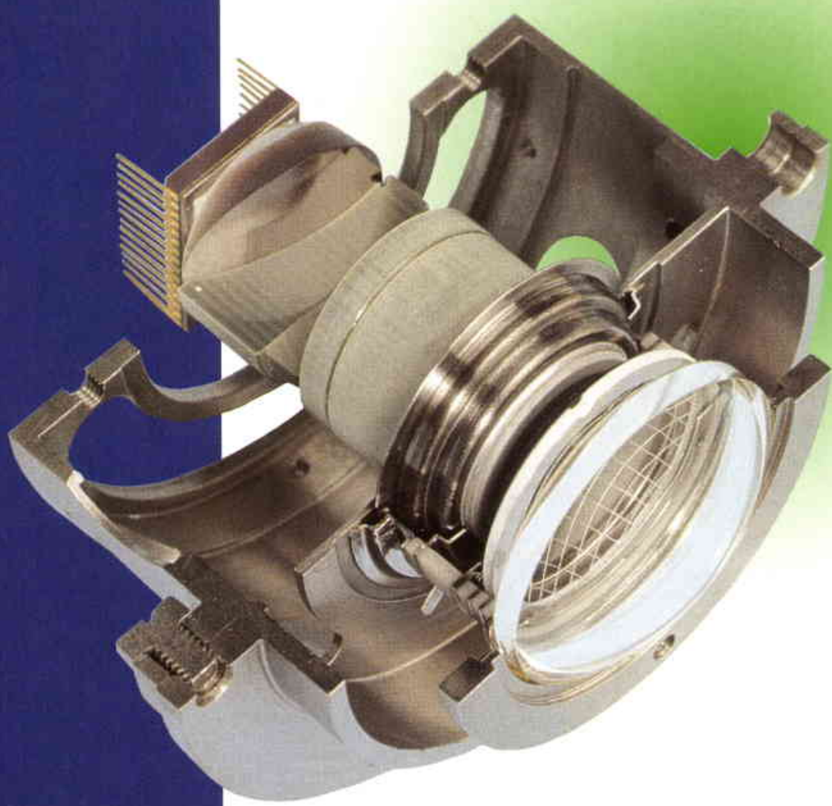

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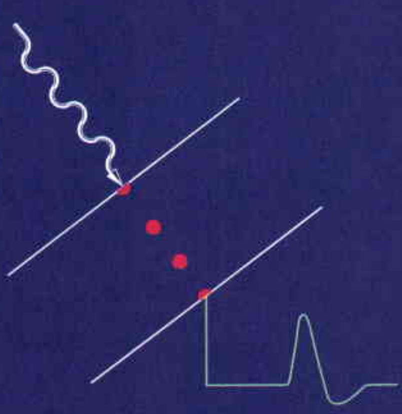

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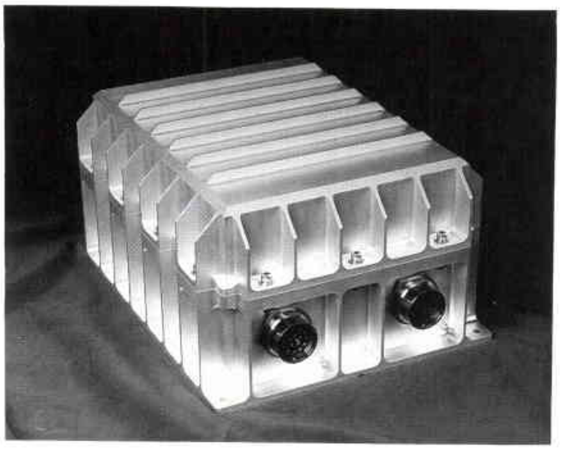

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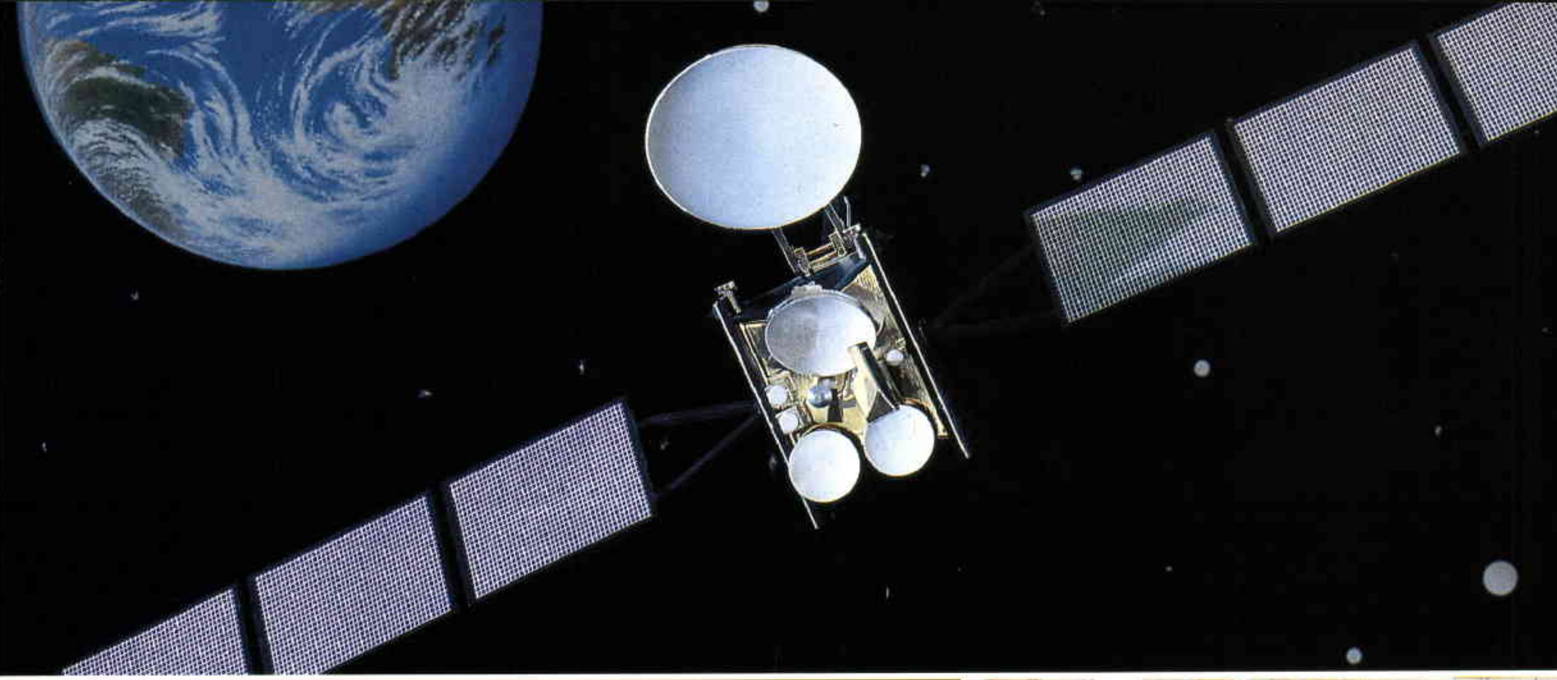

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Die Erforschung von Schweifsternen durch die Raumsonden GIOTTO und ROSETTA

Aus dem Englischen übersetzt von **D. Fischer**

1994. Etwa 200 S. 20 Abb., 3 in Farbe. Geb. DM 48,-; öS 374,40; sFr 53,- ISBN 3-540-57585-5

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Das Buch führt den Leser durch alle Fehlschläge und die glanzvollen Erfolge dieser internationalen Zusammenarbeit unter der Leitung der ESA. Der Autor geht auch auf das ROSETTA-Projekt ein, das derzeit in Vorbereitung ist.

Der Übersetzer hat in Zusammenarbeit mit dem Autor und den wissenschaftlichen Projektleitern bei der ESA den Text für die deutsche Ausgabe aktualisiert und ergänzt.

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Review of Industry/ESA Business Practices within the Scientific Programme – The Industrial Workshops

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Science Projects Department, ESA Directorate for Scientific Programmes, ESTEC, Noordwijk, The Netherlands

Introduction

ESA has been holding intensive discussions with European Industry over the past few years with the purpose of reviewing current management practices followed in the Agency's scientific projects and identifying potential improvements that would lead to efficiency benefits. This activity is a follow-up to an overall review of the Scientific Programme in 1989 by the Science Programme Review Team (the so-called 'Pinkau Committee'), one of the recommendations of which was an intensive Industry/Agency dialogue targetted at improving the efficiency of the contractual/management interface.

This article reviews the background to the joint ESA/Industry dialogue that has been taking place in recent years with a view to further improving the contractual and managerial interfaces within the ESA Scientific Programme. It describes the main events in this continuing dialogue and summarises Industry's and the Agency's perspectives on the major topics addressed in the various working groups. Particular emphasis is placed on the outcome of the joint Workshop held last October, which was a concluding milestone of the initial phase in the ESA/Industry exchange.

Industry has been actively supporting this initiative by contributing both ideas and resources to a series of high-level joint Workshops and Task Forces which have examined specific areas of management practice.

The Horizon 2000 Programme

Prior to 1984, the selection procedure for ESA's scientific projects was essentially geared to choice of a specific project on a one-off basis as and when money became available. Funds were foreseen as becoming available when the needs for already-approved projects were projected to fall below the Scientific Programme's annual fixed income. At this point it became possible to select a new project from the 'candidate missions' for which Phase-A studies were then being conducted.

Whilst this was proving an adequate procedure for the initial ESA Scientific Programme, it became clear that if European space science was to mature and grow, it would be necessary to establish a more coherent approach to planning a programme and subsequent mission selection. A new, more comprehensive approach was therefore presented to the ESA Council Meeting at Ministerial Level in Rome in January 1985 in the form of the 'Space Science: Horizon 2000 Programme'. This Programme foresaw four so-called 'Cornerstone Missions' in each of the main scientific disciplines, interleaved with 'Medium-Size Missions' selected on a competitive basis, each of the mission types having a fixed financial envelope. The current overall Horizon 2000 Programme schedule is shown in Figure 1.

The Scientific Programme serves multiple customers, representing a variety of scientific disciplines, but is funded by a fixed annual budget provided by the ESA Member States. This creates a dynamic environment in which Industry has to respond to scientific challenges, but at the same time the scientific ambitions have to be contained. The missions have to be implemented in an environment in which project cost represents a major constraint. This requires 'checks and balances' to be operated between the various activities, and also between participants within a project, in order to keep each project close to its approved baseline with minimal technical/cost risk, whilst striving to maximise the scientific return.

Figure 2 shows the main elements of a typical scientific project and identifies the main participants. Not only is the scientific community the project's only 'customer', as the main beneficiary of the data, but the scientists themselves are also active project participants, taking responsibility for designing, building and delivering the instruments to be flown on

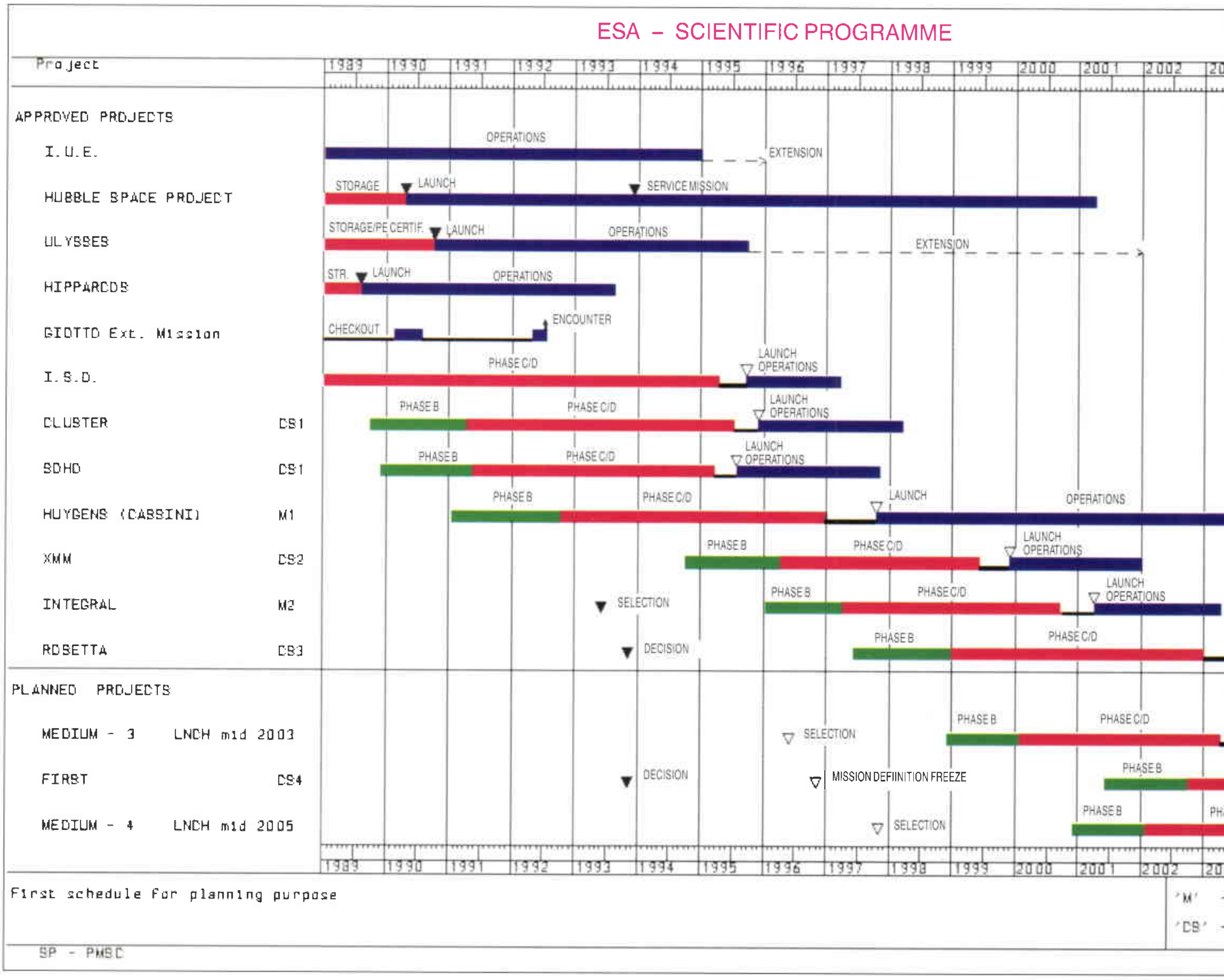


Figure 1. Implementation schedule for the Horizon 2000 Scientific Programme

the spacecraft that ESA is procuring from Industry.

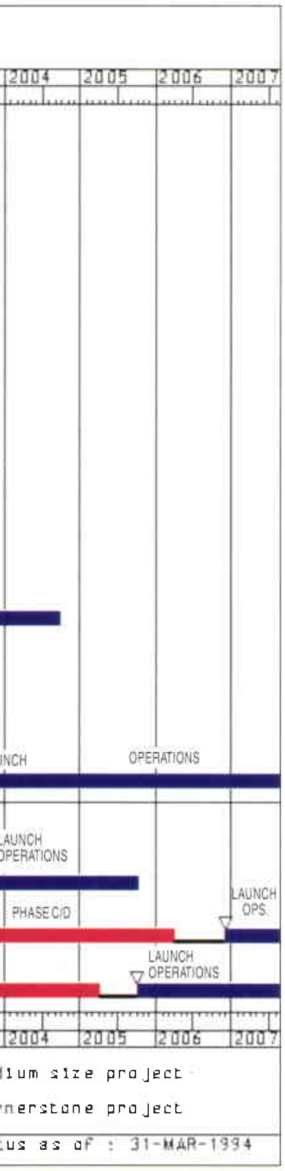
Origins and key activities of the Workshops

Although the Horizon 2000 Programme has provided focus and continuity, at the same time it has placed greater demands on Member States' resources, due to the agreed annual growth in contributions, and also because of increasing financial needs for national funding of ever more complex instruments. Presented with a requested growth in the scientific budget due to introduction of Horizon 2000, Member States wished to review the efficiency of the Scientific Programme to try to improve value for money wherever possible. As a result, the ESA Council requested the Director General to establish an independent Scientific Programme Review Team (SPRT), which was chaired by Prof. K. Pinkau.

One of the many recommendations in the Pinkau Report was a request for a review of the industrial practices relating to the scientific projects. Consequently, a group of consultants (R+I Systems Consultants) was contracted to make a global assessment of the Industry/ESA management interface within the Science Programme. Having conducted enquiries both in ESA and Industry, they recommended, with the agreement of all parties, that a number of specific areas should be examined in detail by a joint ESA/Industry team. This activity was subsequently pursued via a series of joint Workshops and Task Forces (Fig. 3).

In order to establish an industrial forum for the intended exercise, all science-project Prime Contractors were invited to participate, each supported by a Subcontractor of their choice. The Prime Contractors for current projects were invited to assume the industrial lead (Fig. 4).

To balance the participation, the ESA representation was drawn principally from the Science Project and Contracts Departments.



The Third Workshop (Marlow, UK)

Of all the Workshops, the third meeting held in Marlow on 19/20 October 1993 represented a significant milestone in the joint Agency/Industry activities. It established a clear categorisation of proposals in terms of acceptability or otherwise, together with appropriate recommendations for future work. In addition to the ESA, Prime and Subcontractor representatives who participated in the previous two Workshops, Delegates from the Agency's Science Programme Committee (SPC) also attended this event. The Agency participation was also broadened to include ESA's Inspector General and a representative from its Technical Directorate.

The aim of this forum was to provide all participants with an opportunity to express their views openly within the Workshop and to obtain feedback first-hand. The resulting dialogue offered new perspectives in the interpretation of ideas during the discussions, thereby allowing a wider range of opinions to be reflected in the conclusions.

The Marlow Workshop concentrated firstly on reviewing the acceptability of implementing recommendations made via the previous two Workshops, related to project preparation and phasing, management practices/requirements, product-assurance procedures, and the responsibility boundaries between Industry and ESA. It then moved on to review possible future activities resulting from the discussions. In addition, the role of the science/Industry dialogue was examined in light of other ESA initiatives such as the European Cooperation for Space Standardisation (ECSS). The changes that have already been implemented by ESA as a result of the earlier Workshop recommendations were also reported, specific examples being the recent Invitation-to-Tender (ITT) and procurement processes for the XMM project.

Generally speaking, the opinions expressed at the Marlow Workshop reflected converging views on most points, together with an understanding that further work was still necessary to address specific issues.

Major subject areas that were embraced by the presentations and subsequent discussions can be summarised under the following headings:

Reduction of technical/financial risk and improvements in implementation efficiency

During general discussions, attention was focussed on the efficiency of running the programmes. 'Non-value-added' efforts were felt by Industry to have been included in specifications, which potentially led to unnecessary cost. Whilst acknowledging the unique 'state-of-the-art' nature of the Scientific Programme's activities, it was suggested by Industry that, where possible, existing, lower

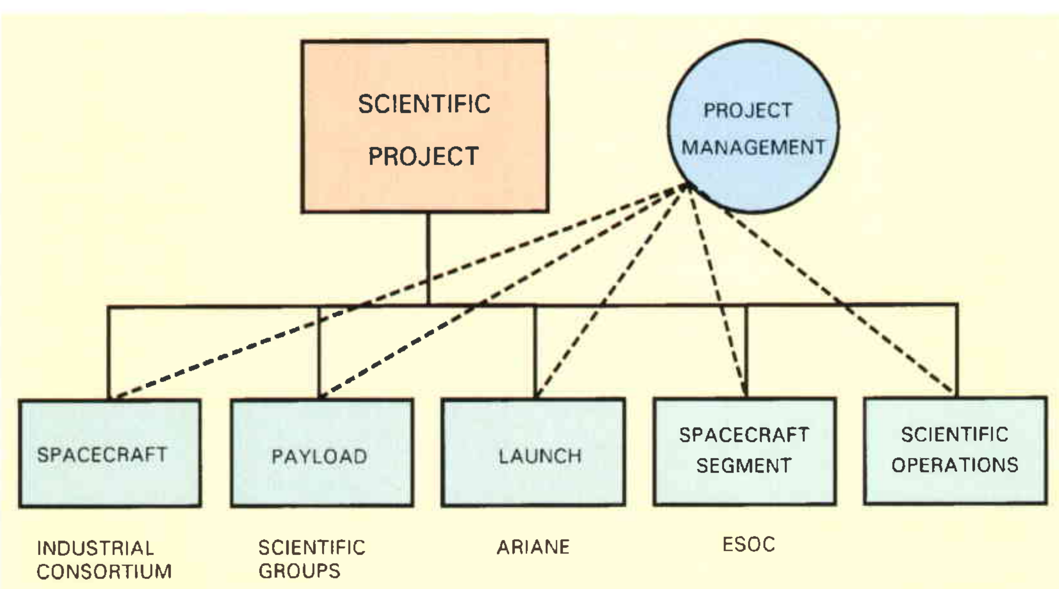


Figure 2. Major elements of a scientific project

Figure 3. Diary of the various Workshops and Task Forces

1988 **Identification of Need for Review**

The British Delegation propose the establishment of an independent review team, under the chairmanship of Professor Pinkau, to look into the costs and the management of the Science Programme, with a view to sustaining the Horizon 2000 activities.

1989 **'The Pinkau Report'**

Science Programme Review Team Report: call for measures to increase the purchasing power of the Horizon 2000 Programme by 40 MAU/Year:

- 20 MAU of the savings to be achieved through changes in procedural, management and industrial policy matters.

1990 **Consultancy**

Follow-up study by R + I Systems Consultants:

- Surveys conducted:
  - Science Programme Review Team
  - ESA
  - Industry: Laben, BAe, Matra Marconi Space, Dasa/Dornier, Aérospatiale, Alenia
- Recommendation: intensify dialogue between Industry and ESA (Science).

1991 **First Workshop in Heelsum (The Netherlands):**

- The Agency initiates the first Industry/ESA(Science) Workshop.
- Joint Task Forces established to investigate critical aspects of activities in the Horizon 2000 Programme:
  - Project Phasing and Technology Planning
  - Management Reporting Requirements and Optimisation of Computer Tools
  - Product Assurance Procedures and Documentation
  - Transfer of Responsibilities

1992 **Second Workshop in Stresa (Italy):**

- The four joint Task Forces findings are presented, and recommendations discussed
- Recommendations are considered for implementation, and the Agency decides to further examine the more complex proposals.
- Working Group established, to investigate 'Contractor Empowerment' possibilities
- ESA formulates its views on major Industrial proposals
- SPC and IPC are informed of progress

1993 **Task Forces & Working Groups - The Third Workshop**

- Task Force work continues on the review of Management Requirements
- Working Group meetings on 'Contractor Empowerment'
- Sub-group formed to look into Flight Operations related activities
- Implementation of recommendations continues
- Third Workshop in Marlow (United Kingdom)

COMPANY	Task Force A PHASING OF PROJECT SELECTION	Task Force B MANAGEMENT REQUIREMENTS	Task Force C PRODUCT ASSURANCE	Taks Force D RESPONSIBILITY BOUNDARIES	Working Group 'Contractor Empowerment'	Sub-group 'Flight Operations'
MATRA MARCONI SPACE	INDUSTRIAL LEADER	X		X	X	X
DASA/DORNIER	X	INDUSTRIAL LEADER			X	X
BAE	X	X	INDUSTRIAL LEADER	X	X	X
AEROSPATIALE	X	X	X	INDUSTRIAL LEADER	X	X
ALENIA SPAZIO					X	X
CONTRAVES	X	X		X		
ETCA	X	X	X			
FOKKER		X	X			
LABEN	X		X			
DASA/MBB	X	X	X	X		
SAAB	X					
SENER	X	X	X			
ESA	X	X	X	X	X	X

Figure 4. Organisation of ESA/Industry Task Forces

risk technical solutions should be given equal consideration, even though newer, more challenging technologies may have been favoured in the project's preparation. The Agency encouraged this approach wherever practical, but emphasised that, where there was an intrinsic shortfall in matching specifications, formal approval would have to be sought. These performance shortfalls must be clearly quantified to allow appropriate cost/risk/performance decisions to be taken.

Geographical return

Extensive discussions took place on the issue of geographical distribution. In the opinion of several Industrial representatives, the relaxation of requirements and fostering of a more commercially oriented approach to spacecraft procurement through competition, could bring improvements in cost efficiency. Whilst noting these views, the motivation for maintaining an Industrial Return Policy was understood and it was acknowledged that authority for any changes was beyond the scope of this Workshop.

Management requirements on industrial contracts

As a general observation after the joint examination of current management practices, it was confirmed that the basic principles of the existing requirements were still applicable in today's project environment. While most elements of the industrial proposals received a favourable response from the Agency, there remains a divergence of views on the principle and practice of concurrent provision of information to ESA and the contractor hierarchy from all layers within a Consortium. Whilst the Agency continues to consider regular access to detail as vital for reasons of 'early warning' and being able to make an independent assessment of project status, Industry favours detailed concurrent information flow only on an exceptional basis.

Under the terms of reference of the Task Force to review management reporting practices, an updated set of detailed requirements on Industry has been produced by a joint ESA/Industry team. It has subsequently been decided to continue the work in finalising the details with regard to the wording and applicability of the requirements. Agreement has also been reached on the future scope of work for the development of electronic data-exchange standards. This effort will be coordinated with similar activities elsewhere in the Agency with a view to harmonising the various requirements.

European Cooperation for Space Standardisation (ECSS)

A summary presentation on the ECSS initiative outlined its objectives and the proposed working structure. It was understood that further discussions would take place between the principal parties to the ECSS activities, to finalise the arrangements, the scope and the priorities of this longer-term effort.

Industry, particularly those contractors involved in the work on the management requirements, whilst recognising the necessity of standardisation aimed at increased European space-industry competitiveness, recommended that duplication of effort should be avoided, and that the science initiative should first be brought to full fruition. It was emphasised by a prime contractor's representative that Industry considers its contributions to the science-Industry dialogue as a worthy investment, and is looking forward to the eventual dividends in the form of Agency-level considerations of the Workshop results.

As an example, it was suggested that the updated set of management requirements for the scientific projects deserve broader examination for suitability to the Agency's other programmes. This 'harmonisation' is to be pursued within the Agency.

Project preparation and phasing

Industry has performed an in-depth review of current project preparation/phasing to explore possible changes that they believe would improve efficiency and establish a better basis for cost-estimation. The proposed revised sequencing of preparation phases is reflected in Figure 5, compared with the current practice reflected in Figure 6.

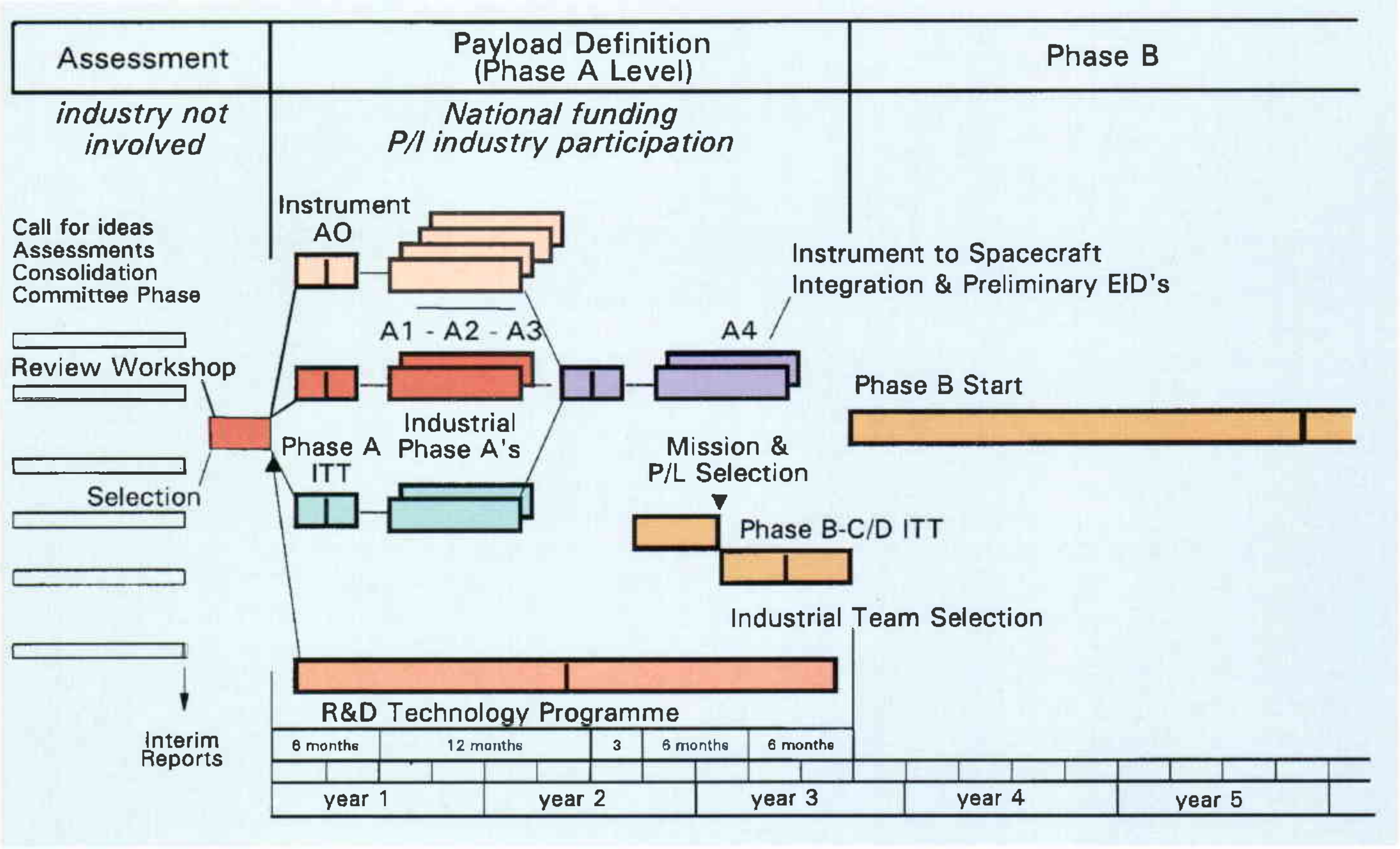
The Agency explained to the Workshop participants the potentially far-reaching effects on Member States, Institutes, Industry and ESA, should the industrial proposals for modifying the project-phasing processes be implemented.

In the Industry-proposed scenario, the Assessment Phase would be more selective, would provide for limited industrial involvement, and would concentrate on only the few missions that were most likely to be implemented. It would be completed by the selection of two potential missions to be passed for Phase-A study. For the Phase-A, there would be two parallel industrial contracts on each candidate mission, the intention being to maintain competition of ideas and Industrial consortia, whilst ensuring earlier industrial involvement and continuity in the implementation of scientific projects.

This selection of two candidate missions for Phase-A study would be complemented by selection of the instruments and Principal Investigators (PIs) at the same time. The implicit motivation for PI selection at this early stage is to provide real instrument payload definition for Phase-A, as opposed to the current practice of defining a 'model payload'. Industry argued that this would provide earlier and better payload definition and thereby increase confidence in Phase-A designs and cost estimates.

As shown in Figure 5, Industry also recommends that technology development activities

Figure 5. Project-selection phasing: New scheme proposed by Industry



be brought in line with project-specific requirements during Phase-A. The output from this expanded work in Phase-A would lead to firmer commitments at the start of subsequent project phases.

The duration of project preparation under the new scenario could be shortened, in Industry's opinion, by two years compared to the current procedure. The latter requires about four and a half years between starting Phase-A and Phase-B and leaves a significant break in the Industrial involvement, as can be seen in Figure 6. However, this provides flexibility in the candidate projects for interaction with the scientific community, and permits mission/instrument design to mature. The PIs are only selected after full mission approval by the Agency's SPC, on completion of the Phase-A studies.

Clearly, a comprehensive analysis of the Industry proposal was necessary to examine all elements in detail, since it claimed better and earlier project definitions and at the same time shortening of the overall cycle prior to the starting of Phase-B. It was recognised that such a reduction could not be achieved without introducing significant changes to the scope and responsibilities of participants vis-a-vis current project phases, and that consultation with SPC Delegations would be necessary.

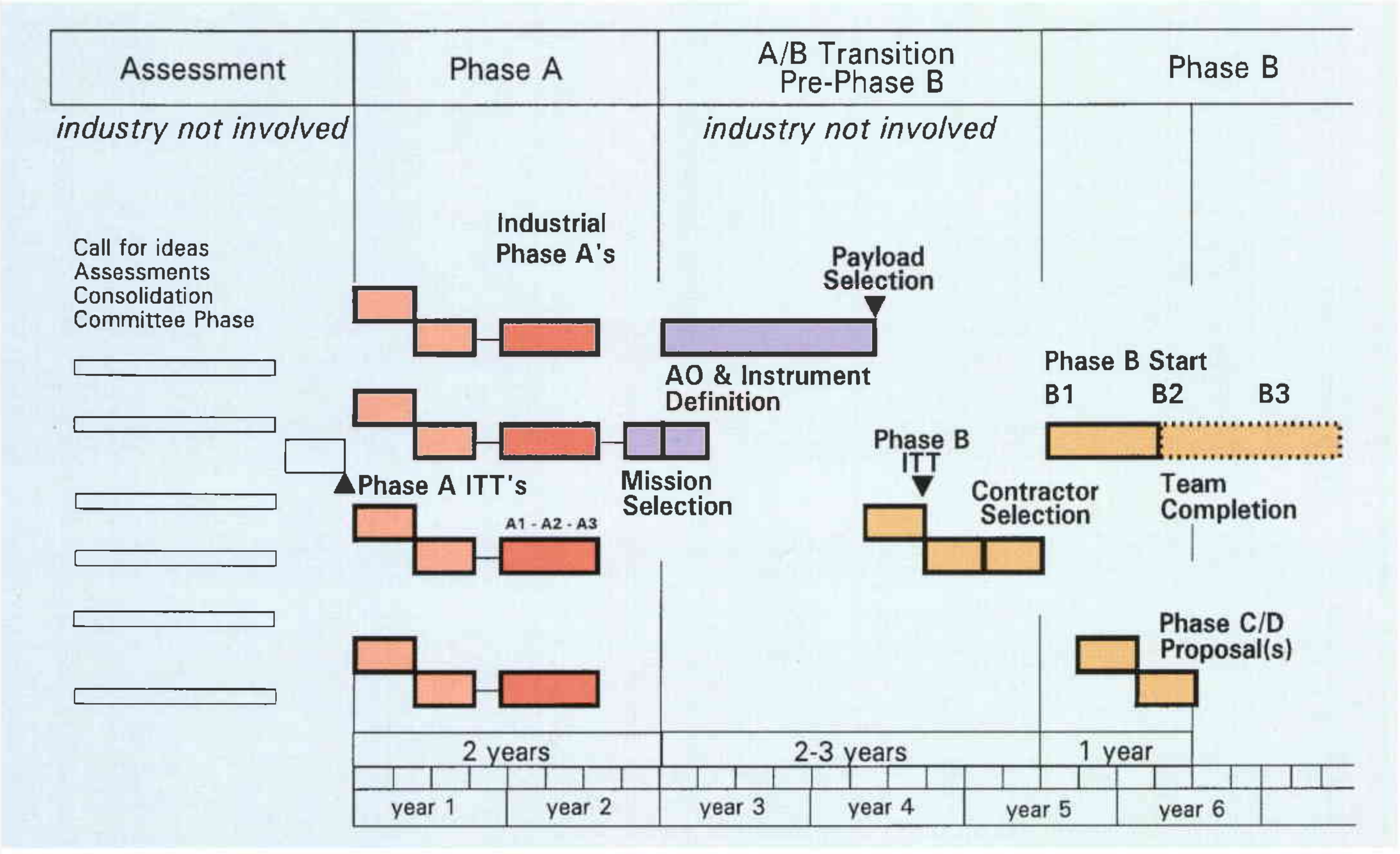
SPC Delegates at the Workshop expressed concerns about possible consequences implicit in the Industrial proposals, including the potential impact of changes arising from agreements for international cooperation, and the potential impacts that de-selection of 'non-flying' Phase-A instruments (baselined for subsequent non-approved missions) might have on the conduct of, and resources available for future missions. It was agreed that the proposals have to be critically reviewed in detail within a smaller SPC forum, to assess their political and practical advantages and feasibility of implementation. The conclusions of these deliberations will be reported to the SPC at their June 1994 meeting.

Role of 'contractor empowerment' in improving efficiency

At the request of Industry, a subgroup under the Task Force commissioned to review 'responsibility boundaries' was formed following the second Workshop in Stresa. This 'contractor empowerment' subgroup's role was to explore the potential for transferring to Industry activities that have traditionally been led by the Agency, such as launcher procurement, payload-interface definition and control, test-facilities responsibility and management, and at the same time assess contractual procedures needed to match the new roles.

Industry stressed the importance of 'contractor empowerment' through streamlining respons-

Figure 6. Project-selection phasing: Present scheme



ibilities, including shortened decision-making processes, and replacing those contracting practices perceived by Industry as inefficient. The ESA position was reflected by the invitation to Industry to further demonstrate its readiness to assume matching contractual/financial responsibility with the increased authority it seeks. In the opinion of the Agency, there are some areas where 'contractor empowerment' would not be applicable in the science-project context, e.g. scientific mission design, payload selection and procurement, and flight-operations design/evolution/execution.

Recommendations agreed by the Agency were implemented on the XMM project through the industrial ITT for Phase-B, released in May 1993. In the context of capitalising on an expanded industrial involvement and desire for 'empowerment', a detailed review of flight-operations supporting activities has started in specialist groups, and further systematic work is planned to address mission-analysis workshops, spacecraft database, simulator design and procurement, mission-control software, flight-operations training, operations manual, and in-orbit performance follow-up. In ESA's view, the extent to which responsibilities could be either embraced by, or transferred to Industry must depend on mission-specific circumstances.

Product assurance

Recommendations made by Industry to reform product-assurance procedures were generally acknowledged by the Agency, as reflected in the ITT for the XMM project. This included reduced documentation requirements, together with recognition of prior experience and PA accreditation of potential contractors. Specific recommendations by Industry regarding PA procedures also include the definition of a joint ESA(Science)/Industry reliability policy, and the inclusion of technical product-assurance requirements in the technical section of the ITT.

Future plans

The ESA (Science)/Industry Workshops have clearly served as a useful forum and constitute a constructive initiative. It was therefore proposed that further Workshops would be planned in order to benefit from major project-related procurement activities within the Horizon 2000 Programme (Fig. 6). According to current Horizon 2000 plans, this would result in convening the Workshops at about eighteen-month intervals, when implementation experiences can be analysed, and future policies determined, for introduction into a new ITT cycle. Major topics already identified for coverage include:

- Management requirements and electronic interface standards
- Project phasing
- Contractor empowerment
- Flight operations.

It was suggested that the inter-Directorate applicability of the Workshop results within ESA should be seriously examined, so that good experiences and useful elements from the science initiatives may be re-used in other programmes as and when appropriate. Whilst there was a general concurrence that the discussions on the subjects addressed should lead to greater efficiency, it was also reconfirmed that quantification in cost-saving terms would remain somewhat intangible.

A general briefing to Industry was given at ESTEC in February 1994. More than a hundred and twenty companies were invited; forty-one companies confirmed their interest by sending representatives to the presentations, which closely followed the theme of the Marlow Meeting.

The composition of the group of Industrialists attending the ESTEC briefing showed a different balance between prime and subcontractor representation compared to the 'typical' Workshop, the subcontractor involvement being greater at ESTEC. Responding to comments made by Industry about the desirability of expanding the role of subcontractors in future joint ESA/Industry activities, proposals were invited from Industry for new arrangements that would raise the profile of smaller companies in the Task Forces and Working Groups.

It is intended to review fully the composition of the Workshops prior to initiating the next set of activities, with the goal of broadening the industrial-opinion base and exploring improvements in working practices throughout the ESA/Industry hierarchy.

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La politique industrielle de l'ESA – Le concept évolutif du 'juste retour'

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La Convention de l'ESA définit le coefficient de retour d'un Etat comme le rapport entre le pourcentage des contrats qu'il a reçus, calculé par rapport au montant total des contrats passés dans l'ensemble des Etats et le pourcentage des contributions payées par cet Etat.

Introduction

La notion de juste retour, qui n'existait pas à l'époque de la création de l'ESRO, a commencé à prendre forme en 1968, lorsque le Directeur général a été amené à garantir un retour minimum de 70% à tous les Etats membres.

La Convention de l'ESA, entrée en vigueur en 1975, couvre de façon assez complète la politique industrielle. Ses objectifs généraux sont décrits dans l'Article VII, dans lequel on rappelle brièvement l'exigence d'une participation équitable des Etats. Plus de détails sont développés dans l'Annexe V qui traite des règles de mise en oeuvre de la politique industrielle. En particulier, l'Article IV de cette annexe définit les règles de calcul du coefficient de retour global.

Ce coefficient est considéré comme un indice de juste retour de chaque Etat. La politique industrielle et la notion de juste retour qui lui est souvent associée, ont fait l'objet d'un intérêt grandissant à chacune des dernières réunions du Conseil de l'ESA au niveau ministériel à La Haye (novembre 1987), à Munich (novembre 1991) et à Grenade (novembre 1992).

Il nous a semblé utile de replacer cette notion de 'juste retour' dans le contexte plus général de la politique industrielle de l'Agence, de rappeler brièvement la méthode utilisée pour son calcul et d'indiquer les évolutions récentes des contraintes imposées dans la répartition géographique des contrats.

La Convention et les objectifs de politique industrielle

L'Article VII de la Convention fixe les principes généraux de la politique industrielle, et l'Annexe V traite plus en détail de sa mise en oeuvre.

Ces textes ont été rédigés en 1974 en préparation de la création de l'Agence Spatiale Européenne et il convient de noter qu'à cette époque, la recherche spatiale en Europe se situait dans un contexte plus favorable que celui dans lequel nous vivons actuellement.

Les grandes orientations de la politique industrielle, qui sont citées dans l'Article VII, indiquent quatre objectifs, ou pour être plus exact trois objectifs et une considération supplémentaire. Ces objectifs sont énumérés suivant un ordre quelconque et il n'y a pas de volonté de hiérarchie entre ces objectifs du fait que l'un est placé avant l'autre.

Le premier objectif cité est celui de la **réalisation des programmes** de manière effective et efficiente. C'est un objectif qui semble évident. Mais il n'est pas inutile de le rappeler car il arrive parfois, en particulier dans certains programmes facultatifs, que d'autres aspects de politique industrielle, qui peuvent conduire à des augmentations des coûts, prévalent.

Le deuxième objectif, c'est l'amélioration de la **compétitivité de l'industrie européenne** face à l'industrie mondiale. Tout le monde est concerné par ce sujet qui a même été abordé dans des discussions avec la Communauté Européenne et c'est une question tout à fait actuelle.

Le troisième objectif, qui est un point de débats fréquents, c'est celui que l'on a qualifié de **'juste retour'**. En fait, la Convention dit simplement que tous les Etats doivent participer de façon équitable à la réalisation des programmes de l'Agence. L'Annexe V définit un peu plus ce que l'on entend par une façon équitable, c'est-à-dire la répartition géographique des tâches, donc des contrats entre les Etats. Cette répartition des contrats doit se rapprocher de façon proportionnelle de la répartition des contributions des mêmes Etats aux programmes en cause.

Le quatrième point, que nous ne considérerons pas comme un objectif mais plutôt comme une position de principe, c'est que la politique industrielle de l'Agence doit se baser sur la notion d'**appel à la concurrence**. La Convention est très claire sur ce principe fondamental: elle dit 'bénéficier des avantages de l'appel à concurrence dans tous les cas sauf lorsque cela serait incompatible avec les autres objectifs définis de la politique industrielle'. Les dérogations à l'obligation de faire appel à la concurrence ne devraient être justifiées que par la recherche de l'un des trois objectifs cités précédemment, c'est-à-dire réaliser les programmes de manière économiquement efficiente, améliorer la compétitivité et enfin assurer la répartition géographique équitable des contrats.

Ce dernier objectif peut quelquefois nous conduire à déroger à la loi normale de la concurrence pour atteindre une répartition équilibrée. Mais une telle démarche ne doit pas avoir un caractère prioritaire. Il convient de noter que, dans le Règlement des contrats de l'Agence, la justification des contrats placés de gré à gré se base sur d'autres raisons telles que la continuité, la spécialisation etc., et non sur une obligation de répartition géographique des contrats.

La Convention et les règles de politique industrielle

Après ce rappel des principes fondamentaux, reportons-nous à l'Annexe V de la Convention, qui porte le titre de Politique industrielle et qui en fait traite essentiellement des questions de répartition des contrats et du retour industriel.

Le premier article de cette annexe définit bien les points à considérer tels que la structure générale de l'industrie, les degrés de spécialisation, la coordination des politiques industrielles nationales, les capacités de production et les possibilités de débouchés. Mais tout le reste de l'annexe traite essentiellement du retour industriel: définition du retour, calcul du retour, obligations en matière de retour et mesures à prendre lorsque ces obligations ne sont pas satisfaites.

En matière de procédure à suivre pour l'attribution des contrats, l'accent est mis sur **la préférence** à donner à l'industrie ou aux organismes de recherche des Etats qui participent au programme. Mais ce n'est qu'une notion de préférence, ce n'est pas une obligation exclusive. Il convient de souligner que la Convention ne dit pas que les Etats membres, qui ne financent pas certains programmes facultatifs, sont exclus; il est simplement dit qu'il y a une préférence à donner d'abord aux Etats participants, ensuite aux Etats membres non participants et enfin aux autres Etats.

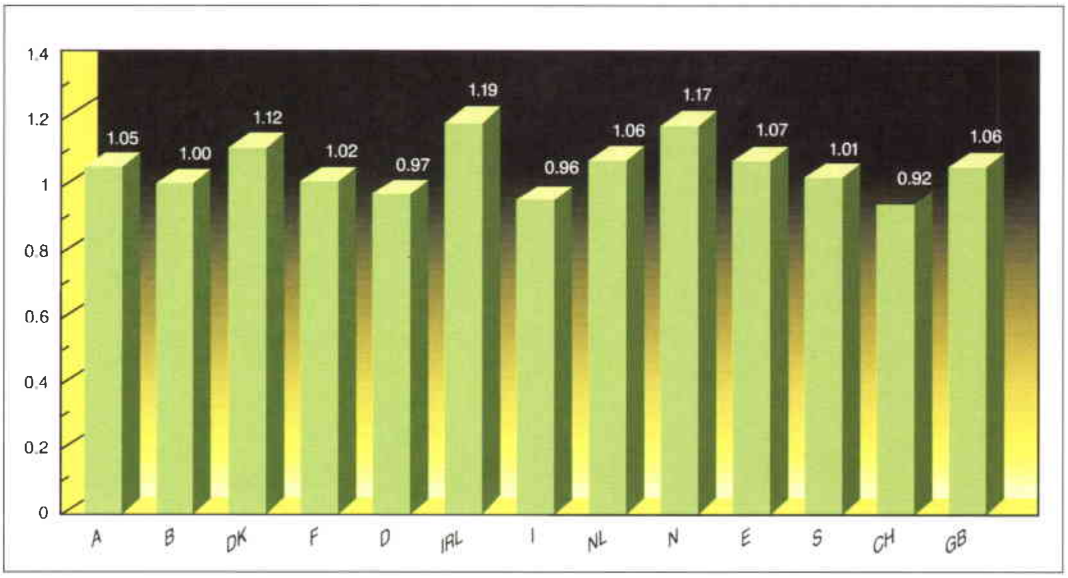
Pour définir **le retour**, des facteurs plus techniques interviennent: qu'entend-t-on par répartition géographique et quelle est la nationalité des firmes qui sont mises en oeuvre? A priori la question semblait relativement simple lorsque l'on a rédigé la Convention en 1974: les firmes avaient le plus souvent un caractère national indiscutable mais il y avait déjà quelques rares filiales étrangères. Depuis cette époque, deux phénomènes ont vu le jour: la restructuration industrielle en Europe, qui a vu plusieurs regroupements de grandes firmes et le rachat de petites firmes par des grandes firmes, et le fait que les firmes ne travaillent pas toujours sur leur territoire national. Elles sont appelées à rendre des services dans les établissements de l'Agence, à faire appel à du personnel qui ne relève pas de la nationalité de la firme d'origine, et là encore, un autre problème est celui de qualifier la nationalité du travail confié à ces firmes.

Dans les articles suivants de l'Annexe, la procédure à suivre pour la politique d'approvisionnement est définie dans ses grandes lignes. C'est le Règlement des contrats qui définit dans le détail cette procédure; c'est donc à ce Règlement qu'il faut se référer pour étudier les implications sur la politique industrielle de l'Agence.

Ensuite, un ensemble d'articles interviennent sur la notion de **coefficient de retour global**. Ce n'est pas nécessaire de les reprendre dans le détail mais il est utile de rappeler que le coefficient de retour n'est qu'un rapport de pourcentages et non pas un rapport de valeurs absolues. Le coefficient de retour, tel qu'il est défini par la Convention, c'est le pourcentage des contrats obtenus par un Etat par rapport au montant total des contrats attribués à tous les Etats, donc un pourcentage, divisé par le pourcentage des contributions de cet Etat par rapport au montant total des contributions, donc également un pourcentage.

Ce coefficient de retour est donc **un rapport entre deux pourcentages** et, non pas comme on le croit souvent, le rapport entre deux valeurs absolues, à savoir le montant de contrats sur le montant de contributions. Derrière cette notion de coefficient de retour, petit à petit, s'est introduite la notion de surplus ou déficit. Ceci a été dû au fait que pour faciliter le calcul du coefficient de retour on a défini la notion de valeur idéale des contrats. C'est une notion arbitraire qui permet de remplacer le pourcentage idéal de contrats par un montant absolu et il est alors plus facile de comparer le montant réel des contrats par rapport au montant idéal. Mais ceci n'est qu'une procédure de calcul et non une définition exacte du retour; rappelons que le retour est essentiellement un coefficient sans valeur absolue.

Au-delà de cette définition, la question la plus souvent soulevée concerne la valeur minimale de ce coefficient de retour et le contrôle de son évolution. Dans la Convention comme dans différentes Résolutions du Conseil, il est clairement indiqué ou rappelé qu'il faut tendre vers une situation idéale dans laquelle tous les coefficients de retour sont égaux à 1. C'est l'objectif prioritaire, on doit se rapprocher de 1 mais il est également clairement dit dans la Convention que si c'est un objectif, ce n'est pas une obligation. Les auteurs de la Convention ont préféré mettre une obligation en définissant un seuil limite en-dessous duquel on considère que la situation est anormale.



Coefficients de retour global (cumulé de 1972 à fin 1993)

Lors de la création de l'Agence, ce seuil a été fixé à 0,8. Des examens formels sont prévus tous les trois ans et si un Etat membre a un coefficient de retour inférieur à ce seuil, le Directeur général est appelé dans l'année qui suit à proposer des mesures qui doivent lui permettre de redresser la situation et de rattraper le seuil minimum. Ce seuil minimum de 0,8 dans la Convention n'est pas un seuil définitif; il peut être revu tous les trois ans, il ne peut pas descendre en-dessous de 0,8 mais il peut être revu à la hausse. Le seuil pour la période qui s'est achevée fin 1993 était fixé à 0.95.

Evolution des contraintes et des procédures

La Convention n'a pas été modifiée depuis la création de l'Agence et reste donc d'application dans tous ses termes. Depuis 1974 des décisions ont été prises soit par le Conseil soit par le Comité de la Politique Industrielle dans différents domaines qui relèvent de la politique industrielle. La plupart de ces décisions portent sur les questions relatives au retour, et à l'intérieur de cette notion de retour, sur deux aspects très différents. Le premier concerne le **seuil minimum** du coefficient de retour global au-delà duquel il y a lieu de prendre des mesures correctives. Progressivement le seuil de 0,8 a été porté à 0,9, 0,95 et lors du dernier Conseil, qui s'est tenu a Grenade en novembre 1992, à 0,96 pour la période triennale de 1994 à 1996. Il y a donc eu une progression très nette de ce seuil.

Le deuxième aspect, qui a fortement évolué, concerne les méthodes et les procédures techniques du **calcul du retour**. C'est suite au Conseil réuni au niveau ministériel à La Haye, où il a été décidé de compenser les déséquilibres observés dans les retours des Etats membres à la fin de la période 1972–1987, que l'on a mieux pris conscience de l'absence de précision des coefficients de retour. La procédure utilisée jusqu'à cette époque pour calculer le retour s'appuyait sur des données évolutives et n'était simplement qu'un outil permettant de déterminer des tendances et rien d'autre.

La compensation des déséquilibres impliquait pour certains Etats de débourser des montants appréciables d'argent et pour d'autres d'en recevoir; il était difficile de rattacher des montants financiers à un outil qui n'était qu'approximatif. Il a donc été nécessaire, conjointement avec la compensation des déséquilibres du passé, de revoir la procédure de calcul et une nouvelle méthode de calcul du retour a été mise au point en 1988.

Cette procédure est basée sur la comptabilité de l'Agence. Au lieu de prendre en compte les projets de contrats, les contrats approuvés par le Comité de la Politique Industrielle, les procédures d'engagement etc., nous utilisons le système informatique qui gère le système comptable de l'Agence, c'est-à-dire les engagements réels et les paiements réels effectués dans le cadre des opérations contractuelles de l'Agence. Nos calculs du retour industriel sont donc faits maintenant en s'appuyant sur le système financier de l'Agence. Ces calculs ont toutes les qualités de ce système mais présentent aussi les mêmes inconvénients.

L'inconvénient majeur du système financier est de vivre en temps réel, c'est-à-dire de prendre les engagements et les paiements effectués tout au long de l'année et de transférer sur l'année suivante les engagements restant à payer. Comme notre système travaille à la fois en monnaies nationales et en unités de compte, on est conduit à utiliser des taux de conversion non constants pour un même contrat. Une autre difficulté du système provient de la notion d'évolution économique. Nous avons des contrats avec formule de révision de prix et d'autres à prix forfaitaire définitif. Pour ces derniers, il est évident qu'il n'y a pas de modifications économiques qui interviennent dans nos statistiques. Par contre, pour les contrats avec formules de révision de prix, lorsqu'il y a révision de prix le montant correspondant est engagé. Ici, il y a une correction qui est réellement faite dans le système financier.

On constate ainsi que le système de calcul du retour industriel travaille essentiellement sur des montants exprimés en unités de compte qui, d'une part, utilisent des taux de conversion variables pour chacun des 15 Etats membres ou associés et qui de plus ne se situent pas dans des conditions économiques constantes, puisque nous ne faisons pas de réactualisation ni de désactualisation.

Remarque finale
Nous avons essayé dans cet article de replacer la notion de juste retour dans un contexte plus général de la politique industrielle de l'Agence. Si l'on se réfère à la Convention, on constate que depuis 1974, en matière de politique industrielle, il y a eu des modifications sur des questions de méthode ou des questions techniques qui relèvent plutôt de l'Annexe V. Mais ces évolutions n'ont pas remis en cause les fondements des principes de la politique industrielle de l'Agence.

Mais par rapport à la Convention, le monde extérieur a changé et le monde de l'Agence elle-même a changé. En 1974, la Convention a été écrite en s'appuyant sur le passé et plus particulièrement l'ESRO, organisme qui travaillait avec des contributions proportionnelles au Produit National Brut de chaque Etat membre, pour réaliser des programmes obligatoires communs à tous les Etats membres et non pas des programmes facultatifs.

Sont venus s'inscrire dans le début des années 1970 les premiers programmes facultatifs avec les programmes de télécommunications OTS puis ECS et Marecs et les autres grands programmes Ariane et Spacelab. L'introduction progressive de ces programmes facultatifs a changé assez fortement le contexte de l'Agence et la notion de calcul de retour global a dû être revue dans la mesure où il y avait également des obligations de retour à l'intérieur de chaque programme facultatif. De plus, le poids relatif des programmes facultatifs par rapport aux programmes obligatoires a constamment progressé. Actuellement ce sont près de 80% du budget de l'Agence qui sont consacrés à des programmes facultatifs qui ont tous des niveaux de contributions variables en fonction de la volonté propre de chacun des Etats participants. De plus, chaque Etat ne participe pas à tous les programmes facultatifs. Dans ces conditions, il est bien difficile d'avoir une politique industrielle cohérente dans la mise en oeuvre de tous ces programmes.

Une réflexion plus large sur l'évolution possible de la politique industrielle de l'Agence pourrait s'appuyer notamment sur les deux considérations suivantes:

- D'une part, le contexte international a rapidement changé depuis ces dernières années. Dans le domaine spatial, des collaborations nouvelles sont en train de se développer entre les différents partenaires. Cela produira des effets sur l'activité industrielle au niveau européen.

- D'autre part, notre vie quotidienne est plus concernée par les activités spatiales qu'il y a dix ou vingt ans. L'Espace est en train de devenir un facteur économique qui fait partie de notre société. Non pas un facteur économique privilégié mais un domaine d'activité industrielle, certes de pointe, mais qui est susceptible de traverser des cycles conjoncturels de croissance et de stagnation comme n'importe quel autre secteur économique.

The ESA Modification Procedure as a Tool for Management and Engineering Control

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In a large development contract with a long duration, the customer's requirements and the work performed by the contractor are more than likely to change over the length of the contract. The changes must be well regulated to minimise the impact on the cost and schedule but also to maintain a very clear control and record of the technical progress and the characteristics of the product.

For the last 20 years, ESA has been using a Change Procedure to manage changes. That tool has contributed significantly to the technical success of ESA programmes, and cost overruns and schedule delays have been manageable. Moreover, the Change Procedure has proven to be an invaluable mechanism for the settlement of contractual disputes, without having to resort to arbitration.

Introduction

It is a characteristic of large development contracts with a long duration that the customer's requirements and the work performed by the contractor do not remain static and exactly as foreseen in the negotiated contract, which itself reflects much of the substance of the original Invitation to Tender and the offer. No matter how detailed the specifications, how exhaustive the negotiations and how vigilant the contractual management, it is the nature of such contracts not to remain totally frozen.

Nor are changes necessarily to be regarded as always unwelcome. They might be the result of an element of intellectual vigour, successful development and enhanced possibilities, though of course they might also reflect a lack of precision in the definition of requirements, inadequate performance or an external and unwanted happening.

Whatever the cause, however, it is essential that the flow of changes be extremely well regulated so that not only are costs, schedule, end performance and similar basic contractual conditions kept transparent, but also to maintain a very clear control and record of the technical progress and the characteristics of the product. The clauses and procedures which aim to ensure this are an essential tool of overall project management which protect the interests of both the customer and the contractor. The clauses used in ESA contracts (and before that, in ESRO contracts) are more detailed than most, and have been applied successfully for more than 20 years.

The causes of changes

The variety of events that can give rise to a modification of the contract is so wide that an exhaustive list would be impossible to draw up, and a categorisation other than by broad generalisations and with an eye to the contractual consequences raises more questions than it answers.

Typical events in development contracts that give rise to changes are:

- a need by the customer to change the specifications because of changed requirements from a third party to whom he has obligations, such as an experimenter or a launch supplier
- a desire by the customer to improve the performance, which is made possible by new technological developments
- the failure of a technology assumed by both parties to be suitable or feasible
- the disappearance from the market, or proof of unsuitability of some essential material or equipment, such as high-reliability electronic components
- a request by the contractor to reduce the performance characteristics for technical or financial reasons

— the failure of the customer to furnish, or to furnish on time, an item or service that he has undertaken to provide the contractor.

The basic contractual rules

In the vast majority of ordinary commercial transactions, it is not expected that the terms of a contract will change. The customer states what he wants and then waits for it to be delivered. If it matches the specification and is suitable for the purpose, that is the end of the matter. If, exceptionally, a party wants to change something in the agreed terms, such as deliverable quantities or place of shipping, the variations would be fully discussed, their consequences explored and their implementation settled before they are introduced.

In the field of major projects and complex technological development, this is in practice impossible. Not only is the need for change innately more likely because of the nature of the activity, but the cost to both parties of any delay to the work while these changes are discussed far outweighs the formal clarity that a discussion would give. Furthermore, in development contracts, the product is not just a simple deliverable item. The acceptable performance of the end-product is subject to test and evaluation, and is measured as a combination of many factors which fall within a range of possible acceptable or unacceptable results. The active interest of the customer in each factor is greater than under a normal sales contract. He follows the development and building process closely and intervenes rapidly if he feels this necessary in order to protect his technical interests, as well as to avoid delays and additional costs.

For this reason, in complex development projects, a contractual provision is often introduced that allows the customer to insist on the introduction of a change, and enables the change to be introduced if necessary before all the consequences have been agreed. Where such provisions exist, there have to be certain protections for the contractor, a clear definition of the types of changes and their effect on the contract terms, and a procedure for their orderly introduction.

There are also some fairly complex legal issues as to how far the change can go in relation to the existing contract (the so-called 'in-scope' doctrine). It is beyond the bounds of this article to examine this particular problem, though it is briefly outlined here*. Contract law, whether domestic, or when codified in an international set of rules such as the Uniform Law for International Sales, tends to say very little about changes to the agreement — usually little more than that the parties are free to change the terms by agreement, and that if the original contract was entered into by special formalities, such as writing, the change must be made likewise. Further rules are mainly concerned with coping with situations where external circumstances outside the contract and beyond the control of the parties change and determine whether, and under what conditions, the agreement can survive. Essentially, changes are not particularly expected or wanted as part of the business relations.

More detailed contractual provisions that anticipate and are designed to permit and regulate changes at the will of the parties are mainly to be found in the world of projects, either in the private field such as large-scale civil engineering, or in the public financing of research and development, with all its uncertainties and risks. Common to these rules is a recognition that the customer can require changes, and a definition of the extent to which these can occur, the responsibility for the financial and other consequences of the change, and a procedure, including powers of decision and binding commitment. These clauses have some legal interest, as they can be seen as pushing the front edge of contractual technology in the same way as their subject matter does for science and engineering. They also show important project management aspects, regarding the set of procedures put in place to manage changes and to maintain a smooth running of the project, in particular where there are a large number of sub-contractors in a multi-layer hierarchy. The ESA clauses and practice are an interesting illustration of these issues.

> Change is inevitable.
> In a progressive country change is constant.
>
> *Benjamin Disraeli*

The right of the customer to impose changes

The right of the customer to insist unilaterally on changes is to be found in, for example, the

* For a more detailed legal examination of some of the issues, see Unilateral Modification Clauses in Long Term Contracts, S.G. Kahn, Revue de Droit des Affaires Internationales. No. 2, 1986.

NASA and the Intelsat conditions, and those of other satellite procurement bodies, and the FIDIC Conditions of Contract (International) for works of civil engineering construction.

Clause 26.1 of the ESA General Clauses and Conditions states:

> *The Agency reserves the right at any time to modify the specifications, patterns or drawings relating to the work covered by the contract.*

Major contracts contain a more elaborated clause, which includes the following:*

> *I. **General***
> *The Agency may at any time, by written order, make changes to the scope of the work to be performed or items to be provided under this Contract. The Contractor shall be obliged to prepare and implement such changes under the conditions specified below. ...*

The clauses leave no doubt that the customer can have the change introduced, contrary to the expressed wishes of the contractor, and, if necessary, before agreement on its consequences has been reached. Typical provisions are:

> *Nothing contained in this Article or elsewhere is to be construed as justifying any decision by the Contractor not to introduce or to suspend the introduction of a change approved or ordered by the Agency ...*

> *If the required introduction date is prior to the next scheduled Change Review Board (CRB) meeting or the CRB postpones its recommendation until a later date or the CRB does not reach agreement, the Agency's project manager may order in writing the prior introduction of the change. This shall not be deemed to constitute acceptance by the Agency of any other aspect of the change.*

This is, admittedly, a somewhat draconian condition, even somewhat shocking to persons who come from a different contractual environment. It has, however, proved over a long period to have been essential and has made a beneficial contribution to the successful conclusion of projects, and to have led to far fewer arguments than might be suspected. There are a number of reasons for this:

— imposition of a change before agreement on all the consequences must inevitably involve some degree of responsibility of the customer for such consequences. The right is therefore only used in extreme operational circumstances where the customer is convinced that a rapid reaction is necessary, and the customer has his own fund of technical skills and experience.

— if there is a real technical disagreement on the need for and the consequences of the change, for example on the performance or reliability, the change requirement is probably the result of an already identified problem. Both sides are likely to want to analyse and discuss the matter until a reasonable certainty as to the solution is found. The contractual consequences are not uppermost in their minds. Where the need for the change is technically agreed, the disagreement centres on such matters as the responsibility for the need for the change, or its impact on cost and schedule. These matters tend to be negotiated, in a fairly objective way, on the basis of existing documents. This can be time-consuming but carries no abnormal risk for either party.

— the large number of changes within a project, and the number of different contractual relationships, past, present and future, that a contractor is likely to have with the Agency contribute to a mutual confidence that both parties will be reasonable.

It must, of course, be pointed out that it is rare for the customer to insist on change in the teeth of opposition from the contractor. The norm is for agreement to be reached before the introduction on at least the major impacts and consequences, even if some subsidiary aspects remain to be discussed in the normal manner.

The 'in-scope' doctrine and the limits of changes

It is a generally recognised rule in contract law and practice that any changes to the contract that a customer can insist on must be within the scope of the original agreement. NASA and Intelsat clauses specifically reserve the right for the customer to make changes 'within the general scope' and there have been cases in which the right to impose changes beyond the scope has been rejected. The reason is self-evident. A completely unrestricted right could allow the customer to demand delivery of something that so differs in nature, perfor-

* Clauses in ESA contracts are subject to negotiation, and will sometimes differ in formulation, but not significantly in substance, from the texts cited.

mance or quantity that the contractor cannot meet the demand, due to lack of skills or resources.

The ESA clauses appear at first sight, but not on closer examination, to contradict this rule. In the definition of changes, one finds:

> *Class A changes are alterations which result from one or other of the following causes:*
>
> *1) A significant alteration to the scope of the work to be performed such as a redefinition of the function, performance or schedule requirements of any item, parts thereof or any associated items, due to changes of the Agency's requirements.*

What seems to be a conflict between the general rule as illustrated in NASA's approach and that of ESA (or of the FIDIC Conditions of Contract (International for works of civil engineering construction, which appear to go even slightly further) is more apparent than real. The ESA clauses measure the scope against the detailed and specific agreed requirements — the contractual baseline — and not against a general 'broad-brush' definition of the scope. This baseline is defined in the change clauses as follows:

> *The baseline from which deviations are deemed to be changes shall be the technical and administrative baseline at the status as agreed and approved by the Agency at the date of the proposal of the change.*

It should be noted that where the baseline is very broadly defined, as for example in feasibility studies, the customer can give a technical redirection within the price — this is sometimes referred to in ESA contracts as an 'in-scope' modification and is not regarded as a contractual change at all.

In the extreme case, were a customer to try to impose changes that alter the very nature of the activity, it would be argued that it is not the subject matter of the contract at all, so the right to impose the change is not covered by the contract.

There is a further protection against the (largely theoretical) possibility of a customer unilaterally imposing excessive changes. Beyond a reasonable and justified degree, such actions can be seen as distorting the original procurement and either the fair competition or the justification for direct negotiation (sole source). Both public procurement codes and ESA internal regulations would oppose this. Of course the issue is not likely to be tested very often — a contractor is usually pleased to take on additional work if he is certain to be paid.

The classification of changes

ESA contracts classify changes into two categories, Class A and Class B. A third category, Class C, which existed in some early contracts, was found to be redundant: by definition it was not a contractual change, and its consequences were the same as for Class B.

Class A changes are defined as:

> *i) A significant alteration of the scope of the work to be performed, such as a redefinition of the function, performance or schedule requirements of any item, parts thereof or any associated items, due to changes of the Agency's requirements;*
>
> *ii) Addition or deletion of specific efforts or items to be provided by the contractor or parts thereof due to changes of the contractual baseline;*
>
> *iii) The Agency's non-execution of any of its undertakings as specified in this contract;*
>
> *iv) Malfunction of any equipment or facilities provided by the Agency during their critical utilisation, e.g. during integration and testing, insofar as these are not caused by the Contractor's negligence.*

> Since 'tis Nature's law to change,
> Constancy alone is strange.
>
> *John Wilmot, Earl of Rochester*

Class B changes are simply defined as any other changes. A simpler version of the Class A definition has recently been introduced without changing the essential meaning:

> *Class A changes are changes which result in an impact to the Contractor from:*
>
> *— The Agency initiating a change in the Agency's documents of the contractual baseline as defined in Article ... or in the time or place of delivery specified in the contract;*
>
> *— failure by the Agency to execute one of its undertakings as defined in Art. ...*

Conceptually, it is not at all hard to identify a Class A change. In practice, it is not always quite so evident. The customer is concerned about a particular engineering solution. The contractor claims that it is part of the contractual baseline, having been specifically offered in his bid. A detailed examination of the documents shows that the issue is not wholly clear, for example, the record of subsequent technical discussions implies that the Agency has endorsed the solution. Or perhaps it is not clearly demonstrable whether the solution will or will not meet the requirements, it is really a change intended to increase confidence in the approach adopted. Or the same technical change appears as a change in requirements, but would, at least in part, have been necessary for the contractor to meet the original requirements. Depending on whether the customer requirements are written purely as end-product performance specifications, or contain design or technology details, the borderline for this point will move, but not wholly eradicate the area of doubt. Over the years, the Agency has moved increasingly to performance-defined requirements, but, concerned as it is with advanced development and scientific excellence, it is far from a hands-off customer placing turnkey contracts.

The world's a scene of changes, and to be Constant,
in Nature were a constancy.

Abraham Cowley (1616-1667)

Similar questions of difficult classification arise where, for example, the contractor is running late and, at the same time, the Agency is late in furnishing a model of an experiment required for the spacecraft testing programme. In purely contractual terms, the temptation on either party might be to 'play poker', waiting for the other party to declare his hand. From the project management view, this might be taking a risk that far outweighs the benefits.

For such reasons, the contract provides specifically that a change may fall partially into one category and partially into another, and a reasonable and equitable approach is enabled.

The consequences of a change

In principle, the consequences of a change are relatively simple. The customer bears the consequences of a Class A change and the contractor bears the consequences of a Class B change. The matter is somewhat complicated by two factors: the effects in a cost-reimbursement environment and the existence of a hierarchy of sub-contractors.

Where a Class A change consists of anything other than a cancellation of work, it is, in effect a new or additional procurement, and all terms of the contract that are affected by the change will be modified as necessary. Such terms may include price, delivery dates and performance specifications, and such lower-level matters as work package descriptions. If there is a performance incentive scheme, the parameters might be modified. In the case of a cost-reimbursement contract with a cost-incentive scheme, the target cost, target fee and other elements are to be considered.

The change may consist of a reduction of the work. This may be the reduction of a test programme or even the elimination of a spacecraft development model. In principle, the negative consequences of the change should be reflected in all elements concerned, such as a price reduction, earlier delivery or a reduction in mass, applying the principles contained in the contract clauses dealing with cancellation (Clauses 31, 32 and 33 of the General Conditions). In practice, one is only forced to such changes when there are major problems in the programme, and the negative consequences tend to be set off against other increases. Very often what is really a negative change will appear as a technical waiver or configuration change, with the danger that it escapes proper contractual scrutiny. This is a topic that might itself justify a separate study.

In a fixed price contract, a Class B change will lead to no modification of the contract terms. If, however, the contract is for a cost-reimbursement price, the costs associated are classified as allowable costs, although they bear no profit, and any targets in a cost-incentive scheme will be unchanged. A Class B change on a prime contractor may, however, be the result of a Class A change between a sub-contractor and the prime contractor. The subcontractor will claim profit, whatever his price type, from the prime contractor, who will then claim the total additional price as an allowable cost to himself. The logic of cost-reimbursement would imply that this is correct — but it can be seen as an inducement to imprudence and lack of cost consciousness. An equitable solution that is sometimes negotiated is to include in the prime contract an interface reserve, which allows such costs, including sub-contractor profit, to be met up to a reasonable point and no further.

It might be asked why, in view of the above, it is considered necessary or useful even to categorise Class B changes or to handle them under the procedures. The main reason is that, although they do not directly affect the contractual baseline as specified in the contractually applicable documents at prime contract level, they will affect lower level documents that are monitored by the Agency as part of its overall project management. As a corollary, the less the customer concerns himself technically with what occurs below the prime contract level, the less he has to concern himself with changes at that level, or carry any degree of responsibility for them.

Finally, it should be emphasised that in the case of a fixed price contract, Class A changes increase the total price by the total cost. In a cost-reimbursement contract, they merely increase the estimated cost to completion and the fixed or target fee. The financial negotiations, therefore, really turn on a relatively small percentage of the total costs. Where the amount of programmatic uncertainty is such as to justify a cost-reimbursement contract in any case, this effect is an additional element in ensuring flexibility in the development process.

Contractor's duty to minimise costs

It is a widely-held, if cynical, view, that it is through the changes that a contractor makes his profit. This view is familiar to anyone who has had the house-builders in. While contractors involved in high-technology research usually have a greater sense of responsibility and higher economic priorities than merely extending the programme, it is considered wise to reduce any such temptation. ESA therefore introduces a clause which states that:

> *The Contractor shall reduce to the minimum any delay to the programme caused by any changes. If a delay due to a Class A change causes extra costs, the Agency shall pay such costs only insofar as the Contractor can prove that this change was the sole cause of the delay. Milestone dates shall only be extended if the Contractor can prove that the Class A change is the sole cause of his requesting a delay.*

This provision has three effects. Firstly, it puts the burden of proof on the contractor. In practice, he is only required to make the proof if the customer can show that there is a case to be made that the contractor is partly the cause of the change. Secondly, it covers the circumstances, mentioned previously, where a change can more properly be classified as a mixture of Class A and Class B. Thirdly, it puts the emphasis on the costs arising from a delay due to a change, which is normally the most significant economic effect, and the one most susceptible to mitigation. The sort of action that a contractor is expected to take to meet this obligation is the immediate cessation of work which he should be aware will be the subject of change, or the restructuring of a test programme to match deliveries.

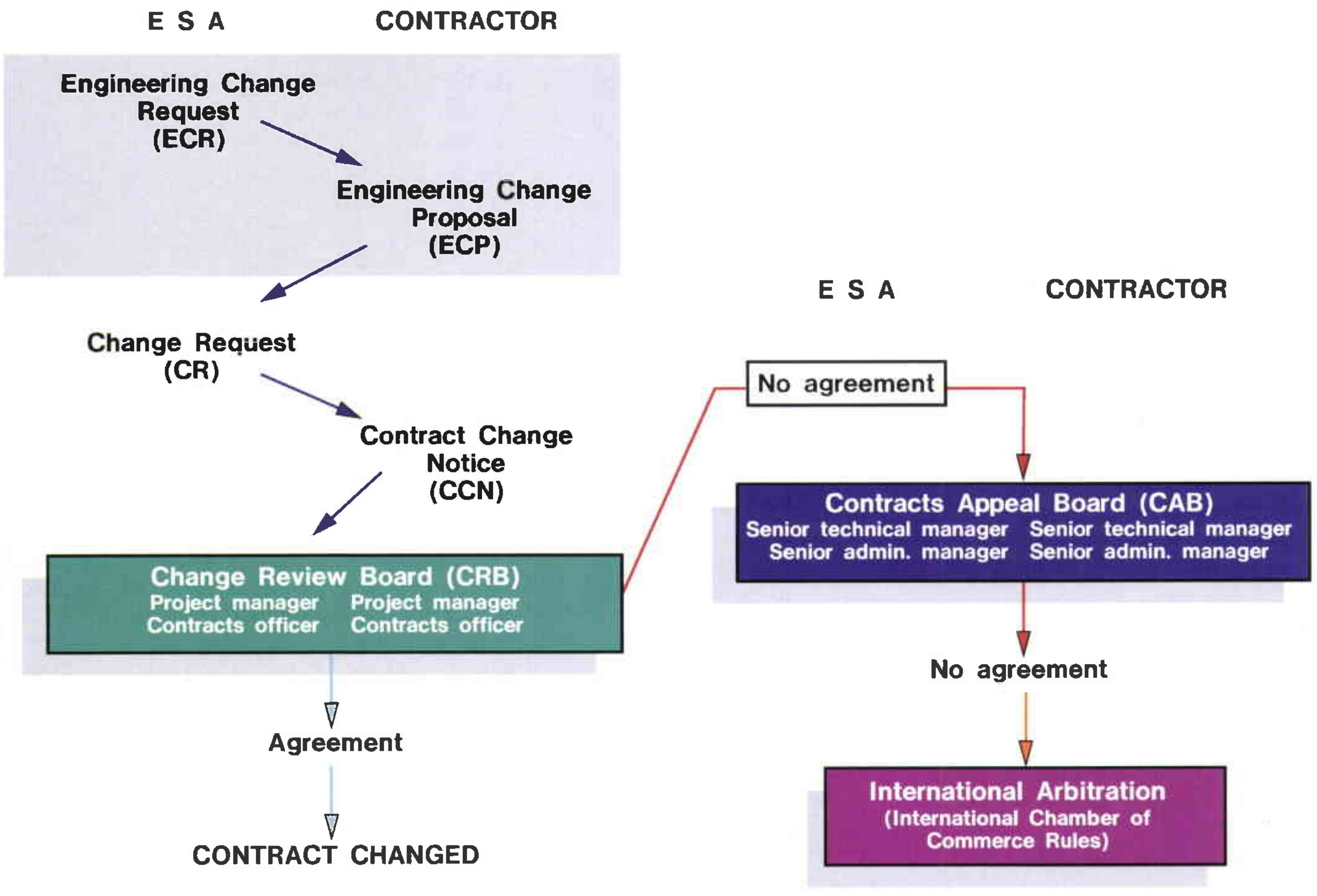
Procedures

The procedures that are used by the Agency to cope with the introduction and management of changes are complex, detailed, and an integral part of overall project management. The main formal provisions are included in the contract and subsidiary procedural aspects are put into the Management Requirements document.

> Change is not made without inconvenience, even from worse to better.
>
> *Richard Hooker (1554?-1600)*

In effect, as with all procurements, the process begins with a request for an offer and the response. In other words, the customer asks the contractor to make an offer to carry out the change (a change request). Usually the customer will say that a change is needed; sometimes, especially with the 'nice to have' changes, he will want to know the costs before considering the change in detail. Alternatively, the contractor may decide on his own initiative to submit a proposal for a change — effectively an unsolicited offer. The reasons for this can vary from an attractive improvement he has identified which might interest the customer, to a change he has to introduce in any case and for which he hopes to recoup some costs.

Care and discipline have to be exercised to avoid the contractor understanding any question or idea of the customer as a formal request requiring a formal answer. If, for example, a project engineer at a progress meeting asks a question which seems to require an investigation involving costs, the contractor must have this confirmed in writing by the customer's Project Manager who alone can authorise such activity, in accordance with the procedures of the management requirements. A further disin- centive to excessive and wasted effort is a provision in some contracts that costs of change preparation will only be allowable if reasonable and properly authorised.



The ESA contract change procedure

In response to the change request (CR), the contractor submits a contract change notice (CCN), which is sometimes, and confusingly, referred to at this stage of the procedure as a contract change proposal (CCP). (In some cases, he will first submit an engineering change proposal (ECP) which deals only with the technical aspects and not the financial or schedule ones. This must be seen as an intermediate step which is useful when there are many potential changes that should be scrutinised for feasibility before management consideration, but does not modify the logic of the procedure.)

The CCN has to be submitted on a specified form. In simple cases, a single form suffices. This form requires a brief account of all the consequences, including the proper contract reference, the proposed classification, a brief technical description, the costs, the schedule effects, and a summary of all other elements affected, such as work package descriptions, deliveries, and test programmes. If the form does not have sufficient room for the information, supplementary pages are used. For large programmes, the form is treated as a summary coversheet, and detailed costing and technical description sheets will be added to match the detail of the original proposal, in order both to allow a proper assessment of the change and to help maintain proper control of the baseline once the change is agreed. Large change notices on such a programme may well amount to substantial documents in themselves.

The changes are negotiated by a Change Review Board (CRB), which consists of the Project Managers and the Contracts Officers of the two parties, assisted by technical experts as required. If a sub-contractor change is being discussed, the sub-contractor may also attend. The CRB meets at regular intervals. At the early stages of a programme, a monthly meeting is normally found to be necessary, though in later stages the frequency may decrease. There is a danger that too many non-settled changes accumulate while the momentum of the work continues. This can lead to uncertainty regarding both costs and technical status and has to be avoided.

If agreement is reached, the CCN, having already been signed by the contractor's Project Manager and Contracts Officer before submission, will be signed by the customer's corresponding representatives, together with an indication of the agreed classification and the costs.

Once signed, the CCN constitutes a fully binding contractual agreement — in legal terms, a rider to the contract. As such, the representatives of the Agency have to ensure that they have, prior to signature, all necessary approvals, including financial ones. This procedure is the only one, as regards the Agency, where, on the one hand, two signatures are required to make a commitment and, on the other hand, where the commitment can be made by the persons directly responsible for the management of the contract. This delegation is, and must be, explicitly made in the contract.

If the parties fail to reach agreement, it is usual to postpone the discussion until the next meeting: further evidence and time for reflection often aid the agreement process. If they again fail to settle the matter, it can be submitted to a Change Appeal Board (CAB), consisting of 'two high-level representatives (from the technical and administrative sides) of the Agency and the Contractor'. It should be said that while many thousands of CCNs have arisen under Agency contracts, only a handful of CABs have had to be called.

The contract also provides that if the CAB cannot reach agreement, the issue is submitted to arbitration under the general provisions of the contract. In practice, a dispute has never reached such a state, and this procedure has never had to be invoked.

Benefits of the system

There can be little doubt, after many years of experience, that a system such as the Agency's Change Procedure is an essential tool in managing dynamic and sophisticated programmes, which works together with the related procedures of configuration and project control. Time consuming as it is, it has contributed significantly to the technical success of the programmes, and to the fact that, at least relative to other programmes of similar complexity, the cost overruns and schedule delays have been kept within manageable proportions.

It has, moreover, proved an invaluable mechanism for the settlement of contractual disputes not specifically related to changes to the contractual baseline, without resort to the arbitration procedure, and it is a mechanism which should be of wider interest.

In the commercial world, outside the space sector, it has been widely recognised for a long time that the courts of law are often an unsuitable forum for the settlement of commercial disagreements of great complexity, especially when difficult technical problems lie at their heart. Court proceedings are costly, formal, slow and public. This was a major stimulus for the growth in the use of arbitration as a means of dealing with such problems. Arbitration proceedings are intended to work with simplified procedures and less formal rules, they can be kept confidential and the parties can choose arbitrators with a specialised knowledge. For many years, this was successful. Recently, however, arbitration itself has taken on some of the heaviness of court proceedings, and while suitable for some cases, it no longer satisfies all parts of the business community. Increasingly, new, simplified and more informal procedures are sought, under the general heading of Alternative Dispute Resolution (ADR). To a considerable extent, the new procedures that are being used bear a strong resemblance to the Contract Review Board and its procedures, which have been used for more than 20 years. While different sectors have to use different approaches to take account of their particular circumstances, there is much in common, and ESA has in this a fund of experience that should be of relevance and applicability beyond the world of space research and technology.

Comet P/Shoemaker-Levy 9 on Collision Course with Jupiter

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A rare cosmic event will occur in July this year. Over a period of seven days, starting on 16 July, the fragmented comet P/Shoemaker-Levy 9 (1993e) will collide with the planet Jupiter.

Introduction

Comet P/Shoemaker-Levy 9 was discovered on 18 March 1993 by astronomers Gene and Carolyn Shoemaker and David Levy. Subsequent observations and orbital calculations have shown that the comet is in orbit around Jupiter and that it was captured into a two-year elongated orbit by the giant planet's gravitational field in July 1992.(Luu & Jewitt, IAU Circ., 1993; Chodas et al., IAU Circ., 1994).

During its initial close encounter with Jupiter, the comet was broken into many fragments by tidal forces and placed on a collision trajectory for its next encounter with the planet. Each fragment of the comet will speed into Jupiter's atmosphere at 60 km/s, marking the beginning of an exceptional astronomical phenomenon.

Astronomers around the World, using both ground-based and space-based observing facilities, will be looking at or 'listening to' Jupiter at that time. ESA will be using its IUE and Ulysses spacecraft and the Hubble Space Telescope to observe this unique event.

The comet and its impact

Comet P/Shoemaker-Levy 9 (1993e), referred to as 'SL9' hereafter, is the ninth short-period comet to be discovered by Gene and Carolyn Shoemaker and David Levy. Observations conducted since its discovery have allowed its jovian orbit to be determined, and backward orbital calculations have indicated that the comet was captured by Jupiter's gravitational field and passed close to the planet (within about 1.4 jovian radii) on 8 July 1992. Almost certainly the tidal forces experienced by the comet during this encounter broke it into the numerous fragments that we currently see (Fig. 1).

Presently, the comet appears to be in at least 19 pieces, the exact nature of which remains uncertain. Each fragment is surrounded by trails of dust and pebbles, moving around Jupiter in an orbit that will result in another close approach in July this year. This time, however, trajectory calculations indicate a minimum miss distance less than the jovian radius, which means that the comet will collide with the planet!

During the comet's two-year orbit around Jupiter, the various fragments have become separated due to non-gravitational forces. As a result, they will impact on the jovian surface over a seven-day period at the time of the collision.

Unfortunately for the Earth-based observatories, the comet's trajectory is such that the collisions will occur on the night side of Jupiter, near the morning limb, out of direct view from the Earth. Thanks, however, to Jupiter's rapid rotation (it makes one full rotation in less than 10 h), the impact sites will become visible from Earth between 20 min and 2 h after the impacts have taken place. This will allow Earth-based astronomers to observe the impact points two hours at most after impact has occurred.

Two NASA satellites should be in a good position to observe the impact directly: the Jupiter-bound Galileo spacecraft from a relatively close vantage point (Galileo will reach Jupiter in December 1995), and Voyager, which will be very far from the action (it is now well beyond Neptune) but will have a direct view of it, albeit with low spatial resolution.

ESA's Ulysses spacecraft, which is heading towards the south pole of the Sun, will be in an ideal position to 'listen to' the radio signals emitted by Jupiter and to search for those associated with the impacts.

The uniqueness of the SL9 event results from the fact that it is the first time that such a collision has been predicted so far in advance. It is therefore no surprise that most observatories are intending to track the event. It is now certain (probability greater than 99.9%) that the collision will occur. Estimation of its timing, which currently involves an uncertainty of 40 min, will be continuously refined until a few days before impact takes place.

The event is also interesting from an observational point of view because not just one, but several collisions will take place in quick succession. This will allow scientists to observe and process the data from one event and then adjust their observing programme, where possible, ready for the next one.

This once-in-a-lifetime event is eagerly awaited by the scientific community because it will enable them to learn more about comets and cometary physics, and about the physics of a celestial body's impact with a planetary atmosphere and its short- and long-term consequences for the planet. How does a planet react to such a strong impact? How does it affect the dynamics of its atmosphere and its energy budget? How long will the perturbations last? These are just some of the questions to which SL9's collision with Jupiter should provide answers.

All that we presently know about such events has been gleaned from impacts that have taken place in the past. Having the opportunity to observe an impact in real-time is therefore of paramount importance, especially as impacts of this magnitude are rare.

We are, of course, very fortunate that such an impact is not taking place on Earth, where it would have devastating consequences. The energy involved in the SL9 impact is estimated to be about 1 000 000 times that which was involved in the Tunguska event in Siberia in 1908, which devastated an area of more than 1000 sq km.

Some predicted impact effects

One of the key parameters involved in the prediction of the effects of SL9's impact with Jupiter's atmosphere is the size of the solid objects involved. We only have estimates of the sizes of the fragments, derived from an analysis of a series of images taken by the Hubble Space Telescope, the last of which was acquired in late January 1994 with the corrected optics (Fig. 1).

The solid fragments, or 'nuclei', cannot be seen directly because they are lost in the glare of the surrounding dust cloud. Sophisticated data-processing and several assumptions about the composition and distribution of the dust-cloud material are necessary to estimate the size of each nucleus. One cannot completely rule out the possibility that the 'condensations' in the fragment train are due only to dust and boulder swarms. If that were the case, the impacts would certainly not be as spectacular, but they would still produce observable effects.

If it is assumed that there is indeed a nucleus at the centre of each of the observed 'condensations', their inferred sizes would range from a few hundred metres, to 2–4 km across for the largest ones (Weaver et al., Science, 1994). To estimate the impact consequences, it is then reasonable to consider a 1 km-sized nucleus. Assuming a cometary density of 0.3 g/cm^3 (in the estimated density range for comet Halley; for comparison, water ice has a density of 1 g/cm^3), this 1 km-sized body would have a mass of 10^{11} kg. If it were travelling at 60 km/s, its kinetic energy would be 10^{20} Joules!

As it enters Jupiter's atmosphere, the body will create a shock wave, which will heat the surrounding gas to about 20 000 K, producing a luminous flash, which will unfortunately not be observable from the Earth, but may be seen by reflection on one of Jupiter's moons. At high altitude (around the 0.1 mbar level), it will start losing mass and energy through ablation (i.e. vaporisation of its external layers due to the high temperatures of the shocked gas surrounding the body). Deeper in Jupiter's atmosphere (at a level of a few tens of mbars), the body will be further fragmented by differential dynamic pressure as its tensile strength is exceeded. Models show that a high-velocity impacting object stops when it has intercepted a mass of atmosphere comparable to its own mass. Because the object is not confined at its 'sides', it will spread laterally, greatly increasing its cross-section. It will therefore slow suddenly, the most recent models (McLow & Zahnle, submitted to Nature, 1994) showing that it will lose more than 90% of its kinetic energy within a single scale height, at a level corresponding to 1–10 bar. This means that it will in fact explode. The kinetic energy will thereby be converted into heat, creating a fireball with a temperature of several thousands of degrees Kelvin.

This fireball – a bubble of vaporised cometary materials and jovian gas at high temperature – will then start rising at hypersonic velocities, while simultaneously cooling and undergoing

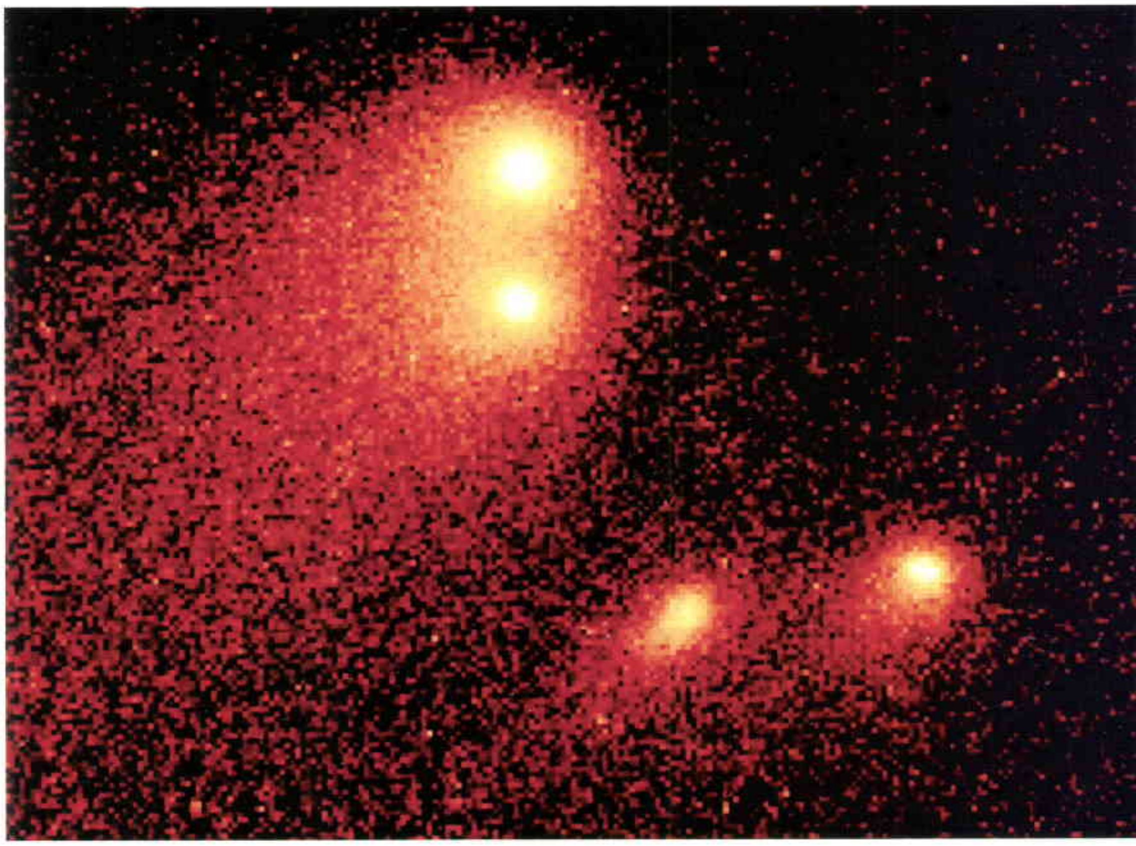


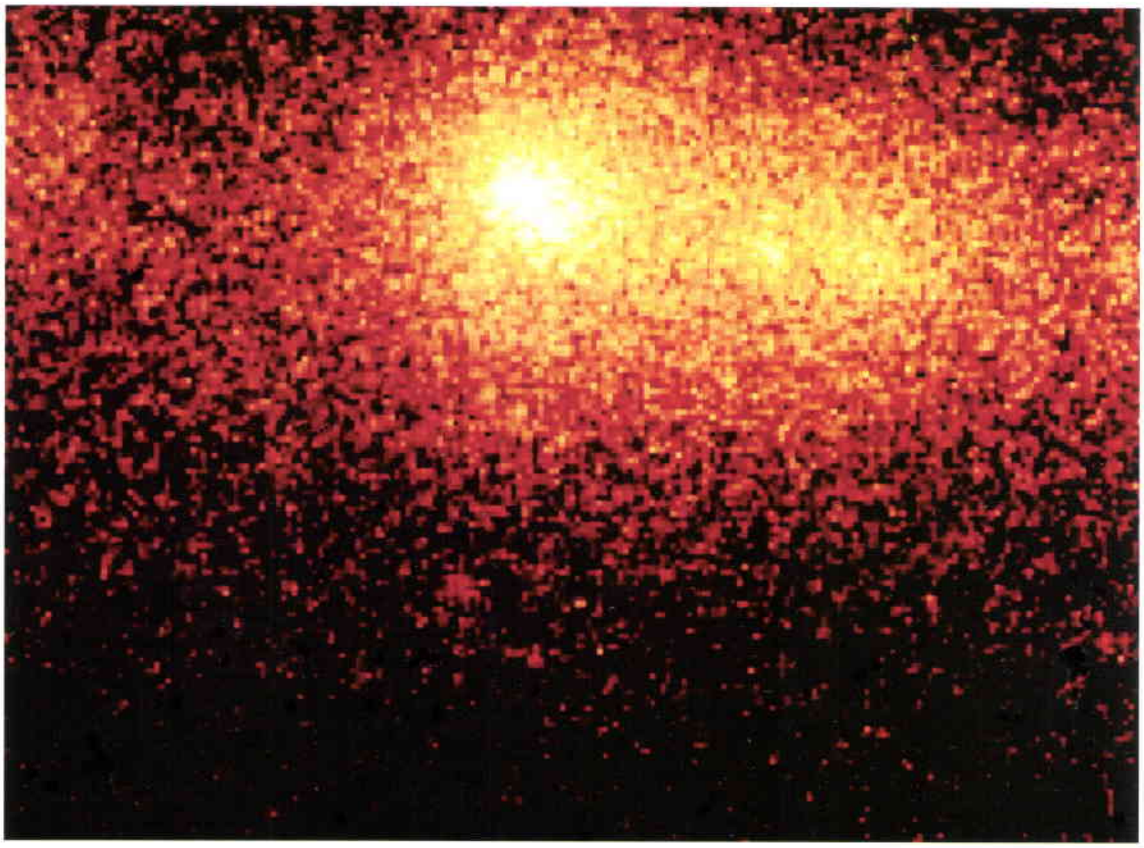
Figure 1. Hubble Space Telescope's view of Comet P/Shoemaker-Levy 9 on a collision course with Jupiter. The images above and bottom left were taken on 24 and 27 January 1994, after the HST repair mission. The image bottom right (facing page) was taken before the HST servicing mission (Photo courtesy of H.A. Weaver & T.E. Smith, NASA/STScI)

an adiabatic expansion. If, for instance, the initial bubble formed at around 1 bar has a diameter of 50 km and a temperature of 3000 K, we can expect it to reach a size of at least 350 km and a temperature of 600 K at the 1 mbar level (Drossart, l 'Astronomie, April 1994). The composition of the bubble will depend on the depth reached by the cometary fragment, but it will certainly contain cometary material, high-temperature-induced chemical compounds, and jovian gas from below the cloud-tops. It will probably also carry condensable volatiles, which may form unusual clouds. It will then start diluting, on time scales varying from a few minutes to a few hours or days, but thermal stratospheric modifications could last several weeks or even months if the amount of dust and condensed materials is sufficiently large.

The fireball will probably produce another luminous flash, the brightness of which is difficult to estimate, but it should at least double Jupiter's luminosity for a few seconds (Drossart, 1994). Again, it will not be observable from the Earth, but it may well be seen reflected on a Galilean satellite. It is also possible that explosions of smaller fragments, if they occur above Jupiter's clouds, might be detectable with large telescopes. The plume created by the rising fireball could also be observable at the limb of the planet, if SL9's impact is sufficiently close to it and if the plume reaches a sufficient height (the maximum predicted height is about 3000 km).

For the conditions considered above, the energy involved is equivalent to a 10 million Megaton explosion. For comparison, in the Tunguska event, when an asteroid of some 30 m radius exploded a few kilometres above the Earth's surface, the energy involved was 'only' equivalent to that of a 10 Megaton explosion. It still destroyed everything within a 30 km radius! Unprecedented energies will therefore be involved in the Jupiter/Shoemaker-Levy event.

It is also useful to compare it to the event that may have occurred on Earth 68 million years ago, leading to the extinction of numerous living species, including the dinosaurs, and



which is estimated to have released about $2x10^{23}$ Joules of energy. It must also be remembered that some 20 impacts will take place just a few hours apart, so that the medium- to long-term effects will be cumulative.

The planned observations

Observations of the comet

Observations of SL9 as it orbits Jupiter will provide valuable new data on the physics of comets. Analysis of the disruption of the parent body during its close approach to Jupiter has already placed interesting constraints on its tensile strength (which maintains the body's cohesion), indicating that it was a poorly cemented comet (tensile strength between 200 and 1500 dyne/cm^2). This tends to support the idea that comets are aggregates of smaller bodies held together by frozen material.

Observation of the behaviour of the individual fragments as they approach Jupiter, as well as their behaviour in the planet's magnetosphere, will furnish more information on their nature and cohesion. The vaporisation of the nuclei and the spreading of the vaporised material within and possibly outside Jupiter's atmosphere should also allow us to detect some cometary materials that are usually hidden within the nucleus.

Cometary interaction with the jovian magnetosphere

Observable magnetospheric effects could result either from the passage of the comet through the jovian magnetosphere, or from the 'fireball' and the ejecta resulting from the impact. The comet's fragments will pass through the night-side of the magnetosphere, releasing large amounts of gas and dust. The ionisation of the cometary coma material caused by the two main processes of solar ultraviolet radiation and electron/neutral collision, may produce observable effects. Mass loading of Jupiter's magnetosphere may produce effects observable in either the ultraviolet, visible, infrared or radio ranges.

Atmospheric effects

The rising bubble will carry with it jovian gases that are usually below the levels accessible to observations. The impacts may provide the opportunity to detect these compounds, as well as some possible compounds resulting from the high-temperature-induced chemistry taking place. The study of the dilution of the plume and the tracking of the newly-formed clouds could provide information on the Jovian winds. If the particles composing these clouds are small enough, they may prove very persistent (lasting several weeks or perhaps even months). By changing the amount of sunlight that is absorbed, they could affect the planet's thermal budget on a global scale.

Some more exotic and controversial effects are also suggested, such as the creation of a new storm feature like the Great Red Spot or, more modestly, like other smaller jovian vortices.

The interior of Jupiter

It has been predicted that the energy released by the impacts in the jovian atmosphere will excite seismic waves, which will then propagate within the planet as global oscillations. It has been calculated (Lognonné et al., submitted to Icarus, 1994) that these waves could have an observable thermal signature in the atmosphere, which would allow us to probe the planet's interior, as seismic waves on Earth allow us to probe the interior of our own planet. The observations planned to address this aspect could provide unique new data on the giant planet's interior.

Physics of impacts

The observations of what happens with Jupiter's atmosphere – the way the clouds dilute, the thermal-transient modifications or global climatic changes – will provide valuable information about how a planetary atmosphere reacts to a strong impact. This will help us to understand what probably happened on Earth 68 million years ago. Scientists postulate that at at that time a massive amount of dust was ejected into the Earth's atmosphere, creating clouds that blocked out the sunlight and produced a general cooling of our planet.

Could the Earth suffer another such impact in the near future? It is generally believed that impacts by objects 1 km in size or larger only occur about once every one million years, and impacts by objects 10 km in size (probable size of the object responsible for the dinosaurs' extinction) or larger occur just once every 100 million years, on average.

ESA's coverage of the event

The Hubble Space Telescope has already been following comet Shoemaker-Levy 9's progress quite intensively. It even provided excellent pictures of the comet prior to the HST refurbishment mission, taking its first image of SL9 on 1 July 1993. The comet was also one of the HST's earliest solar-system targets after its repair (Fig. 1).

The HST images are being used to estimate the size of the core of each fragment embedded in its own coma. HST will also be used intensively to follow the comet's evolution as it approaches Jupiter, and should provide a wealth of data on the characteristics of each nucleus and their evolution during the final phases of the approach to Jupiter. HST should be able to provide observations of the comet's predicted further fragmentation, if that should indeed happen.

The SL9 event will also be a major target for IUE, which will be fully devoted to observing it during the critical period. IUE's observations will be directed towards the magnetospheric disturbances caused by the comet's passage through the jovian magnetosphere, and in particular to study of the variations in the comet's brightness as it passes through critical regions of the magnetosphere (i.e. study of the perturbation of the Io torus). IUE will also observe the atmospheric effects, particularly $H3^+$ line emissions in the auroral regions. IUE will establish pre-impact reference measurements of Jupiter's atmosphere, and will be a good platform from which to study the long-term global modifications of the impact region.

Although this event will not be a special target for Ulysses, this spacecraft's radio instrument is very suitable for observing impact effects. Ulysses is equipped with the most sensitive radio receiver ever flown covering the sub-1 MHz range. It is already recording the radio emissions of Jupiter, the most intense radio source in the Solar System, on a regular basis. The normal characteristics of the jovian emissions are very well documented and even small changes in these radio emissions resulting from the SL9 impact should be detectable. In July 1994, Ulysses will be about 5.3 AU from Jupiter, 2.5 AU below the ecliptic plane at 31°S Jovian latitude. It has been estimated that Ulysses will have a direct view of the ejecta plumes if they achieve heights of a few thousands of kilometres.

Finally, Ulysses' observations, by providing an accurate timing of the impacts, may be used to help the Galileo spacecraft to play back only the data acquired during the key periods around the impacts. Ulysses would then be the second ESA spacecraft, after Hipparcos (see ESA Bulletin No. 77, p. 143), to help Galileo to make the best use of its reduced data-downlink capability.

Regular information about the event

Thanks to a group of US scientists, regular information is being posted on a computer-accessible Bulletin Board, on an 'ftp server'. This is accessible via anonymous ftp:

pdssbn.astro.umd.edu

Satellite Servicing in GEO by Robotic Service Vehicle

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The geostationary orbit has a high commercial and strategic value, as do the satellite systems stationed there, for telecommunication, TV broadcasting, and weather forecasting. To safeguard the huge capital investments made as well as the usability of the orbit itself, it will soon be necessary to have adequate means of remote intervention for the servicing and repair of satellites. Since the physical, technical and economic constraints of such a mission make servicing by astronauts impossible, robotic service vehicles will have to do the work. ESA is now studying a robot-based Geostationary Service Vehicle, which would be similar to deep-sea and nuclear servicing robots.

Introduction

ESA is presently investigating the characteristics and potential of a Geostationary Service Vehicle (GSV) which could provide in-orbit inspection of geostationary satellites and intervention when necessary. So far, three types of services or 'interventions' have been identified:

— inspection of a satellite that has a severe malfunction and where a close-up view of the satellite could help to clarify the problem. This diagnostic data can be a basis for recovery actions from ground.

— mechanical assistance to a satellite in trouble, for example, with a non-deployed solar array or antenna, to restore operation.

— end-of-life re-orbiting of uncontrolled satellites into a graveyard orbit, an operation that will become more and more important in order to maintain the commercial exploitation potential of the geostationary orbit (GEO).

As was demonstrated recently with the successful repair of the Hubble Space Telescope, very good servicing results can be obtained if the subject satellite is built with the intention of being serviced later. However, because of the existing fleet of conventional satellites, a GSV must also be able to perform meaningful intervention tasks on commercial spacecraft that are not designed for in-orbit servicing.

GSV system overview

Concept feasibility

The baseline thinking is that a GSV should 'pay for itself', at least once it is in orbit. However, its capabilities and services must be sufficiently comprehensive to be attractive to satellite operators. This means that in order to be commercially viable both the development and operational costs must be kept within very tight bounds. Many of the enabling technologies for a GSV exist but still need to be adapted for use in space and to be proven in flight. A number of technological challenges also still need to be resolved, including the rendezvous, circumnavigation and approach to a non-cooperative spacecraft followed by its robotic capture and berthing.

Typical target spacecraft are spinning or three-axis stabilised telecommunication satellites positioned (or drifting) along the GEO arc. Examples of satellites with real problems for which a GSV could have been very useful are given in Table 1.

Table 1. Examples of satellites for which GSV services could have been very useful

Satellite	Problem	GSV action
Olympus	Satellite in unknown configuration and not controllable	Close-up inspection
Anik-E2	Only partial deployment of C-band reflector	Close-up inspection/mechanical intervention
TV Sat1	Non-deployment of solar panel	Mechanical intervention
Marecs-A	Solar array drive stuck	Mechanical intervention

Commercial potential

From an economic point of view, mechanical interventions are the type of GSV intervention with the greatest revenue potential. However, since spacecraft failures are unpredictable, it is difficult to base a commercial plan on the intervention missions alone. Re-orbiting missions, on the other hand, could provide a more steady income. If it was planned to move the spacecraft when depleted from its operational slot into a graveyard orbit using a GSV, a telecom satellite could continue operating until propellant depletion (roughly six months of extra exploitation). Additional revenues would be generated, and a reasonable share of this extra profit could be claimed by the GSV operator. Another potential GSV service is to re-orbit 'dead' satellites which could otherwise be a collision hazard to other satellites. For inspection tasks, revenues are expected to be low, although they could become considerable if the inspection leads to the recovery of the satellite.

It is estimated that a GSV could become economically viable if the design costs of the GSV can be kept in the range of two to three times the launch cost. This could be achieved by maturing the required technology via separate technology programmes to reduce the design risk. Here, ESA could play a key role in mobilising the available European expertise to provide a technical and commercial basis for a GSV.

Basic GSV configuration

The proposed configuration for a GSV (Fig. 1), synthesised during ESA's recent industrial study, is a satellite that would use the maximum upload capability of a dedicated Ariane-4

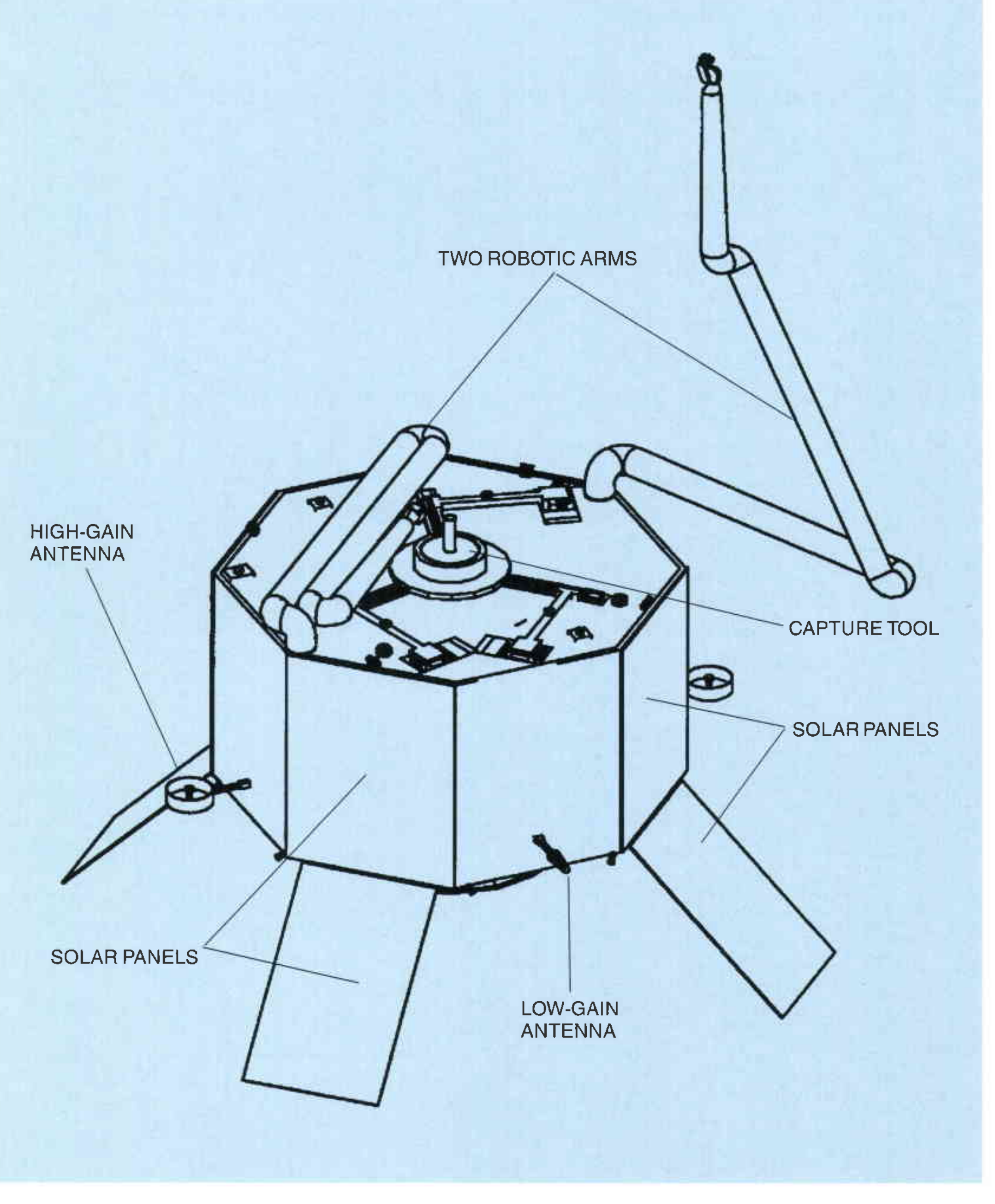


Fig. 1 A proposed GSV configuration

launch, thus a 4.2 ton spacecraft at launch. With a dry mass of approximately 1.2 tons, roughly 3 tons remain for fuel, which means a total delta-v of 3687 m/s (for a bi-propellant with a specific impulse of 300 seconds). The hexagonal configuration proposed uses the full fairing diameter of the launcher, and the height of the spacecraft is sized in proportion to the three tons of fuel. Solar panels would unfold from the outer surface of the hexagon, and the rendezvous sensors, the robot arm and its tools would be located on the top surface of the GSV. The bottom surface would be dedicated to the launcher interface ring and the GSV propulsion system.

GSV operation

It is proposed to operate the GSV through a dedicated, portable ground station. The S-band would be used for communication and the dedicated station would be co-located with the customer's main ground station. A key driver in the design of the antenna arrangement on board the GSV, will be the continuity of the communication link during all proximity operations. Low gain S-band antennas with wide lobes are proposed, especially for approach operations when the target spacecraft may obstruct the GSV antenna visibility.

GSV orbital manoeuvring Fuel consumption and GSV lifetime

The primary requirement for a commercial GSV is its capability to reach as many target spacecraft as possible during its operational life. Once launched and positioned at its 'home' location, the GSV's ability to reach a troubled satellite is directly related to the amount of fuel the GSV operator is prepared to expend. The main fuel consumption parameters are the speed at which the GSV moves along the orbit, the phasing and inclination differences for which correction is needed, and the number of re-orbiting operations. Based on a scenario consisting of 25 re-orbiting missions, 10 inspections, 3 mechanical interventions, and 2 dead satellite removals, the proposed GSV configuration would have an operational lifetime of five years.

Rendezvous

The basic phases of a rendezvous are illustrated in Figure 2. After a call for assistance, the GSV begins the transfer to the troubled satellite by moving from its home position toward the target spacecraft, with a drift orbit a few hundred kilometres below the geostationary orbit. When it arrives within 10 km of the target spacecraft, the GSV is transferred back to the geostationary orbit (points S1 to S2). The GSV then approaches the target carefully (S2 to S4) and circumflies it to obtain status information (S4 to S5). The GSV then makes its final approach in preparation for capturing the target.

The rendezvous is performed with the help of ground tracking, radar tracking or angular measurement with a star-tracker, and eventually TV-camera tracking.

Final approach

When the GSV is within 50 metres of the target spacecraft, it begins its final approach and, using its robotic arm, captures the target (S6 to S7). The target is docked to the GSV itself and later they are 'rigidised' so that both spacecraft form one rigid compound. The robotic servicing intervention can then begin.

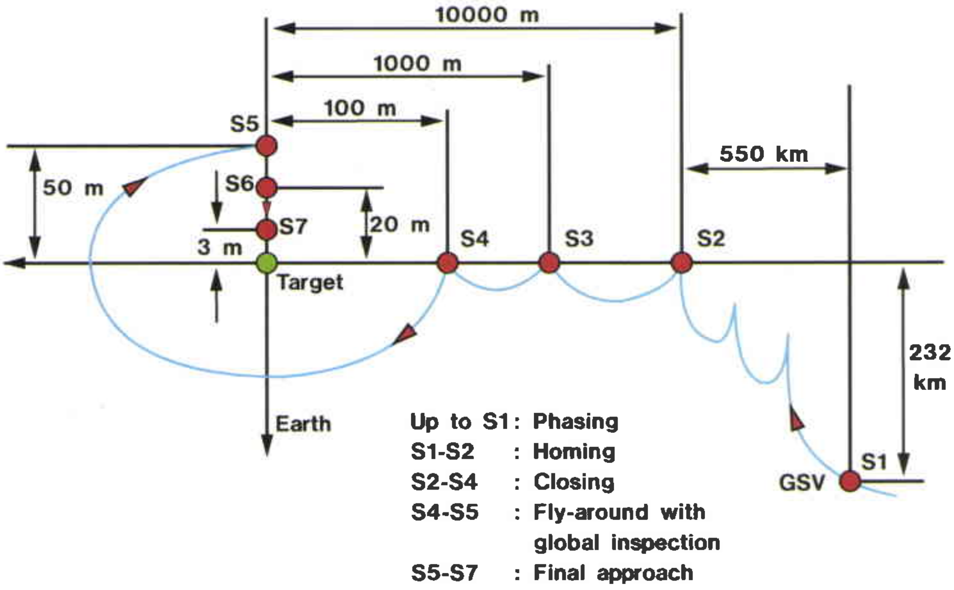


Fig. 2 The basic phases of the GSV's rendezvous with a target satellite

The GSV approaches a controlled satellite stabilised in its nominal Earth-pointing position from behind, along the Earth direction. In the case of an uncontrolled satellite, the target is expected to spin slowly around its main axis of inertia; for most satellites, this axis is perpendicular to the solar-array plane. The GSV then makes its final approach along the spin axis of the target satellite. At the very last moment, the GSV (or possibly its robotic capture tool) will be spun up to synchronise with the target.

For both controlled and uncontrolled satellites, it seems realistic to assume that the GSV can maintain a relative position and attitude accuracy of ±5 cm and ±2 degrees with respect to the target. This does not apply for the roll axis of a spin-stabilised target since the roll-motion synchronisation will be done by a rotating capture tool. Possible nutations around the spin axis could be compensated by the robot holding the capture tool. After capture, the GSV will slow down the rotation of the target until both spacecraft attain the same rate. The 'rigidisation' between the two can then take place: the single point attachment between the two spacecraft is replaced by a more stable, multi-point fixation structure to strengthen and stiffen the bond between the GSV and the target satellite and to free the robot arm for other uses.

GSV robotic system

Why robots?

A GSV will be uncrewed, and the broad variety of tasks to be done, in combination with the unpredictable nature of the servicing tasks, calls for a flexible and multi-functional flight segment. Robotic systems are the only means available today to fulfil these needs. In addition, a robot can be controlled in a telemanipulation mode by a remote ground operator. In the case of a GEO-stationed spacecraft, the direct telecommunication link enables a good bandwidth. Because of the short time delay between ground control and the flight segment, the GSV robot can be operated in a telemanipulation mode of very good quality. This means that the motion of a ground master arm manipulated by a skilled operator, can be 'slaved' by the GSV robot and, in that way, quasi-human repair capabilities can be obtained.

As far as the robotic interaction with a conventional satellite is concerned, two major problems appear: 1) the limited options for capture/berthing and docking, and 2) the accessibility of the repair area for the GSV robotic system.

Robotic capture, berthing and docking

The robot arm must capture the target satellite, berth it to the GSV to align the axes of the two spacecraft, and dock it firmly. On a satellite that is fully covered with thermal insulation, there are few possibilities for proper mechanical interfacing with the GSV. However, two 'hard points' that are available on virtually all GEO satellites are the nozzle of the apogee boost motor and the launcher interface ring. The nozzle may not provide sufficient stiffness for use as the final docking interface but could serve as a first 'hook' for capture and temporary attachment. Rigidisation between the GSV and the launcher interface ring can then be performed. Due to a lack of standardisation in nozzles and interface rings, the capture and rigidisation mechanisms of the GSV must be highly adaptive.

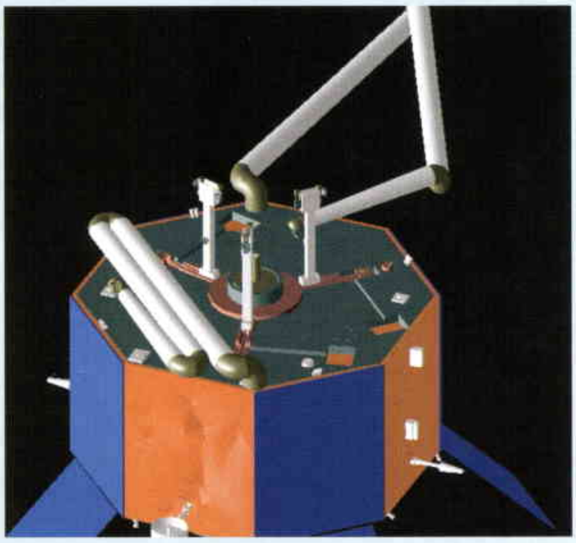
An example of a nominal GSV manoeuvre with a stabilised target is illustrated in Figure 3. The GSV will service the Anik-E2 satellite, whose C-band reflector had only partially deployed. The GSV robot first prepares the spacecraft by erecting the docking/rigidisation structure (Fig. 3a). The GSV then approaches Anik-E2 from behind (Fig. 3b) and captures it by its main engine nozzle (Fig. 3c). The robot will do this using a dedicated capture tool. In the case of a spinning spacecraft, the GSV will be spun up to the same speed along the same axis. The capture tool's 'stinger' is inserted via the nozzle in the combustion chamber and expanded to prevent the target from escaping. Then the capture tool clamps to the outer ring of the nozzle to achieve a greater stiffness. The robot arm berths the spacecraft to the GSV (Fig. 3d) by latching the other end of the capture tool into its fixed position. The robot arm is now released and picks up a gripper from its toolbox (Fig. 3e). The robot then performs the intervention: it reaches for the stuck antenna, releases it and deploys it into its operational position (Fig. 3f).

In the case of an uncontrolled tumbling target (Fig. 4), the capture tool will be spun up in synchronisation with the rotation of the nozzle. The robot arm also compensates for part of the orbital motion by keeping the capture tool aligned with the nozzle. It is expected that the images provided by the rendezvous camera on the main body of the GSV will give sufficiently accurate information so that the robot arm can safely insert the stinger of the capture tool in the combustion chamber. During insertion, the robot will continuously adjust its motion based upon distance and contact force measurements. After latching, the robot arm and the capture tool will gradually eliminate the tumbling motions, and the berthing and docking of the two spacecraft will then follow.

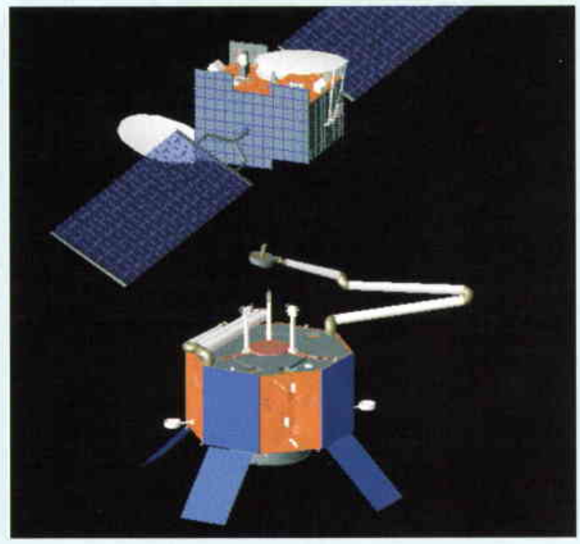
Robotic mechanical intervention

The intervention for servicing can be divided into three sub-phases:

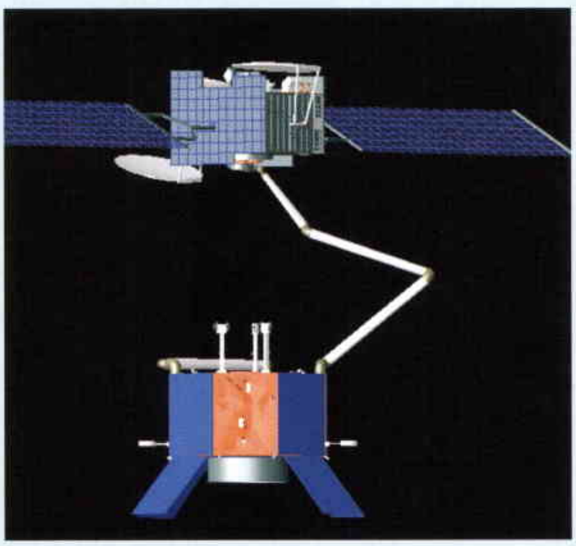
- reaching the repair zone
- close inspection of the repair zone
- intervention using tools, e.g. removing and replacing sections of the thermal blanket, severing restraint cables that prevent deployment of the antenna or solar array, or hinging/removing deployable mechanisms that are stuck.



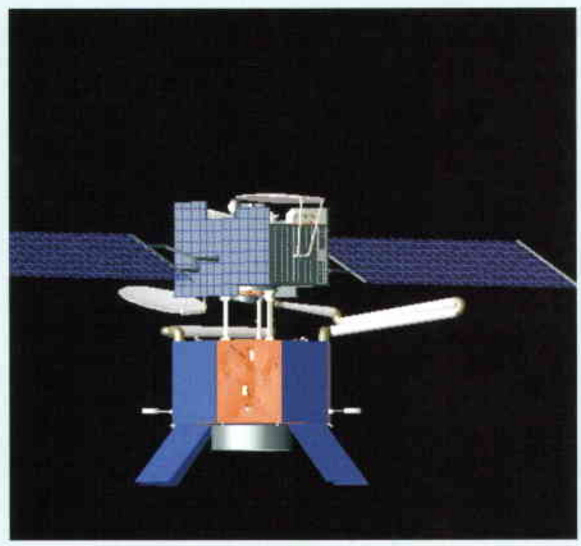
3a. GSV prepares the docking interface by folding out the three satellite supports



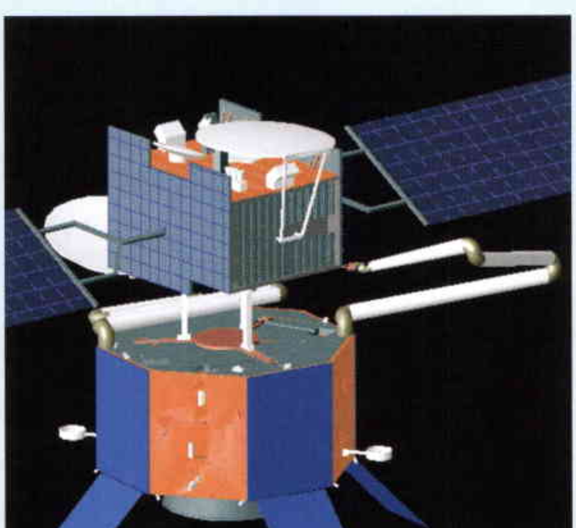
3b. GSV approaches the target satellite and is ready to capture it



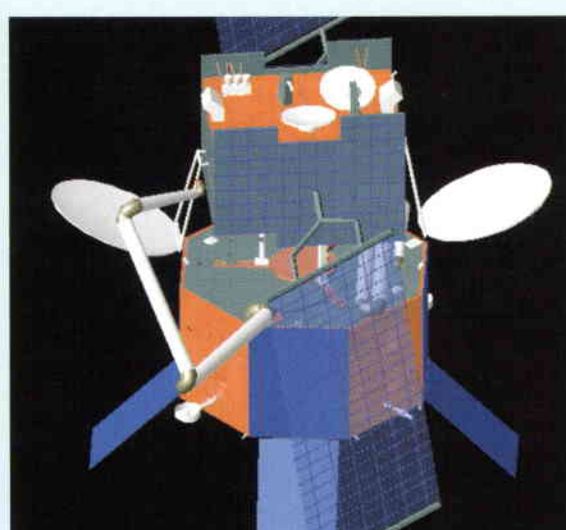
3c. The robot inserts its capture tool into the satellite's apogee motor nozzle



3d. It places the captured satellite on the supports and docks it

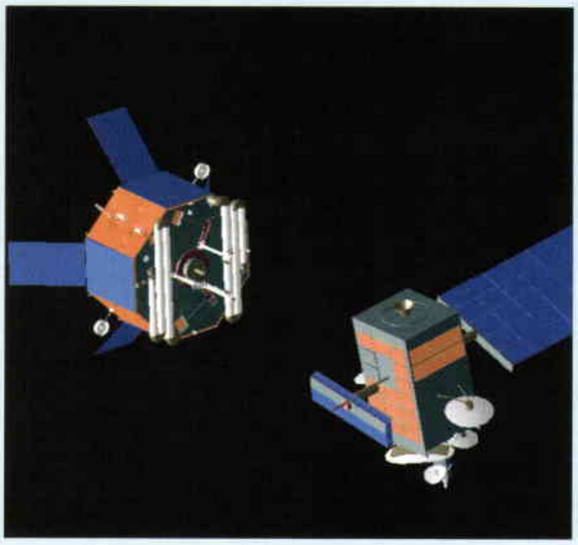


3e. The arm takes the gripper tool from the toolbox and grasps the jammed reflector (white disc on Anik's top face)

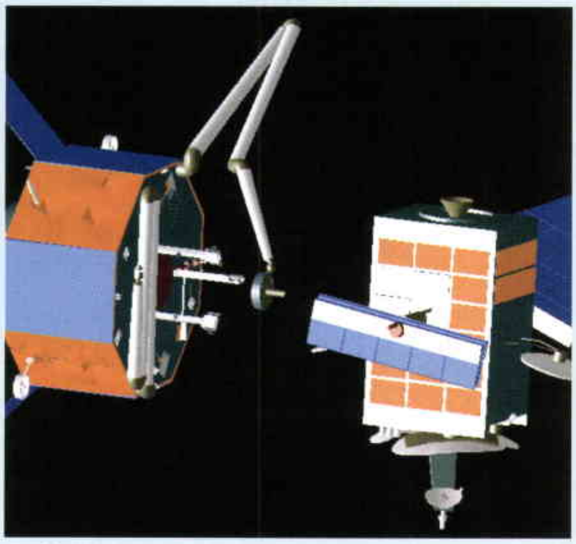


3f. It folds the jammed reflector out into its nominal position. The repaired satellite will then be released.

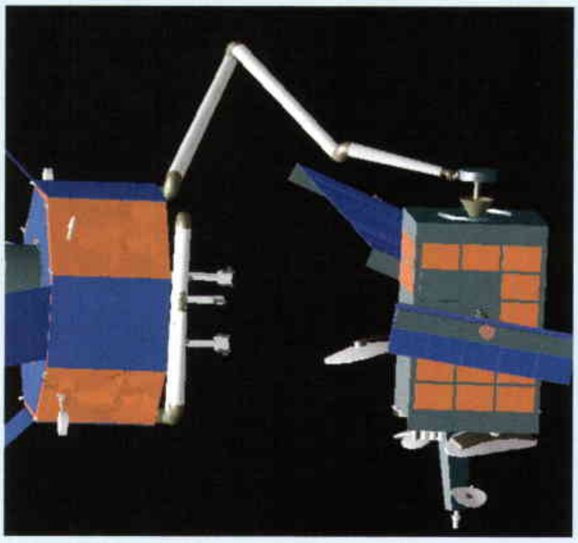
Fig. 3 A nominal GSV manoeuvre with a stabilised target, the Anik-E2 satellite whose C-band reflector only partially deployed



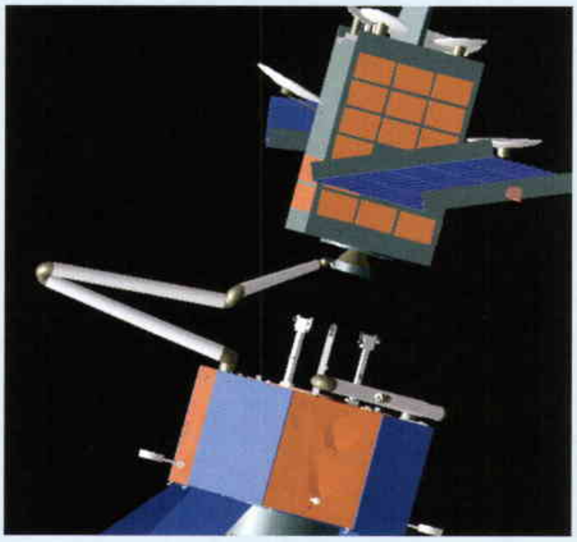
4a. The GSV approaches the target satellite and starts spinning along the same axis



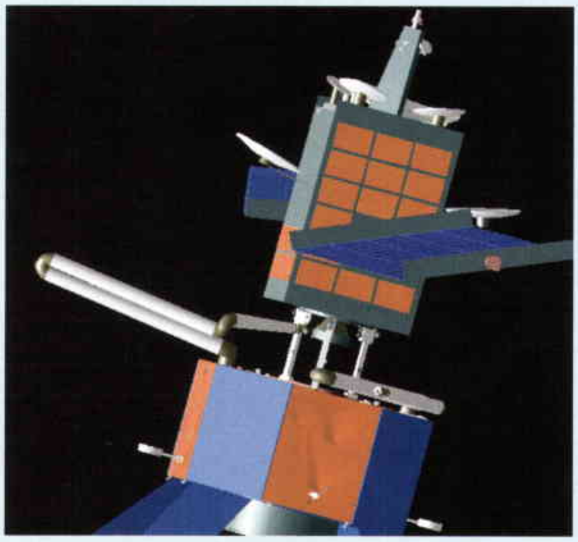
4b. One robot picks up the capture tool and moves toward the satellite (spinning synchronously)



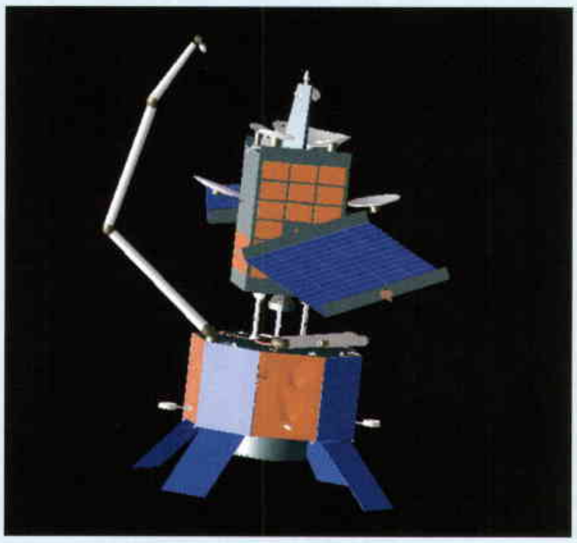
4c. The robot inserts the capture tool's 'stinger' in the nozzle and locks it



4d. The captured satellite is slowly rotated and moved to the docking interface



4e. Finally, the satellite is docked to the GSV



4f. One arm, with a camera on its tip, provides ground control with close-up images of the repair zone

Fig. 4. A GSV manoeuvre with an uncontrolled, tumbling satellite which is spinning about an axis orthogonal to the apogee motor axis

A major disadvantage of the capture and docking concept described, is the distance (roughly 5 metres) between the repair area and the GSV. Indeed, most of the defects are expected to be at the other extreme of the satellite where the payloads and subsystems, such as antenna reflectors, are located. It will require innovative robotic systems that can easily access the servicing area and at the same time provide good local precision, dexterity and stiffness to enable a good repair.

Robotic concepts

An obvious solution is to have one or two large robot arms that operate from the top face of the GSV and which can access the service zone directly. This straightforward solution can adequately solve the accessibility problem but a severe limitation is that these big crane-type robots have limited manipulation capabilities. First, the precision is in the order of centimetres or even decimetres which is often insufficient for repair work. Secondly, the local dexterity, i.e. the freedom of motion available at the robot tip, in this stretched position, is generally quite poor. This necessitates a very specific tool set to compensate for these limitations, implying less universality and thus less possibilities to cope with unforeseen defects.

Another candidate concept is a micro-macro manipulator. This is a cascade configuration of a large manipulator carrying a small, instrumental robot. Technically, this is a very attractive solution since both robots complement each other well. The large one acts like a cherrypicker-crane that carries a small, dextrous robot (often with two arms) to the repair zone to do the precise part of the work. This concept is popular on ground and in LEO, but the equipment tends to be heavy and the concept is therefore less effective in GEO where every kilogram counts. It is also a more expensive solution which jeopardises the potential commercial future of a GSV.

At the research level, new robotic concepts are being developed which could be very useful for later versions of a GSV. For instance, there are already testbeds of a small robot which is able to build a lightweight structure (e.g. a truss) on its own, and over which it can move easily. Such a scaffold could provide a universal structure used to bring a small instrumental robot to where it is needed.

Robotic tool set

In the same way as a human worker needs a comprehensive tool set for repair tasks, a GSV robot cannot perform all the tasks mentioned with one universal end-effector. A number of tools that are required were identified in the industrial study:

— a satellite-capture tool
— a docking/rigidisation tool
— a satellite close-up inspection tool
— a two-finger gripper
— a cable/pin cutter
— a self-reacted lever-force tool.

Some tools, such as inspection cameras, can be permanently mounted on the robot arm. Others must be detachable end-effectors, preferably designed as a modular family to minimise mass and volume.

Control concept

The GSV proximity and robotic operations normally require complex control systems. However, due to the availability of a continuous and direct communication link, the general control concept for a GSV is to have only the bare minimum of control functions implemented on board. For rendezvous, these necessary on-board functions are to ensure attitude and position stability, and back-up procedures to ensure the integrity and health of both the GSV and target satellite, in case ground control is lost. For robotics, the control functions on board are to ensure robot arm motion stability and accuracy, and to perform guidance for time critical motions such as the capture of a target satellite.

Spin-off potential

The similarity between robotic servicing in GEO and deep-sea exploration and exploitation and nuclear-reactor servicing is striking. Remote intervention in hostile environments is expected to become increasingly important in the future, with new applications such as in the clean-up of radioactive or toxic waste, firefighting, demining, the handling of explosives or inflammable material, security and police work, telemedecine, and in many other areas. A technology programme for the development of a GSV could act as a precursor to robotic servicing in the other environments, offering promising potential spin-off benefits to those terrestrial applications.

Acknowledgement

The authors would like to acknowledge DASA in Bremen and Ottobrunn (D) and its subcontractors, SPAR in Toronto (Canada), GMV in Madrid (E) and ESYS in Guildford (UK), which have studied Geostationary Service Vehicle concepts under ESA contract.

ESA's Precise Orbit Determination Facility

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With the ever-increasing sophistication of on-board payload instrumentation, requirements for accurate knowledge of a spacecraft's position and velocity continue to become more and more stringent. Since the early space missions, they have changed by three to five orders of magnitude. Earth-observation missions based on platforms flying in near-Earth orbits have applications that may only be feasible if decimetre or centimetre accuracy can be achieved in one or more of the position components.

This article presents an outline of the ESA-developed Precise Orbit Determination Facility and discusses in detail some of its achievements to date, particularly with respect to the ERS-1 mission and Global Positioning System (GPS) applications.

Introduction

One of the best-known examples of today's high demands on orbit determination is satellite altimetry, for which measurements with centimetre accuracy of the spacecraft's height above the sea have to be combined with knowledge of the radial position component of its orbit.

Several types of tracking system can be used to achieve such levels of accuracy. The classical one is Satellite Laser Ranging (SLR), making measurements of the two-way transit time of a laser pulse between ground station and satellite. More recent developments use measurements of the one-way (pseudo-)range and phase of signals broadcast by the spacecraft of the Global Positioning System (GPS), or one-way Doppler measurements of the radial velocity with respect to a ground station (the DORIS system discussed below). Another promising system, involving two-way ranging and range-rate measurements (PRARE), will fly on the ERS-2 spacecraft in 1995, after testing on a Russian Meteor spacecraft.

A facility for Precise Orbit Determination (POD) has been maintained and developed by ESA since the early 1980s. This facility provides tools both for assessment studies for future missions, and for handling the various relevant tracking types. The emphasis has been on the development of a relatively automated operational approach, with rapid availability of orbit and related products, and this is being well-validated by the results now regularly being achieved for ERS-1 and for the determination of the GPS satellite orbits. More recent applications have been connected with the data being acquired from the Topex/Poseidon spacecraft, which offers in a single mission laser, altimetry, DORIS and on-board GPS data – a perfect test-bed for a POD facility. Ground-support requirements for the navigation problems associated with In-Orbit Infrastructure (IOI), in particular accurate relative orbit determination, have also played a role in the facility's design.

The POD model

The better orbits needed for getting the most out of the on-board instrument data can sometimes only be achieved by making use of the instrument data themselves (or can at least be assisted by their use). Figure 1 illustrates the relationship between the quality of the orbit solutions, the tracking network, the scientific payload, and some of the models that are needed in the orbit-determination process. Examples of physical phenomena for which such models are required include the Earth's gravity field, the height of the ocean above an appropriate reference surface, and corrections to the tracking measurements due to propagation of the signals through the troposphere and ionosphere.

The three major areas involved in determining an orbit are: integration of the equations of motion (and of their sensitivities to the various unknown dynamic parameters – the so-called 'variational equations'); the model of the tracking measurements; and estimation algorithms.

Integration of the equations of motion

As Einstein discovered, time is not a universal coordinate, but depends on the frame of the

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observer. For near-Earth-satellite orbit determination, the frame of choice is a local quasi-inertial frame with its origin at the Earth's centre of mass and with a time coordinate that is the proper time at the Earth's surface. This time coordinate is called Terrestrial Time (TT) and is realised in practice with a set of atomic clocks distributed around the World that provide the International Atomic Time (TAI). Because the speed of light is constant, space coordinates also depend on the choice of frame. The reference frame so constructed is not an inertial frame, but it is more suitable for describing the motion of a near-Earth satellite. When the equations of motion are integrated in this reference frame, only minor corrections to the acceleration are needed.

The more important forces affecting the orbital motion of a satellite are listed in Table 1. Earth's gravity is the most significant for the types of orbit considered here. Recent advances in gravity modelling achieved by NASA Goddard Space Flight Center and by the University of Texas at Austin have led to the so-called 'JGM-2 model'. This is a spherical-harmonic development to degree and order 70, a total of 5038 coefficients. The tidal distortions of the solid and fluid parts of the Earth by the varying gravitational pull of the Moon and Sun are likewise modelled using extensive series expansions involving many numerical coefficients, determined partly on the basis of geophysical and astronomical theory, and partly by direct estimation within satellite orbit determinations. Surface forces (aerodynamic and radiation pressure) may require detailed modelling of the spacecraft geometry and attitude motion. Perturbations arising from attitude- or orbit-control manoeuvres have often to be handled by an a-priori model as well as estimation of correction parameters.

Table 1. Forces perturbing the orbital motion of a satellite

- Earth gravity
- Luni-solar gravity (direct and tidal)
- Planetary gravity
- Aerodynamic drag and lift
- Solar radiation pressure
- Terrestrial radiation pressure (albedo and infrared)
- Thermal radiation from spacecraft
- Manoeuvres (orbit and attitude).

Tracking-system model

Several factors involved in the tracking-system model are listed in Table 2, some of which are discussed in more detail below.

Measurements are always accompanied by a time tag which tells us when they were made. This time tag has sometimes to be corrected because the clock at the station or on the satellite that produced the measurement had some bias with respect to Universal Time, or UTC. The clocks on-board satellites have the relativistic time scale of the satellite, which differs from the time scale on the ground. The constant term of this difference can be corrected by introducing a permanent drift into the satellite's clock before it is launched, but fine corrections, some of them periodic, have to be performed in order to obtain the full accuracy allowed by the measurement.

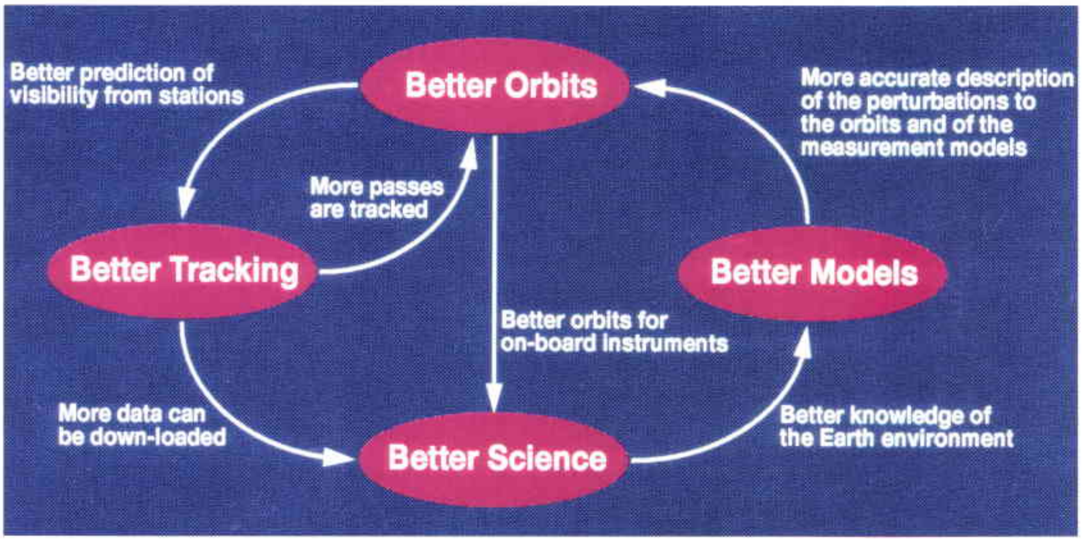


Figure 1. Relationship between the quality of orbit determination, the tracking network, the scientific payload and the model(s) used in the orbit-determination process

Estimation algorithms

Estimation algorithms may be based on a batch approach, whereby a large quantity of data is processed in one single inversion to solve for the desired unknown parameter set. An alternative approach is a filter process, in which individual measurements, or groups of measurements, are used sequentially to provide a weighted correction to the current parameter estimates. The main estimation

Table 2. Factors involved in modelling range or Doppler measurements

- Ionospheric and tropospheric propagation
- Station position at the measurement epoch
- Station timing and frequency reference
- Satellite timing and frequency reference (one-way systems)
- Offset between satellite antenna and centre of mass
- Satellite attitude steering laws.

algorithm in dynamic-orbit and geophysical-parameter determination is, however, a batch least-squares method, implemented in the 'BAHN' program. Some modifications have been necessary to increase the efficiency of the inversion when GPS-type tracking was introduced, to allow for the estimation of a large number of parameters (more than 2000 per run) with reasonable computer usage (CPU times).

The multi-arc approach is a kind of combination of both batch and filter methods. Here, previously computed equation systems for individual tracking arcs (data covering typically a few days or weeks) can be accumulated to obtain solutions for geodetic and geophysical parameters whose effects can only be clearly separated by processing data covering a long period of time. This is, for example, the case with gravity and tidal parameters or accurate models of ground-station positions and motions.

Software system

The software system comprises pre-processing modules (data and communications handling; decompression and re-formatting, and data-quality monitoring utilities; pre-processing filter and corrections, and initial parameter estimation); the BAHN orbit and geodetic parameter-estimation program (for accuracy analysis, propagation determination); the MULTIARC program, whose function was described above; and various post-processing modules (for accuracy assessment, clock bias estimation, graphical output, etc.). The entire system has been developed in-house in a powerful mainframe environment, and is currently being ported to a Sun Unix platform.

ERS-1 precise orbit determination

The ERS-1 spacecraft (described in several previous Bulletin articles) was launched in July 1991 into a nearly-polar, 780 km-high, Sun-synchronous orbit. Laser-ranging and altimeter data are routinely processed in the POD Facility at ESOC, and the results summarised in a monthly Orbit Report.

Satellite laser ranging

Satellite Laser Ranging (SLR) data have been the most widely used tracking data for computing accurate orbits. An SLR system measures the time between the transmission and reception of a laser pulse emitted by the station and reflected on the satellite. Multiplying by the speed of light, the distance between the satellite and the SLR station can be obtained with 1–2 cm accuracy, once various corrections have been applied. The geocentric positions of the stations have to be known as accurately as possible. Hence, very accurate models for the rotation of the Earth, tectonic plate motions, solid tides and ocean loading (the time-dependent deformation at the site due to the varying mass distribution of the water in the oceans) need to be used. The most powerful technique for obtaining the necessary position and tectonic velocity data has been the reduction of SLR data gathered by tracking the Lageos spacecraft (two small satellites in 5900 km-high orbits). Several years of Lageos-1 data have been processed with the POD software for this purpose.

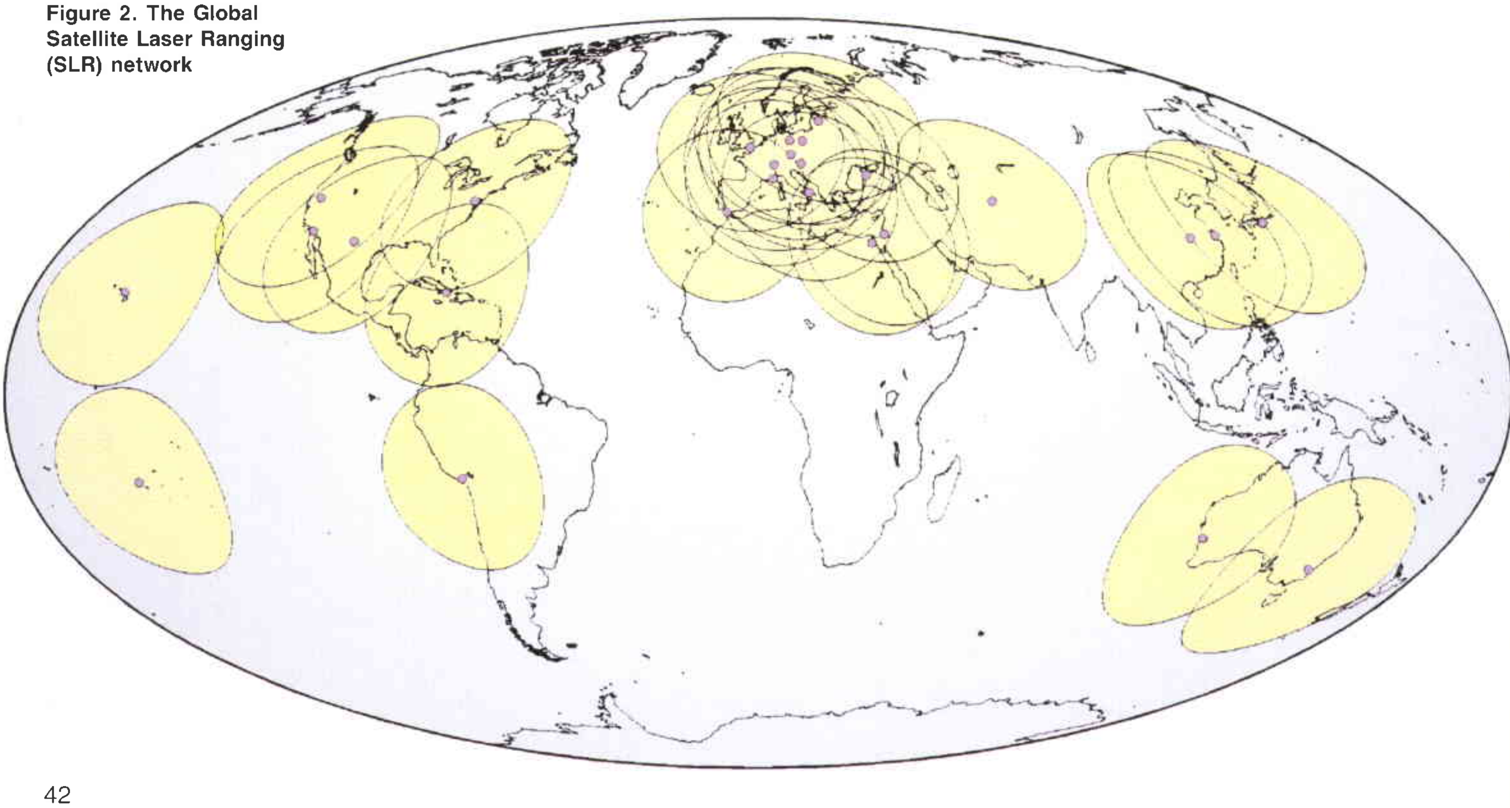


Figure 2. The Global Satellite Laser Ranging (SLR) network

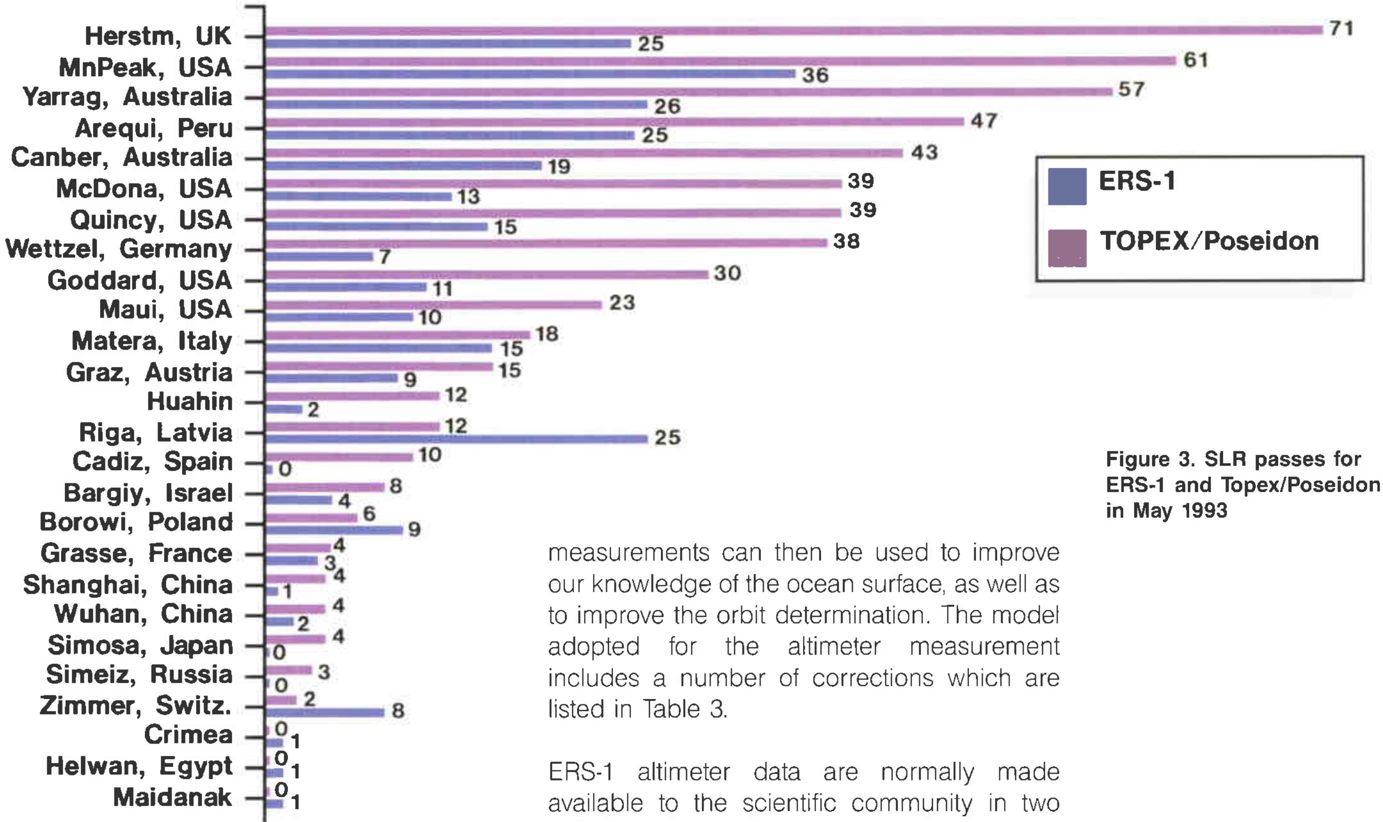


Figure 3. SLR passes for ERS-1 and Topex/Poseidon in May 1993

Another essential aspect in using SLR data is the centre-of-mass correction: not only must the centre-of-mass and the location of the laser retroreflector reference point be known very precisely in the spacecraft reference frame, but also the spacecraft attitude as seen from the station. This is quite simple for spherical spacecraft like Lageos or Starlette, but becomes rather complicated for satellites like ERS-1 and Topex/Poseidon.

Figure 2 shows the global SLR network, with most of the stations located in the Northern Hemisphere, and in Europe and North America in particular. The visibility regions shown refer to the ERS-1 orbit. Figure 3 gives an idea of the number of passes per month for ERS-1 and Topex/Poseidon. ERS-1 is generally tracked by less than one pass per day and SLR station, while some stations track Topex/Poseidon more than once per day.

Satellite altimetry

A satellite carrying an altimeter measures its own height above the ocean surface. If the satellite's position is known, the instantaneous height of the ocean surface can be computed. The ERS-1 altimeter is able to measure the ocean surface with a precision of a few centimetres. To take advantage of this, it is necessary to compute the radial position of the satellite at the decimetre level. The altitude measurements can then be used to improve our knowledge of the ocean surface, as well as to improve the orbit determination. The model adopted for the altimeter measurement includes a number of corrections which are listed in Table 3.

ERS-1 altimeter data are normally made available to the scientific community in two different forms:

- Fast Delivery (FD) altimeter products: these data are available at the Mission Management and Control Centre (MMCC) at ESOC with a very short delay (hours). The preliminary corrections applied are based on a predicted orbit computed at the ESOC MMCC the previous day using S-band range and range-rate data from the Multi-Purpose Tracking System (MPTS) installed at the Kiruna ground station, together with fast-delivery altimeter data. The radial accuracy of these orbits is better than 2 m, whilst along- and across-track it is around 9 m and 4 m, respectively.
- High-quality products: these are based on more precise orbits and better corrections are applied. They are available with up to a year's delay.

Table 3. Correction model for altimeter data

- Ionospheric propagation correction
- Wet and dry tropospheric correction
- Centre-of-mass correction
- Altimeter instrument bias
- Geoid
- Sea-surface topography
- Solid-Earth tide
- Ocean tide
- Ocean loading effect on ocean bottom
- Inverse barometric effect (depression of ocean due to excess atmospheric pressure)
- Electromagnetic bias (a function of the roughness of the sea surface).

The corrections applied to the FD data are not adequate for precise orbit determination and so we replace them with more accurate ones. Since the launch of ERS-1, a considerable effort has been made by the ESOC POD team to improve all the corrections to the altimeter data. This is reflected in the continuous improvement obtained in the altimeter residuals, which were around 1 m at the beginning of the mission and are now just slightly more than 20 cm, reflecting much better orbit solutions (Fig. 4).

Several areas have been addressed to achieve this improvement:
- Monthly sea-surface topography models are computed at ESOC, which not only allows the quality of the altimeter tracking data to be improved, but also permits some oceanographic/meteorological phenomena like 'El Niño' to be observed.
- The altimeter instrument bias and the electromagnetic bias are estimated regularly.
- Tidal models have been extensively investigated and new models computed.
- A model to estimate the wet tropospheric correction to the altimeter measurements with an accuracy similar to that of the best-available atmospheric models, has been developed.
- Geoid, solid tides and ocean-loading corrections are applied using the best available models. Improvement of these models is also foreseen.
- Improvement of the ionospheric correction is under development.

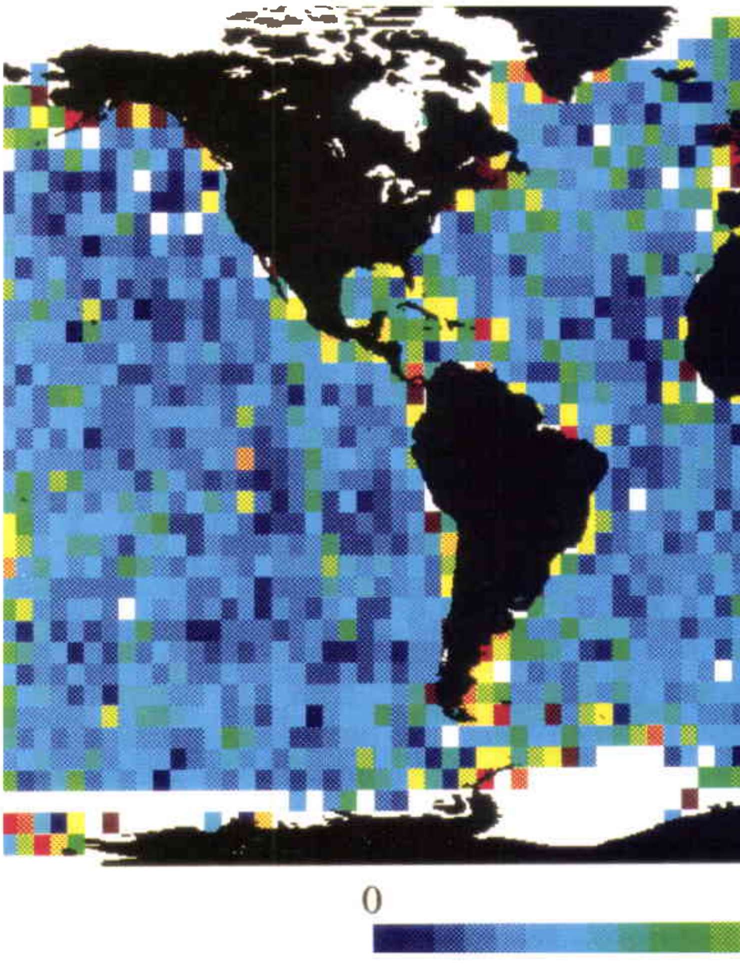
After including all of these corrections, the quality of the enhanced FD altimeter data is comparable to that of the high-quality products. This enhanced product will provide very useful tracking data for the MMCC orbits for future altimeter-carrying missions like ERS-2 and Envisat-1.

Orbit accuracies achieved

Several methods are used to assess the accuracy of the ERS-1 precise orbits:
- *Measurement residuals* (differences between actual and modelled measurements after orbit determination) give a good indication of the quality during a pass. SLR residuals are currently about 9 cm for ERS-1 and 5 cm for Topex/Poseidon. By evaluating the contributions of the various error sources in the altimeter residuals, that of the radial orbit error can be inferred.
- *Overlap test*: In parallel with the routine ERS-1 precise orbit determination, in which orbits are generated in consecutive four-day arcs, one-day orbit solutions are computed every five days. The 12 hours in the middle of these one-day solutions are used to compute orbital-height differences with respect to the four-day solutions. Over a period from the beginning of June to the end of September 1993, the total rms of the difference amounted to 6.8 cm. This value shows the internal radial consistency of the orbits, but it is an optimistic indication of the radial orbit accuracy, because the same data and the same dynamic models were used in both solutions.
- *Comparison with external solutions*: The ERS-1 preliminary orbits supplied by the German Processing and Archiving Facility (D-PAF) are computed using different software and dynamic models. Comparison of the D-PAF orbits with our solution shows differences of about 13 cm.

Altimetry calibration

During its commissioning phase, ERS-1



overflew the 'Acqua Alta' Oceanographic Research Platform off the coast of Venice (I) once every three days for the purpose of calibrating the spacecraft's altimeter. The bias computed from the Venice overflight calibration was −42 cm, the minus sign indicating that the altimeter was under-measuring.

The first attempts to estimate the altimeter bias in the precise orbit solution began at ESOC shortly after the beginning of the ERS-1 35-day repeat cycle, in May 1992. The value obtained for the bias was −46 cm (based on a mean equatorial Earth radius of 6 738 136.5 m), which was in remarkable agreement with the Venice calibration. Since then, the bias has been routinely estimated in both solutions, showing a behaviour that has more to do with the poor ionospheric corrections applied to the FD altimeter data than with the instrument itself. From global-analysis techniques, the altimeter bias can be estimated with accuracies of a few centimetres.

Sea-surface topography

Ignoring tidal variations and assuming that the Earth were uniform in density and topography, the shape of the ocean surface would be very close to an ellipsoid. However, there are variations in density and topography and these give rise to a complex gravity field. This gravity field in turn defines an equipotential surface, the 'geoid', which is quite irregular compared with an ellipsoid. In reality, the mean sea surface is not the geoid, because of ocean currents, tides and winds. The sea-surface topography is therefore defined here as the difference between the sea surface and the geoid after corrections for tidal effects.

The sea surface can be determined using ERS-1 altimetry in conjunction with very precise orbit information. If the Coriolis force acting on moving water is balanced by a horizontal pressure-gradient force, the current is said to be in 'geostrophic equilibrium' and is described as a 'geostrophic current'. It is therefore possible to compute ocean geostrophic circulation maps from the sea-surface topography, as well as their temporal variations.

Since May 1992, sea-surface topography models have been computed at ESOC every month using ERS-1 data (Fig. 5a). These models have been compared with tide-gauge measurements in the Pacific and Indian Oceans (Fig. 5b) and the standard deviation of the differences has been found to be 6.9 cm. The high accuracy of these models therefore makes it possible to analyse temporal variations in the ocean currents, or large-scale sea-surface topography variations, like the 'El Niño'.

The high accuracy of the ERS-1 orbits, together with the high quality of the altimeter measurements, will provide significant improvements to our current knowledge of the marine geoid, especially at high latitudes.

Tidal models

The sea surface is varying with time, mainly with diurnal and semi-diurnal periods due to the rotation of the Earth in the presence of the Sun and Moon. The extraction of ocean tidal components from the analysis of satellite altimetry data will allow the computation of semi-diurnal and diurnal tides more reliably than has been possible so far. (Unfortunately, the fact that ERS-1 is flying in a Sun-synchronous orbit makes it very difficult to compute similarly accurate models for the solar tides.)

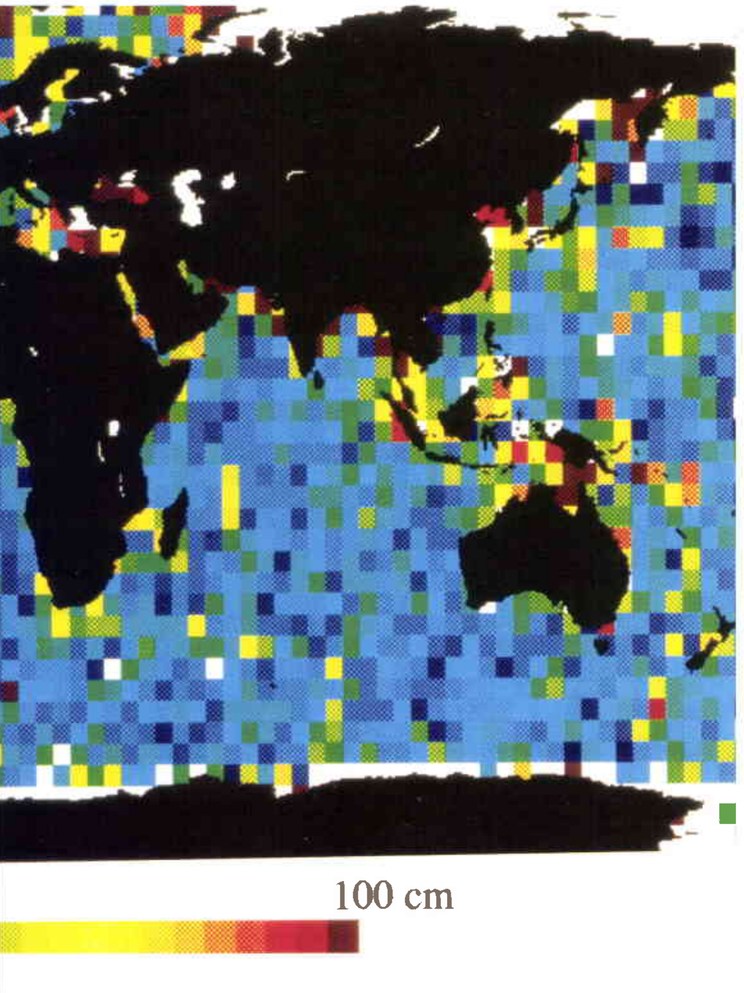


Figure 4. ERS-1 altimeter residuals (in centimetres) in December 1993

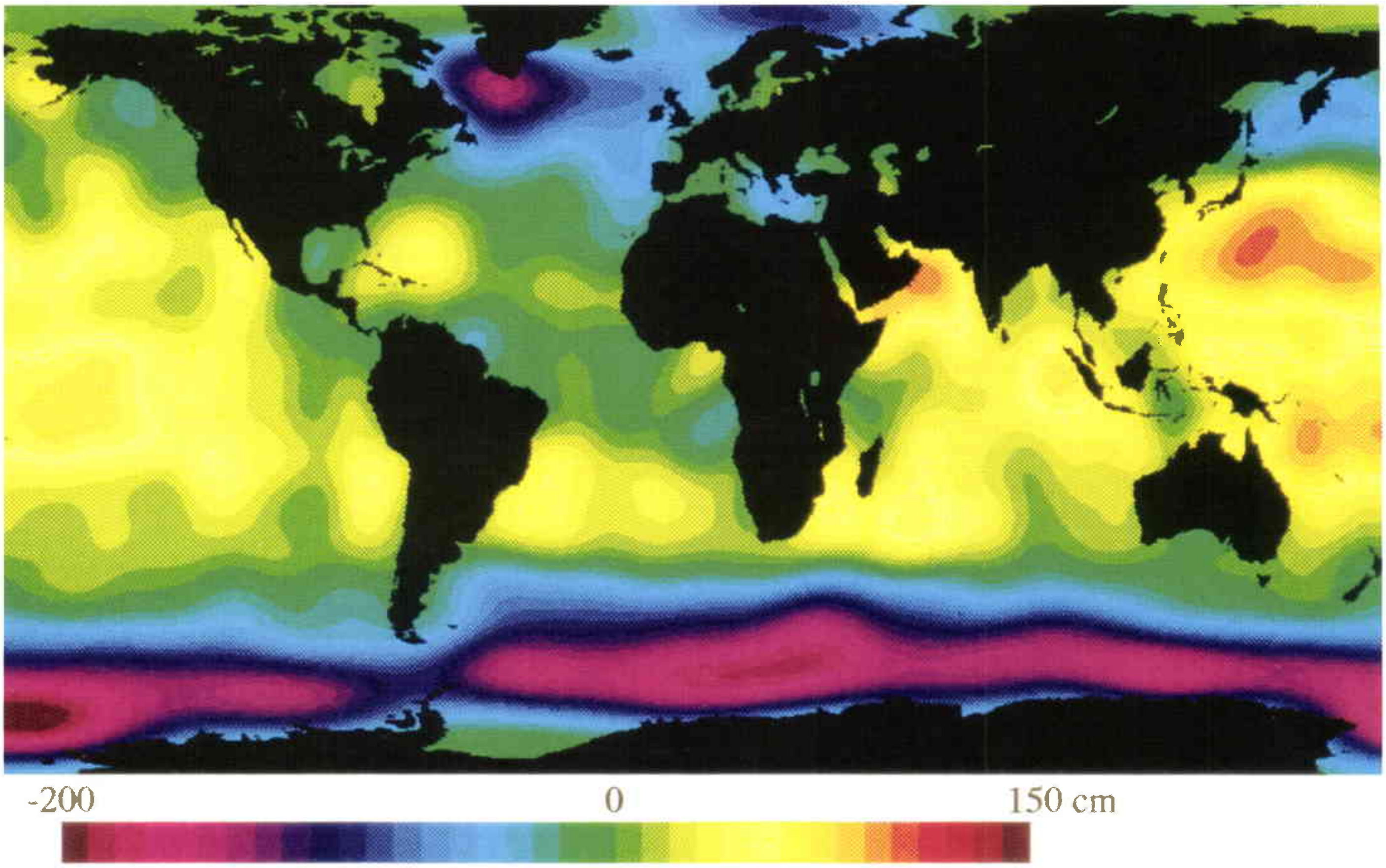


Figure 5a. Sea-surface topography in December 1993 from ERS-1

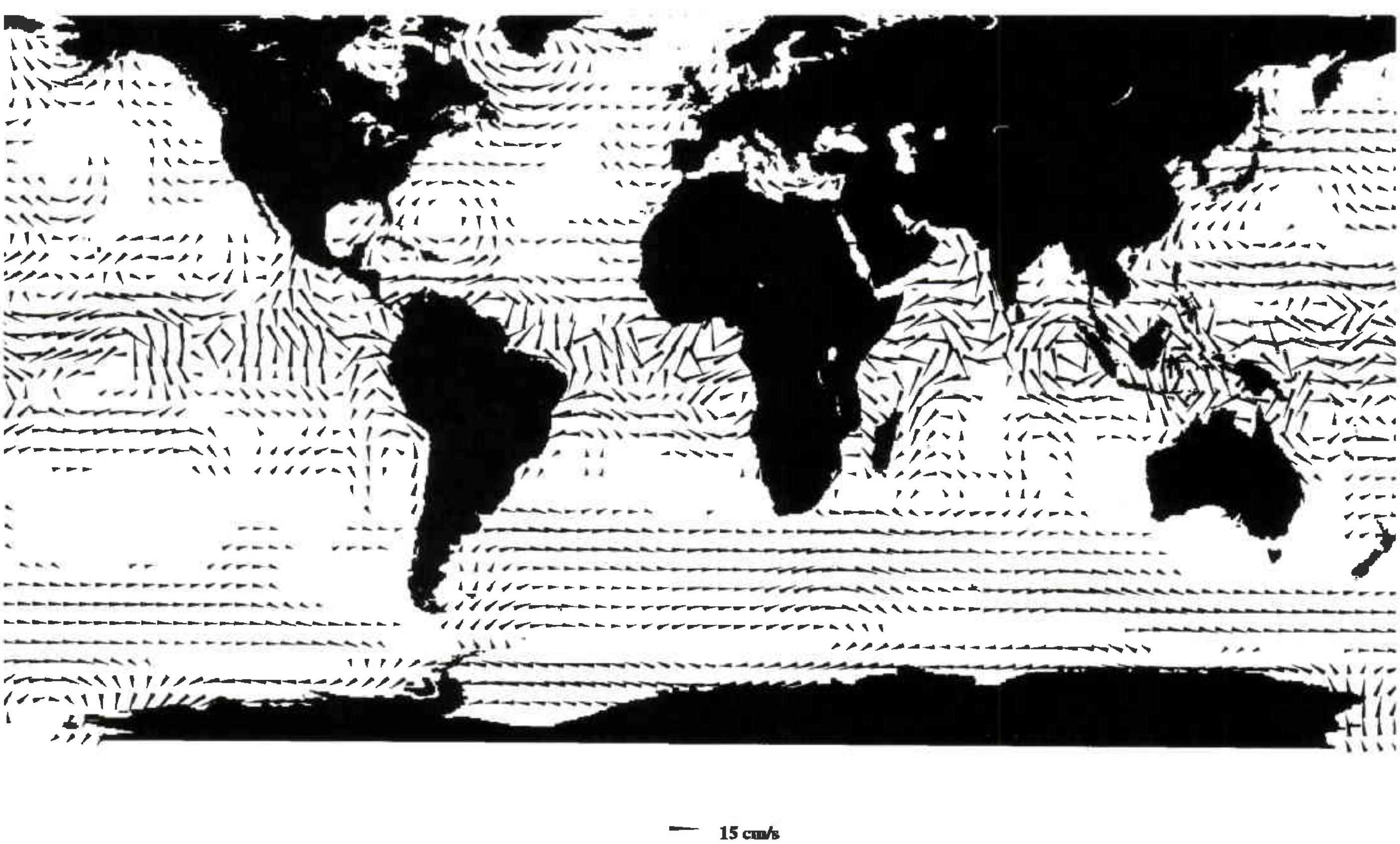
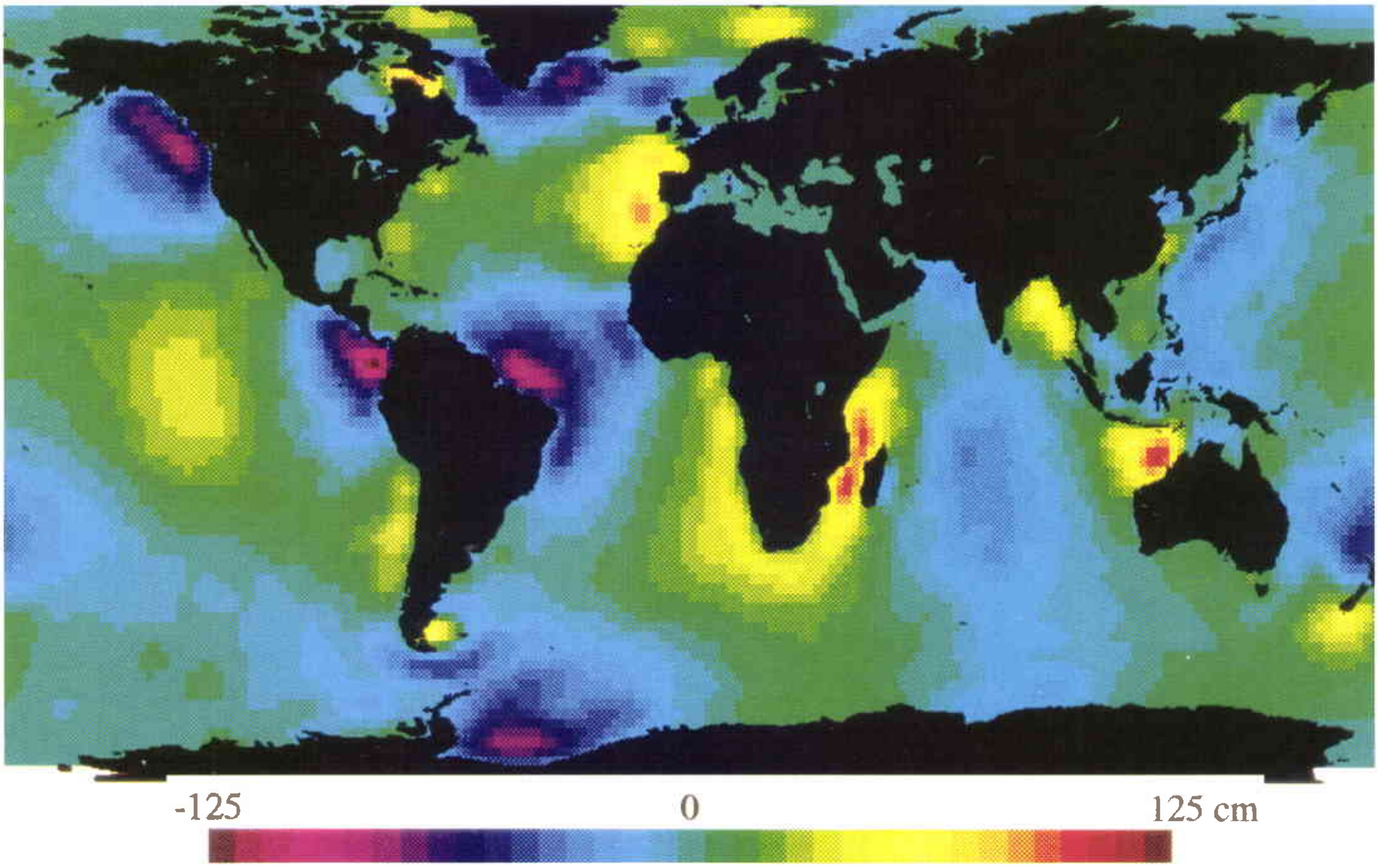


Figure 5b. Ocean currents in December 1993 from ERS-1



The principal lunar tide (M_2) creates the major perturbations in the ERS-1 altimeter measurements, which have a period of 14.77 days and an amplitude (rms) of 36.5 cm. Given the very dense spatial distribution of the altimeter measurements and time scale of the perturbations, it is possible to compute very accurate models for M_2 using relatively short intervals of data (Fig. 6).

GPS tracking and data-analysis facility

The Global Positioning System (GPS) was designed primarily as a worldwide military navigation system by the US Department of Defense. As early as 1983, however, it was agreed that it would also be made available, with a reduced accuracy, to civilian users.

The GPS system consists of three components: a space segment of GPS satellites, a control segment that monitors and operates those satellites, and a user segment that employs GPS receivers to observe and record transmissions from the satellites and perform position, velocity and time calculations.

The GPS satellites have near-circular orbits with an altitude of 20 200 km, a period of a little less than 12 h, and an inclination of 55°. They are located in six orbital planes, with nominally four satellites per plane, providing global coverage with four or more satellites simultaneously observable above 15° elevation.

A significant new element of the ESA POD Facility has been under development since 1990 in the form of a GPS Tracking and Data Analysis Facility (GPS-TDAF). GPS-TDAF is designed to achieve high-accuracy orbit determinations for spacecraft carrying GPS receivers, and to perform error analysis for future missions. Such accuracies have been demonstrated for the Topex/Poseidon spacecraft, which carries an experimental GPS receiver, showing radial agreement within 3–5 cm compared with other solutions. A large degree of automation and reliability is required in the system, which can support future Earth-observation and science missions and an In-Orbit Infrastructure (IOI). Additional objectives relate to the continuous monitoring of the positions and ionospheric propagation effects at the sites of the ESA tracking network, which is of relevance for all missions using these stations.

High-quality receivers and antennas (Fig. 7), together with associated communications interfaces, have already been installed at four ESA stations – Maspalomas in Spain, in June 1992; Kourou in French Guiana,

Figure 6. Ocean tidal height at 12:00 UTC on 13 October 1993 due to the mean lunar tide, from ERS-1

Figure 7. A GPS installation in Perth, Australia. The small GPS antenna (in the foreground) is mounted on a concrete pillar to achieve millimetre-level stability

in July 1992; Kiruna in Sweden, in July 1993; and Perth in Australia, in August 1993 – and similar installations are in preparation for the Malindi (Kenya), Villafranca (Spain), Redu (Belgium) and Odenwald (Germany) stations.

The International GPS Service for Geodynamics (IGS)

A major stimulus in the development of the GPS-TDAF has been our active participation as an Analysis Centre and Operational Data Centre in the IGS, which came into being via a Call for Proposals issued in April 1991. A very successful three-month campaign was conducted in the summer of 1992 and, following an interim service, IGS became operational on 1 January 1994.

The IGS is designed to generate the following data products:
- high-accuracy GPS satellite ephemerides
- Earth-rotation parameters (polar motion, length of day)
- coordinates and velocities of the IGS tracking stations
- GPS satellite and tracking-station clock information
- ionospheric information.

Currently nearly 50 stations are contributing data to the IGS and a considerable number of agencies are involved world-wide (Fig. 8). The IGS Governing Board includes representatives from the major entities and geographical regions involved (there is also an ESOC representative). The Central Bureau is managed on its behalf by the Jet Propulsion Laboratory in Pasadena (USA).

The IGS processing carried out by the ESOC GPS-TDAF involves about 20 Mbytes of data per day (Fig. 9). Daily and weekly products – GPS data files, GPS orbit solutions, GPS satellite clock corrections, Earth-orientation parameters, etc. – are transmitted via Internet to a global database at NASA's Goddard Spaceflight Center and to the International Earth Rotation Service (IERS).

A combined IGS orbit solution for all the GPS spacecraft is available within about two weeks, based on the solutions supplied by the seven participating Analysis Centres. The agreement of the majority of the individual solutions with this orbit is usually within 10–20 cm. Another important IGS product is the corrections for the GPS satellite clocks.

The geocentric coordinates of the 25 or so stations used in ESOC's IGS solution are now determined with 1–2 cm accuracy. The regular variation of the Earth's rotation (polar motion, length of day) is also computed daily with this same accuracy. GPS has proved to be a powerful tool for this purpose.

Further developments

DORIS

A serious disadvantage of laser ranging is its dependence on clear skies. This led to the design of a new satellite tracking system called 'Doppler Orbitography and Radio-positioning

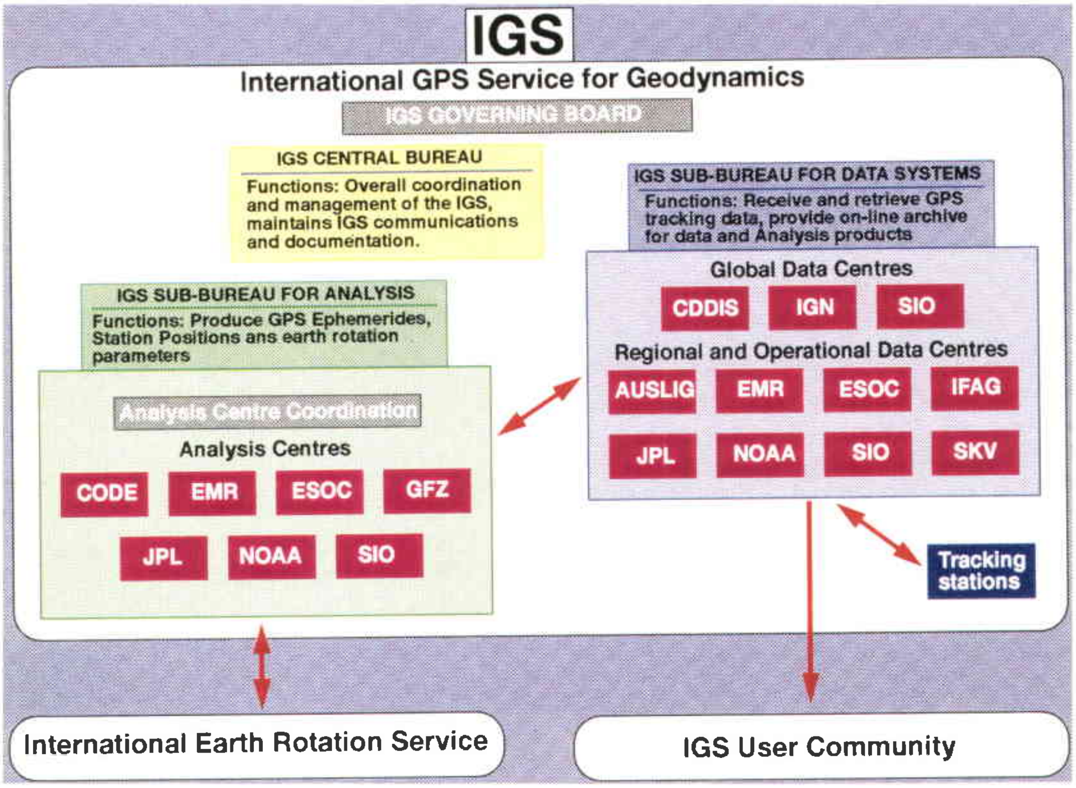


Figure 8. Structure of the IGS

Integrated by Satellite' (DORIS), as a collaborative effort by CNES, IGN and GRGS in France. It is based on the one-way measurement of Doppler shifts on radio signals transmitted by ground beacons and received by DORIS's on-board package as the satellite passes within range of them. Each beacon transmits two signals with very stable frequencies; the first provides the precise Doppler measurement, and the second the meteorological and housekeeping data. Together they provide a tool for eliminating the first-order effect of signal propagation through the ionosphere.

Fifty DORIS beacons have been installed to date, of which at least 40 are fully operational. Together they ensure a homogeneous observed coverage of about 80% of the Topex/Poseidon satellite's orbit.

The ability to handle DORIS data has been implemented in the ESA POD Facility. The agreement between orbits computed from DORIS data and orbits computed from SLR data is within about 3 cm radially for Topex/Poseidon.

ERS-2 and Envisat-1
The ESA Earth-observation programme begun with ERS-1 will be continued throughout the remainder of the decade with the ERS-2 and Envisat-1 missions, which will fly in very similar orbits. In addition to laser tracking, ERS-2 will be tracked with the Precise Range and Range-rate System (PRARE), while Envisat-1 will be tracked at least with DORIS. The ESA POD Facility is therefore being prepared for participation in the processing of these data and in the assessment of the orbit solutions.

Comparison with the ERS-1 laser solutions demonstrates that, with the improved models and software, solutions based only on Kiruna S-band tracking and FD altimetry can deliver radial accuracy at the decimetre level, and around 4 m and 2 m along- and across-track, respectively, for ERS-2.

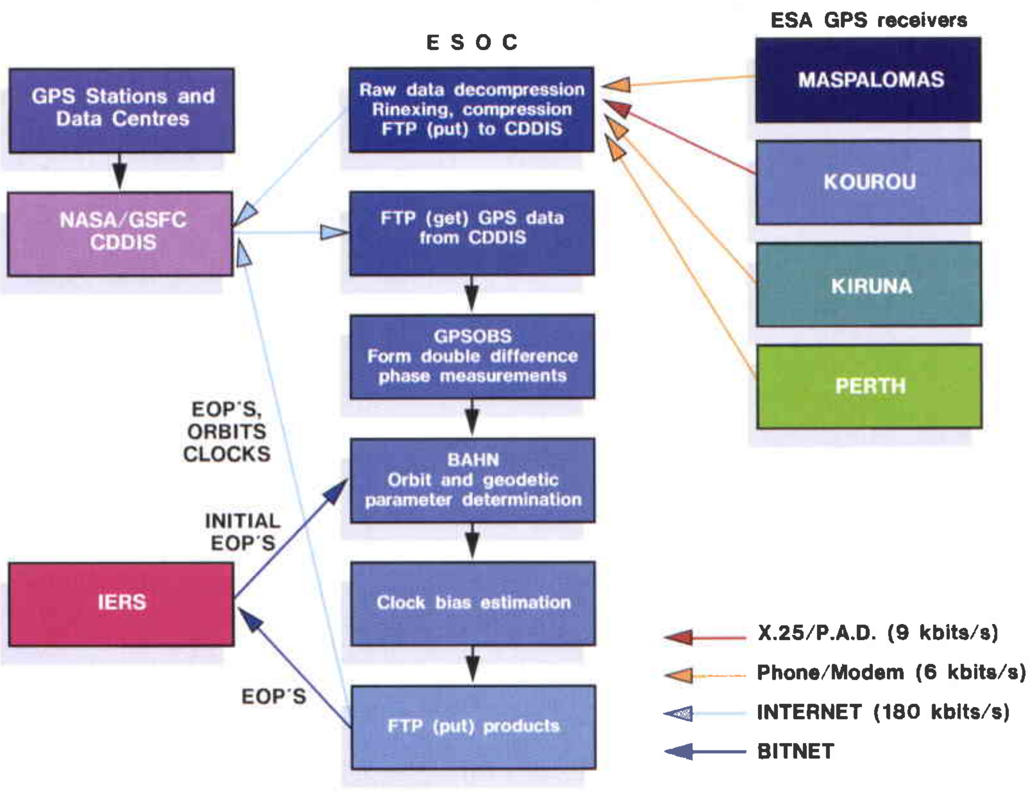


Figure 9. IGS data flow at ESOC

Conclusion
ESA's Precise Orbit Determination Facility is one of the most advanced systems available in the World today. It offers not only high accuracy and reliability, but also rapid POD product availability. It provides a solid basis for one element of the ground support that will be needed in the coming years for Europe's Earth-observation missions, and for future satellite-navigation systems, in-orbit infrastructure, and rendezvous and docking activities. The tracking techniques involved, particularly GPS, are also highly relevant for future science missions that require accurate orbits for success.

Acknowledgment
The development of the POD Facility has benefitted from the contributions of S. Casotto (Logica), J. Feltens (MBP), C. García Martínez (GMV), R. Píriz (GMV) and R. Zandbergen (Logica), as well as those of L. Agrotis, P. Duque and several young-graduate and other trainees.

Using Advanced Graphic MMI Techniques for Telemetry Monitoring — The Eureca Experience

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Traditionally, spacecraft control and monitoring systems have displayed incoming telemetry as lists of data or as plots either against time or another parameter value. More powerful and intuitive methods of displaying the data are emerging and the most important appears to be the use of mimic diagrams — animated, graphic representations of a system.

To explore the potential benefits of these advanced man-machine interfaces, ESOC developed a prototype Eureca Mimic Diagram System (EDMS). It has greatly improved the method of working during a mission, particularly during the most critical phases when staff are under great stress. It could provide the basis for the design of the display subsystem for future control systems that use the same software infrastructure.

Background

For more than 15 years, ESOC has been using internally-developed infrastructure software to monitor and control spacecraft. It is currently using the Spacecraft Control Operation System (SCOS). The monitoring of incoming telemetry within this infrastructure has been based on the use of a display subsystem which provides the data in the following ways:

- Alpha-Numeric Display (AND) (Fig. 1): a maximum of 64 telemetry parameters represented by their digital value
- Graphic Display (GRD): telemetry parameters represented graphically as values plotted either against time or against another parameter value
- Scrolling Display (SCD): telemetry parameters represented either graphically or as a digital value in a defined time window.

These display facilities, together with the software infrastructures, have been used satisfactorily to monitor the 25 successful missions controlled to date by ESOC Operations Control Centre (OCC) teams.

More powerful and intuitive methods of displaying telemetry data, however, are emerging. The most important method appears to be the use of mimic diagrams — animated, graphic representations of a monitoring system (Fig. 2).

ESOC has recently attempted to provide the operators of Marecs and Meteosat satellites with some mimic features. Although these experiences could be considered successful, a systematic and standard approach to the use of these techniques in the displaying of telemetry data must still be established.

ESOC's prototype mimic diagram system

In order to explore the potential benefits of using advanced man-machine interface (MMI) techniques in spacecraft monitoring and control, ESOC's Data Processing Division decided to develop a prototype system that provides mimic features and is based on the SCOS-1B infrastructure, a second-generation version of the SCOS infrastructure then in use, and which runs on Sun workstations rather than on the traditional Intel workstations.

The prototype system was to be tested during the mission to retrieve ESA's orbiting Eureca satellite and return it to Earth (the mission took place from 21 June to 2 July 1993). This prototype, named the Eureca Mimic Diagram System (EMDS), was to be a subsystem of the Eureca Dedicated Control System (EDCS), which is used to control the overall operation of Eureca. The aim was to provide the Eureca Spacecraft Engineer with a set of mimic diagrams related to the spacecraft subsystems that are considered critical for the Orbital Transfer Manoeuvre and Retrieval Phase. The EMDS was to include mimic diagrams that represent the data handling system, the attitude and orbital control system, the power supply system, the thermal system, and the

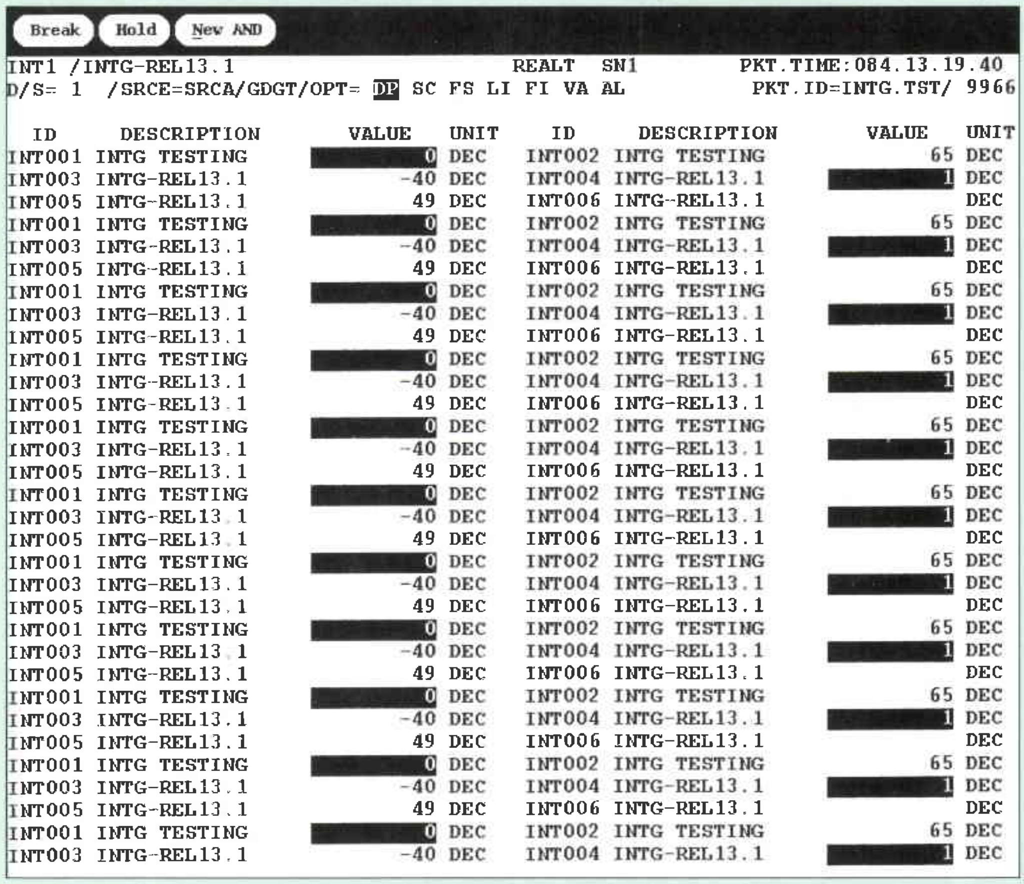

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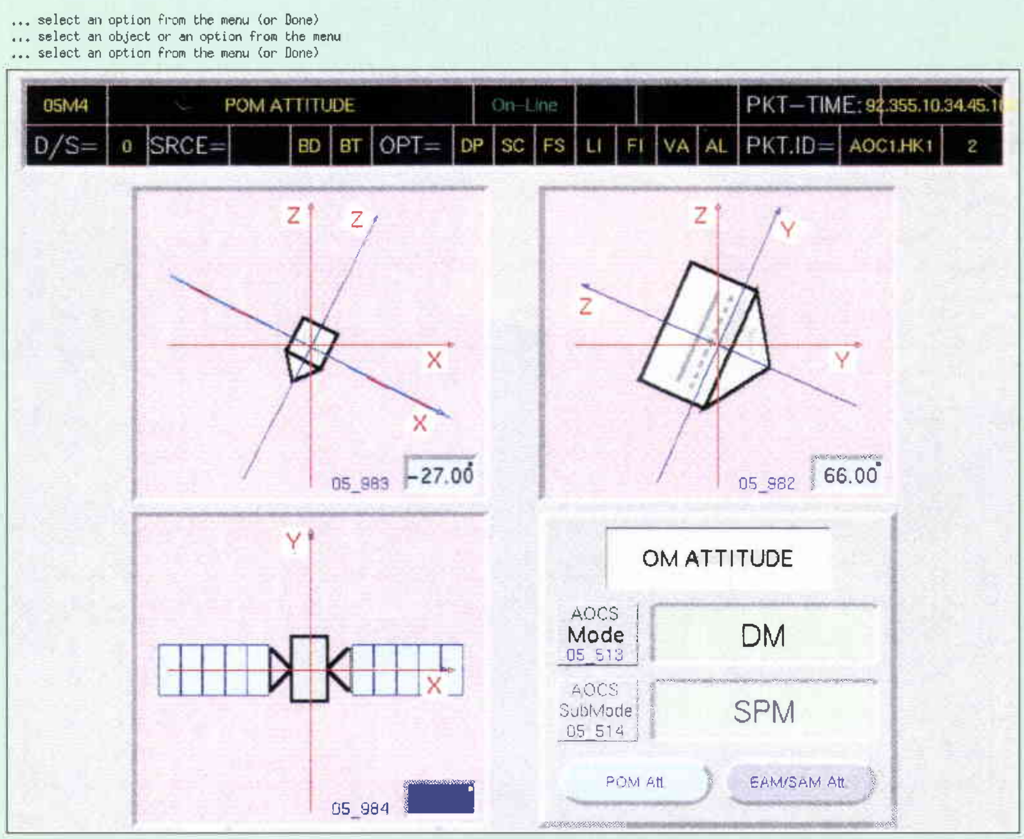
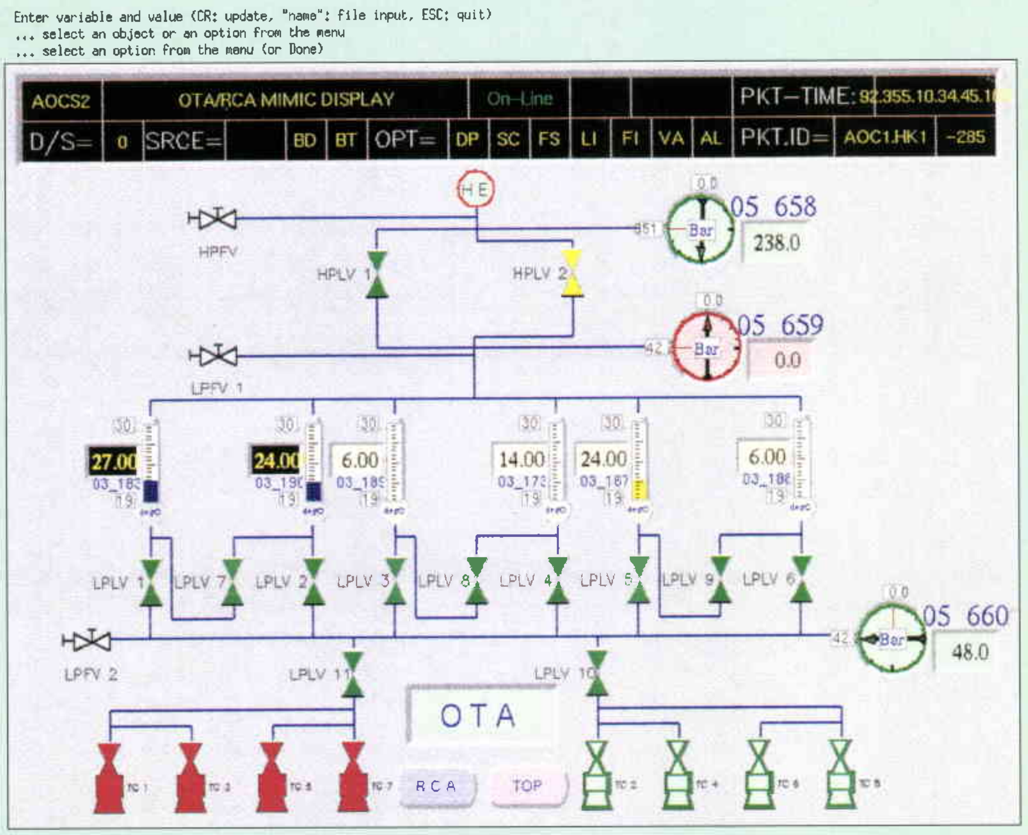
Fig. 1 An example of an alpha-numeric display of 54 telemetry parameters

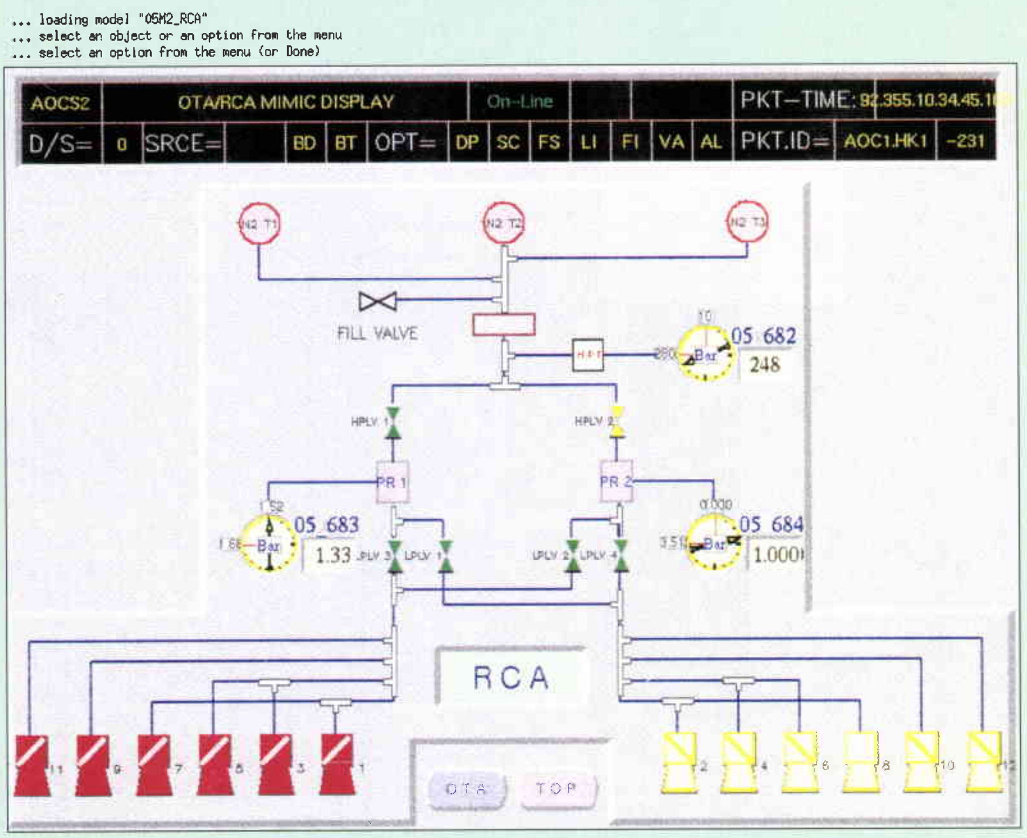


2a. The screen that displays the spacecraft's attitude along the three axes

Fig. 2 Three mimic diagrams used to monitor a spacecraft's attitude and orbital control system



2b. The screen used to monitor the Orbital Transfer Assembly (OTA)



2c. The screen used to monitor the Reaction Control Assembly (RCA). To move to the OTA screen, the user clicks on the 'OTA' button at the bottom of the screen. To move to a higher level within the system hierarchy, the user clicks on the 'Top' button.

telemetry, tracking and command system. An additional mimic diagram was designed to enable the Safety Engineer to monitor simultaneously the most critical parameters for each of those subsystems. Figure 2 shows some of the mimic diagrams used to represent the Attitude and Orbital Control System.

Design and development constraints

For the development of the prototype, the normal ESOC software development life cycle had to be modified to take into account:

— the shortage of available time
The decision to develop the prototype was taken in December 1992, with the Eureca Retrieval Mission scheduled at that time to take place in April 1993. This short development time meant that the time available for the developers to familiarise themselves with the software graphic tool used to design the mimics had to be reduced.

— the limited available manpower
The ESOC Data Processing Division and the Mission-Dedicated Section (Eureca Project) undertook the initiative without budget extension and, therefore, could not solicit industry involvement.

In addition, the task of convincing operators who had been using the well-tested, reliable traditional techniques of spacecraft monitoring and control to switch to a new system based on different MMI techniques and hardware supports, was not an easy one. Moreover, doing so when approaching a critical mission phase such as the Eureca Retrieval, only aggravated the problem. Most notably, since the System Prototype Development Phase overlapped with a very hectic period for the Eureca user community, there were problems in collecting systematic and exhaustive user requirements.

It must be pointed out that, although the system was developed under the Data Processing Division's initiative and without complete user requirements at the outset, the Eureca users were very supportive and cooperative. Indeed, both the developers and the users have learnt throughout the iterative life cycle of the prototype.

— a new infrastructure
In order to be able to use the software graphic tool required to create mimic diagrams, the mimic system had to be based on the infrastructure provided by the second-generation version of the SCOS infrastructure software, SCOS-1B.

Besides the technical constraints, a major issue was the integration of the SCOS-1B software, which was not part of the original Eureca design assumption, with the Eureca Dedicated Control System (EDCS) software. This had to be achieved without any impact or risk to the ongoing Eureca operations.

— lack of an applicable standard
Unlike with other software development projects, at the start of this project, there was no standard approach to the use of MMI techniques that could be applied to the definition of user requirements, the architectural design or the implementation of the system.

ESA's Committee for Operations and EGSE Standards (COES) had begun to define standards for MMI for mission control systems but only preliminary guidelines were available. It was therefore necessary to define a design style, as well as some new animation and dialogue techniques but without deviating from the preliminary COES guidelines.

The lack of a standard was the main reason for selecting an incremental approach to the development of the prototype. With this approach, the users are given a very rough version of the system to try out and, based on their comments and recommendations, the system is modified to better meet their requirements. The users then experiment with the improved version of the system and the developers refine it further. The process is repeated until the users are satisfied with the system.

Selected design

In the EMDS, a mimic diagram is identified by the following basic components (Fig. 3):

— the mimic header
— the graphic layout of the system
— the dialogue widgets.

The mimic header is a common set of fields that provide the user with the mimic mnemonic and title as well as the contributing telemetry packet characteristics. The graphic layout of a mimic diagram is the part containing the graphic representation of the system that is to be monitored. Dialogue widgets are the MMI components, such as on-screen 'push buttons' and pop-up screens, that the operator uses to interact with the mimic diagram.

Graphic layout

The graphic layout of a mimic diagram usually includes both static and dynamic objects.

Static objects are used to represent system components that are not driven by any parameters. They are usually a simple graphic representation of the system or subsystem to be monitored, but there is no graphic animation of its behaviour. They are used only to illustrate the system or subsystem.

Dynamic objects are used to represent system components whose attributes change according to the value of the driving parameter. In the case of a spacecraft, the driving parameter or parameters will always be a telemetry parameter or a logical combination of telemetry parameters.

In turn, dynamic objects include both analogue and digital objects. Analogue objects give a synoptic representation of the parameter, for example, a thermometer is used to represent temperature. Digital objects use numbers and text to provide the user with a digital representation of the parameter value.

Figure 4 contains examples of graphic objects used, namely a set of meters, that have both analogue and digital representations of the same parameter. The two types of representation are complementary and are used together when possible. A digital representation provides precise information about the parameter but is difficult to read, while an analogue representation gives less accurate information but is much easier to read. This is true mainly for those models of parameters whose range is a continuous numeric one such as temperature or pressure, while the parameters such as status variables or a switch, whose range is a discrete set of values (e.g. a switch with only ON and OFF values), are more effectively represented by an analogue model.

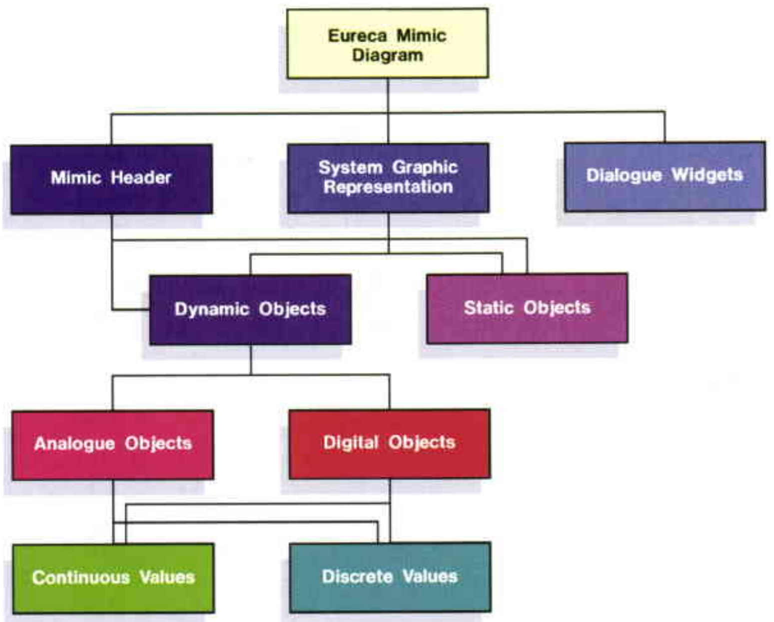


Fig. 3 Structure of an EMDS mimic diagram

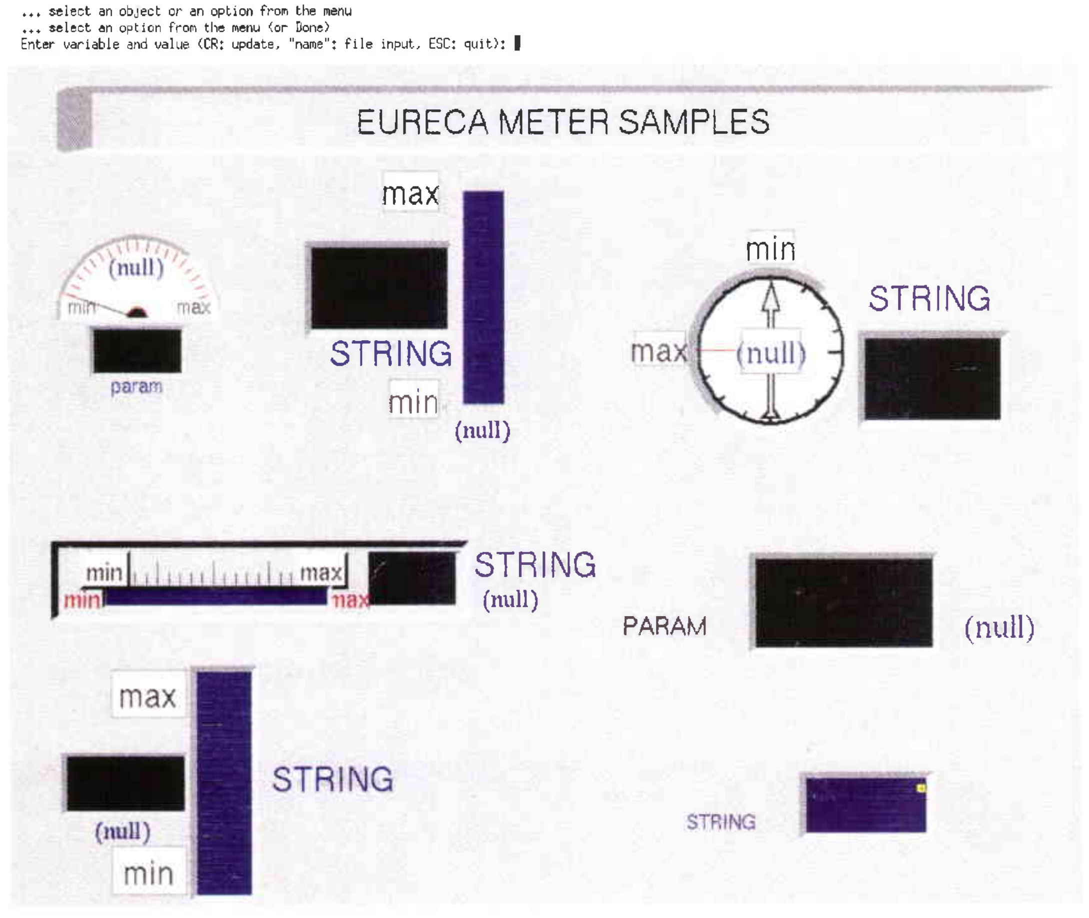


Fig. 4 Some basic graphic objects, meters in this case, used in building mimic diagrams. With the thermometer, for example, the actual reading would be shown in the black box (digital object) while the temperature level and its acceptability with respect to the specified limits would be shown in colour in the pictorial representation of the thermometer (analogue object). The units, maximum and minimum levels, etc. can also be customised.

Dialogue widgets

Each Eureca mimic diagram represents an interactive task; it responds to the input provided by the user via different input devices, namely the keyboard and pointing devices like the mouse or trackball.

The SCOS-1B software provides all the MMI features needed in order to start and stop a mimic diagram. However, once a mimic is up and running, further interaction with the operator is required — the operator uses the dialogue widgets, which include on-screen 'push buttons' and pop-up menus, to control the mimic diagram.

Table 1 Basic graphic models and their configurable attributes

Model Name	Model Type	Configurable Attributes
Thermometer	Analogue continuous	Range, descriptive text
Barometer	Analogue continuous	Range, descriptive text
Speedometer	Analogue continuous	Range, descriptive text
Box	Analogue discrete	Text, status, colour table, edge width, fill style
Switch	Analogue discrete	Descriptive text, colour
Line	Analogue discrete	Width, style, colour
Output text field	Digital discrete	Text colour, background colour
Numeric output field	Digital continuous	Digit font, digit height, range, background colour, digit colour, descriptive text, numeric format
Push area	Dialogue widget	Highlight colour
Push button	Dialogue widget	Text, button colour, highlight colour

A set of these widgets has been implemented in the EMDS. They are devoted mainly to the following functions:

— navigation through the mimic diagram
Once the required mimic is running, the operator can navigate through the levels of the mimic hierarchy, i.e. from an overview screen to a screen with more detailed information, just by clicking the pointing device on the relevant push buttons, or above the specific area that is to be examined in more detail.

— 'help' function
By clicking the pointing device on some of the graphic objects, pop-up windows appear, giving detailed information about the models.

Mimic creation

SL-GMS, a commercial graphic modelling tool, was used to define the graphic layout of the mimic diagrams. The optimal approach is to build a sub-models library — a library of all the basic objects such as a box or a thermometer that can be used in more than one graphic layout (several examples are shown in Figure 4).

Each object in the library has a set of configurable attributes that can be changed to define:

— a link to the telemetry parameter or logical combination of telemetry parameters that will be driving the object's behaviour (animation)
— the object's size, colour, measurement units, etc. (Table 1).

The configurable attributes are the same for all objects belonging to one class, e.g. for all types of meters or all types of switches. However, all classes of objects share the same colour convention for the parameter validity against the limit:

— green for 'in-limit' values
— yellow for 'soft out-of-limit' values
— red for 'hard out-of-limit' values
— grey, blue or another colour when the telemetry parameter is not checked against a limit, as is the case, for example, with a parameter that indicates memory usage.

The development approach

At the start of the project, the user requirements had to be based upon the engineering layout of each spacecraft subsystem as it was provided by the manufacturer. This approach was taken mainly because the developers were unfamiliar with the new philosophy and the users could only allocate a limited amount of time to the definition of their requirements (they were involved in the preparation for the Eureca retrieval on a full-time basis).

Since it was felt that it was important to gain the confidence of the users immediately, it was decided to deliver the first version of the system, although it was incomplete and by no means the final configuration, in an early training phase. Once the first versions were delivered and following a period of familiarisation with the new MMI, the users realised the potential of this different way of presenting the spacecraft status. They began to define ad hoc diagrams that fit their own needs, for instance, designing an overview of a system that, using the existing control system, is monitored using more than one alphanumeric display. Once the requirements for a mimic diagram were defined, a first graphic layout of the mimic was produced within one or two days.

The first release of the EMDS prototype system was delivered to the Mission Operations Division at the end of January 1993. It was subsequently used during the entire Eureca Retrieval Simulation Programme, and fine-tuned throughout that exercise. It was then used during the actual critical Retrieval Phases in June/July 1993.

The iterative prototyping approach used in designing and developing the system eased the familiarisation of the users with such a new technology. The users' cooperation and their growing interest in the new tools made possible the development of a system that fully satisfies the users' requirements from the functional point of view.

At the same time, much effort was spent trying to apply as much as possible design criteria aimed at maximising the reusability of the results achieved. In that way, a first attempt at defining standard MMI features was made.

Architectural layout of the Eureca SCOS-1B

The operational configuration of the EDCS is shown in Figure 5. The hardware platform hosting the EMDS subsystem is a VAX machine. The connection with the traditional Intel workstations was made via an Ethernet (serial-line) connection while the communication with the new Sun workstations was based on the TCP-IP protocol. This made it much easier in terms of connectivity to the EDCS, to use a Sun workstation rather than the currently-used Intel workstation.

One of the advantages of the TCP-IP connection is that the connectivity is controlled at the application level. With the currently-used serial line, any time a workstation must be connected, disconnected or switched between the primary and back-up computers, human intervention is required to operate a patch panel.

During the Eureca Retrieval Phase, four Sun workstations were connected to the EDCS VAX back-up computer via TCP-IP. During this phase, the EDCS back-up machine was isolated from the operational system, allowing the introduction of the mimic displays without risk to ongoing operations. The back-up machine received Eureca telemetry and acted as a 'warm' back-up throughout the whole phase.

The four Sun workstations were located as follows during the Retrieval (Figs. 6 and 7) (the first three were in the main control room):

- above the Flight Director position
- above the Spacecraft Operation Manager position
- at the Software Support desk
- at the Safety position (in the Project Support Room).

Each Sun was configured to allow up to nine tasks to run at the same time, making it a very valuable tool and allowing, for instance, the Flight Director and the Spacecraft Operation Manager to be able to access up to three Intel screens and nine Sun screens.

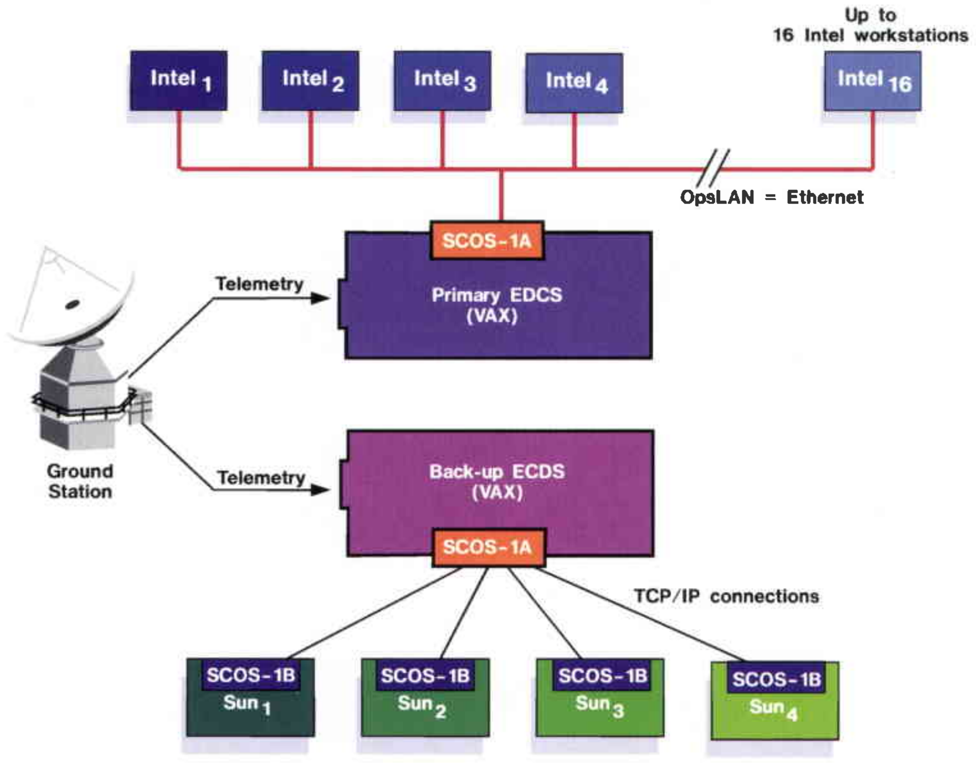


Fig. 5 Operational configuration of the ECDS

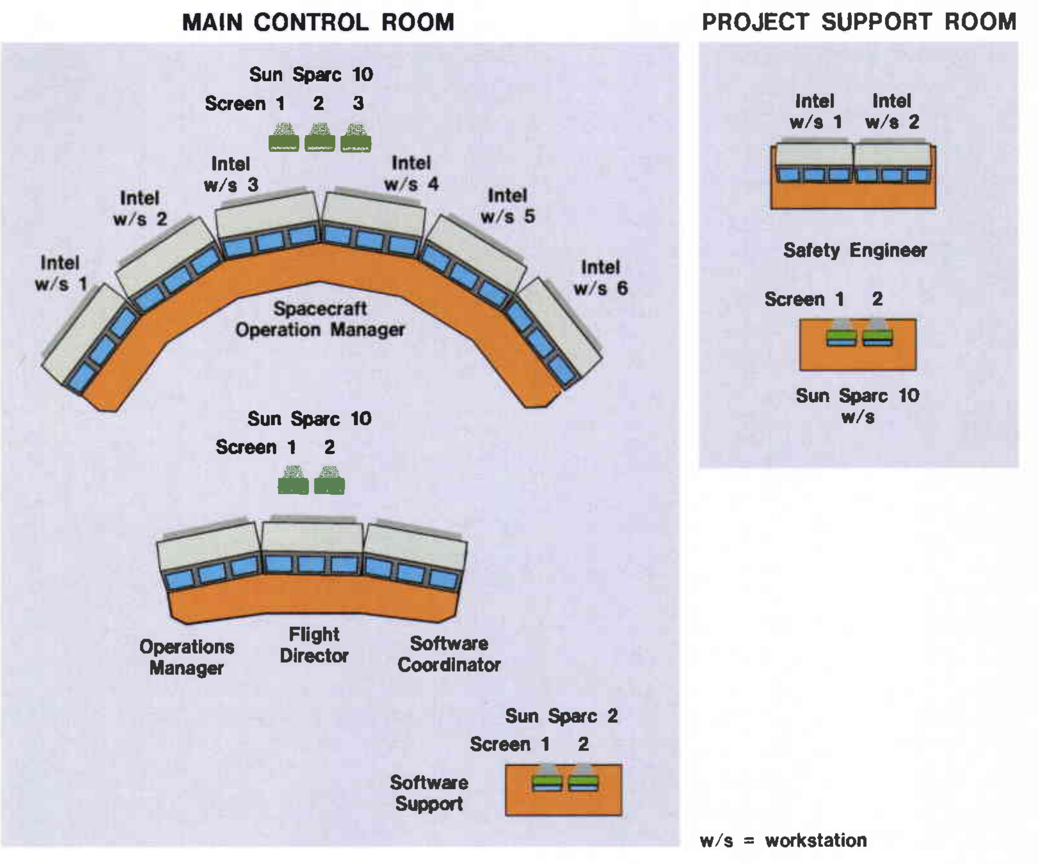


Fig. 6 The main control room and the project support room during the Eureca Retrieval Mission. Four Sun workstations were used to monitor incoming telemetry with the prototype EMDS.

User response and evaluation of the experience

User cooperation since the first delivery of the system has been very valuable in allowing the prototype to be tuned, particularly from the MMI point of view.

The EMDS has shown that the introduction of MMI techniques can greatly improve the method of working during a mission, particularly during the most critical phases of the mission, when operations staff are under great stress. Users recommended, however, that the animated graphic representation of the subsystem be considered to be complementary to the traditional alpha-numeric display, rather than a replacement of it.

The EMDS also provides a different way of navigating through data. The traditional navigation techniques (i.e. 'retrieving') only allow the users to move backward and forward within a collection of historical data. With the graphic representation, it is possible to navigate through the mimic hierarchy. The EMDS showed that the best design for a mimic diagram system is to implement a hierarchical view of the entire spacecraft. The ideal approach would therefore be to start from a graphic representation of the whole spacecraft.

Future plans

After the successful conclusion of the Eureca mission in July 1993, the EDCS software has been 'frozen'. However, the EMDS subsystem, which resides in a stand-alone environment, will be modified and improved to take advantage of the knowledge gained to date.

EMDS is an incremental system that can be used as a basis for future control systems that use the SCOS-1B infrastructure. It can also be used as a testbed for user assessments of screen layouts for future control system infrastructures (e.g. SCOS-II).

The EMDS sub-models library, which contains all the models commonly used when defining a mimic diagram, forms the bulk of a common infrastructure that is available to all projects that use SCOS-1B. Each object has a default standard configuration that can be modified to suit the context.

The display facilities provided by SCOS-1A, the traditional display on an Intel workstation (described in the first section of this article), are inconveniently divided into three different subsystems — alpha-numeric, graphic and scrolling displays — leading to additional operator interaction with the control system.

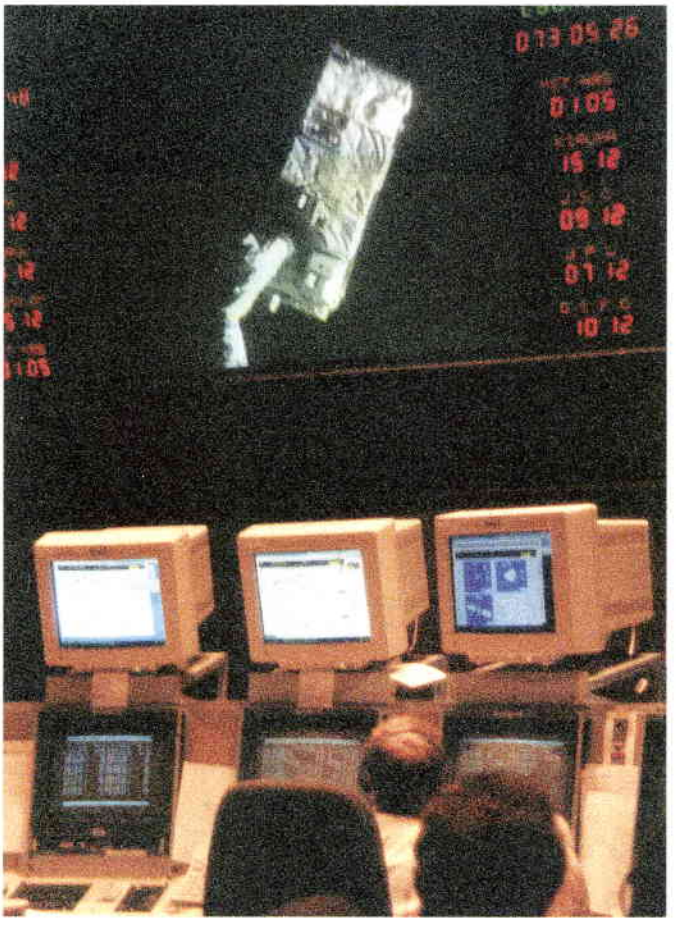


Fig. 7 The Sun workstation screens being used by the Spacecraft Operation Manager during the mission. The traditional Intel workstations are below the Sun screens. More data is displayed on screens above the operators' heads.

The software used to produce mimics, however, also provides a set of facilities to support the creation of graphic displays and scrolling displays. The idea therefore would be to develop a unique display environment that uses a single task comprising all the possible displays: mimic, alpha-numeric, scrolling and graphic displays. The implementation of such a system would greatly improve the quality of the work that the Spacecraft Analyst and the Spacecraft Controller must perform during a mission, by decreasing the number of interactions that they must have with the system.

Some of the concepts used when defining EMDS MMI, could be applicable in the design of general spacecraft control systems MMI, given a suitable hardware platform. For example, hierarchies can be used to facilitate moving through the system. Push buttons and pop-up menus can also be used to increase the speed at which a task is executed, reducing the amount of interaction that the user has with the system by minimising the amount of input that must be entered.

The application of the concepts developed is however not only limited to the use of the dialogue techniques, it can be extended to other components of a mission control system, such as telecommanding. For example, the telecommands and telecommand sequences to be imported into the Manual Stack, a basic task in the uplink of a command, could be listed, for example, on a pop-up screen or a scrollable list, and selected with the pointing device using the same graphic interface as used for monitoring the incoming telemetry. Each selected telecommand or sequence would still be subjected to the required database checks, in the same way as the checks are done when importing telecommands onto the Manual Stack with the traditional interfaces, thus maintaining the existing security aspects.

As noted earlier, the lack of a standard that encourages a common design style as well as animation and dialogue techniques was a problem in the design and development phase of the prototype. ESA's Committee for Operations and EGSE Standards (COES) is currently developing a Human/Computer Interaction standard that could help to resolve the problem. In a further attempt to coordinate efforts, ESOC established a Mimic Working Group at the beginning of 1994 to define mimic design guidelines for the use of the SL-GMS and SCOS-1B infrastructure.

The EMDS prototype has also been used in order to verify some of the intermediate results achieved in the establishment of a standard, both with the purpose of obtaining useful feedback and to ensure the greatest reusability of the prototype, minimising the work needed to adapt it to whatever the final result in this area will be.

Conclusion

A lot of work is still required in the development of advanced graphic MMI techniques in telemetry monitoring. Although EMDS was intended to pioneer rather provide a final solution, the project represents a significant step for ESOC in the field of man-machine interaction for spacecraft monitoring and control.

Acknowledgement

The authors would like to thank S. Haag (ESOC) and all the SCOS-1B team members for the valuable support provided.

Evolution of the Technical Computing Services at ESTEC

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At the request of the Information Services Division, TNO-TPD (the Institute for Applied Physics of the Dutch National Organization for Applied Research) has recently made an analysis of the conditions for a transition of the Technical Computing Services at ESTEC from a centralised model to a distributed computing infrastructure. This study, based on the requirements for high-performance computing in ESA in general, and within ESTEC in particular, involved interviews with many representatives of the technical and senior management at ESTEC. This article summarises the study's findings and conclusions, and it also describes the changing role of information technology in the ESTEC environment.

Computational applications for space engineering

In almost all disciplines of space science and technology, an important new method of doing engineering and research has emerged over the last decade alongside the traditional theoretical and experimental models. This new approach, often referred to as 'computational science', can be described as experimentation by means of computer simulation using mathematical models in place of physical systems. Typical applications (by no means an exhaustive list) are:

- Computational Fluid Dynamics (CFD), which can simulate the airflow around complex three-dimensional spacecraft during hypersonic flight.
- Computational Electromagnetics (CEM), which reproduces electromagnetic fields in complex three-dimensional structures such as antennas with arbitrary source terms.
- Structural Mechanics (SM), which can predict the response (overheating, deformations, fractures) of a complex structure such as a spacecraft to applied stimuli.
- Image Processing (IP), which transforms raw satellite telemetry data into finished products, ranging from maps of earth resources to astrophysical imaging.
- Molecular Dynamics (MD), which can track the evolution of huge assemblies of interacting molecules and permits subtle details of the molecular coupling (often only described in terms of quantum physics) to be translated into observable macroscopic effects.

These methods, although relying on different mathematical models and different processing techniques, all require the handling of very large data sets and the execution of many floating-point operations for each program step in order to produce accurate results. In line with the trend towards 'concurrent engineering', several techniques have been developed which can combine two or more such methods to produce even more accurate results (e.g. by combining CFD and CEM, charged flows can also be taken into account).

Trends in information technology

Processors

In order to perform a meaningful simulation in a reasonable time, a computer has to be able to execute millions of floating-point operations per second (Mflops). Before 1980, such power was only available on large mainframe computers, which by their very nature had to be operated by specialists as centralised resources. The advent of powerful mini-computers in the early eighties, followed by Personal Computers (PCs) and eventually by the popularity of work stations with user-friendly graphical interfaces in the late eighties, has changed the picture completely, leading to the distribution of substantial computing power over a variety of platforms.

Despite large mainframes having their power increased over the last decade by several orders of magnitude, by adding more processing units and attaching vector and array processors, the gap between these machines and desktop computers has narrowed dramatically of late, and today's RISC (Reduced Instruction Set Computing) work stations can match the speed of mainframes at a much lower cost.

This trend has received a substantial impulse from the emergence of parallel-computing technology. Loosely stated, parallel processing means having several processors working simultaneously on different parts of the same problem, thereby reducing the overall time required for the completion of a computational task. Parallel computers can be built today by assembling together many relatively cheap RISC processors. Since the design and manufacturing costs of computer systems typically increase more than linearly with their processing power, parallel processing can be remarkably cost-effective when compared to traditional sequential or vector-based processing.

It should be noted, however, that while programming tools and compilers that make it easy to develop new parallel applications are now widely available, it is sometimes not as easy to convert applications that have been developed for sequential or vector processing to a parallel-computing architecture. When one considers that the capital investment in software is often much greater than that in hardware (typically the life cycle of software is 8–10 years, as opposed to the 3–5 years of hardware), it can be expected that traditional scalar and vector supercomputers will continue to play a very important role for a number of years to come.

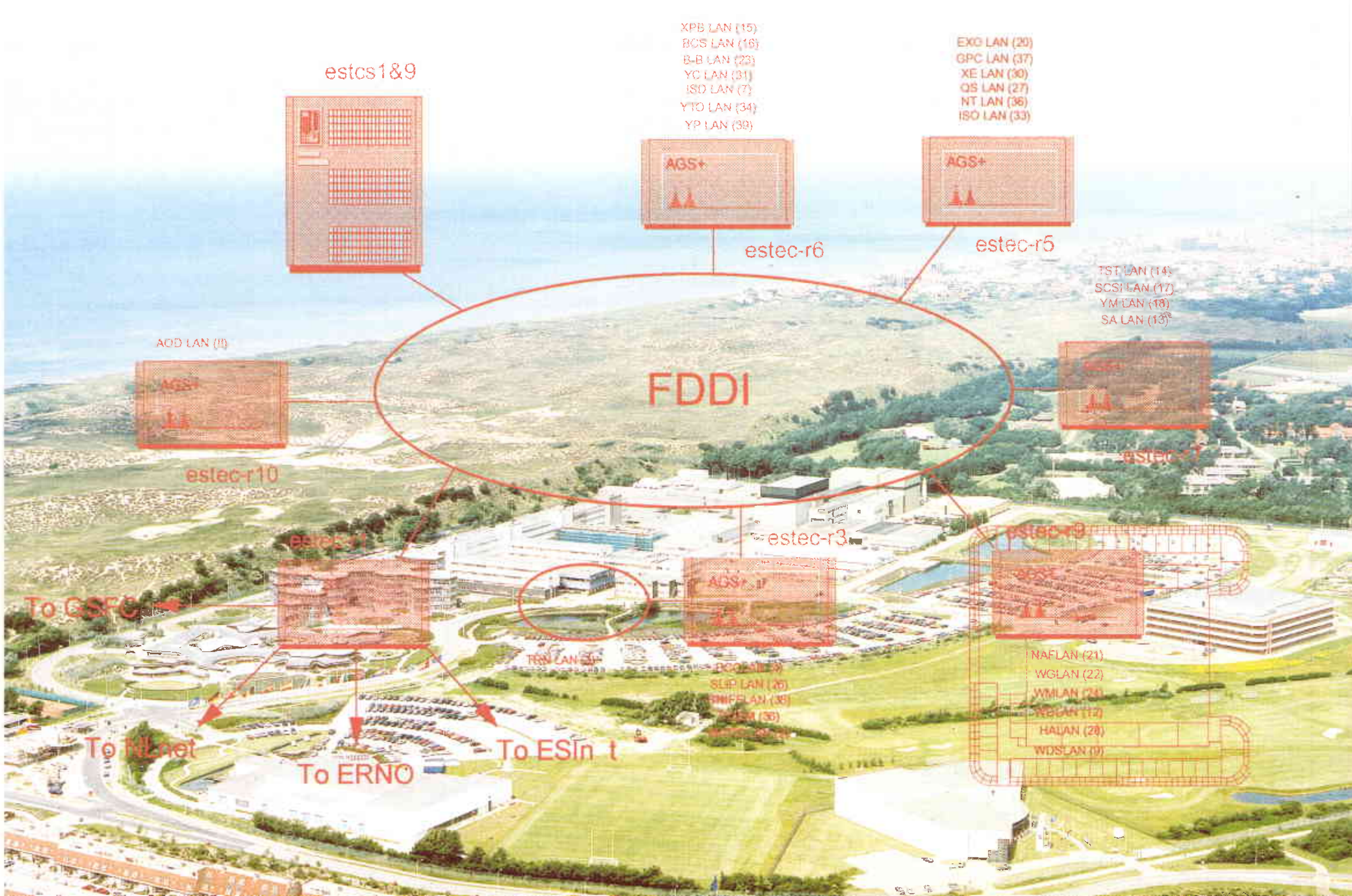
Networks

Traditionally, computer networks have been centred on providing point-to-point connections between individual users and the computer where they were executing their applications. This was true for mainframe computers, as well as for the first local mini-computers, both typically based on proprietary communications protocols.

The emergence of a 'distributed computing' concept, whereby different tasks (accessing data, processing, displaying, printing, etc.) were performed on different computers, while still appearing to the user as a single logical entity, created a completely new demand on the network infrastructure: rather than point-to-point connections, what was required was the ability to provide seamless access from a variety of platforms to a variety of computers and applications, using standard multi-vendor protocols.

A key event for the network infrastructure was the construction, and completion in 1992, of the new Erasmus building on the ESTEC site. The Automation and Informatics Department

Figure 1. Schematic of the ESTEC network infrastructure



now housed in that building is highly involved in providing technical support to the Project teams located in the main ESTEC complex, a few hundred metres away. This logistical fact highlighted the need for a structured network based on a high-speed site-wide fibre-optic backbone, and local subnetworks connected to the main backbone with wiring centres located throughout the ESTEC buildings. This concept, first implemented for Erasmus, has since been extended to many other areas and will cover the bulk of the ESTEC site over the next couple of years.

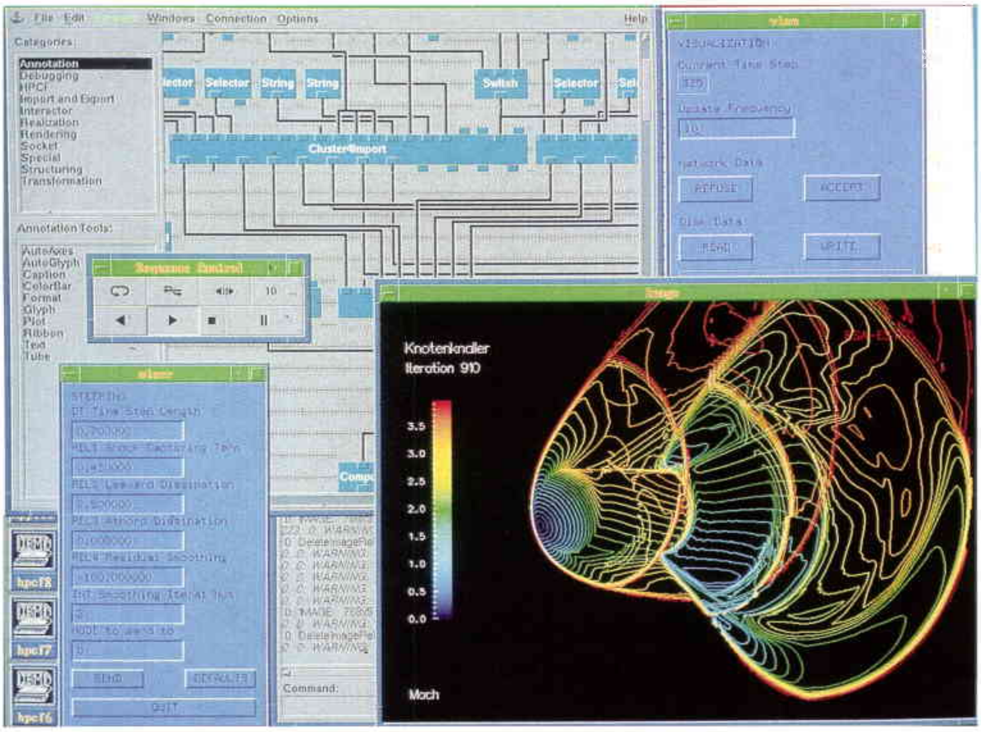


Figure 2. Example of a graphical user interface

Software

The trend in recent years has been towards 'open' software standards, allowing machines from different vendors to work together at the operating-system level (Unix, OSF, Posix), the user-interface level (X-Windows and OSF-Motif), and the network level (TCP/IP, OSI). This brings many advantages, including:

- interchangeability and flexibility, allowing selection of the most cost-effective platform at any given moment
- 'client-server' computing, which permits applications to be split into manageable components, thereby allowing for more flexible and scalable systems
- re-usability of equipment and portability of software
- wide acceptance, saving on software and re-training costs.

User interfaces

In the same way that the rapid developments in hardware technology have broken the 'ivory tower' of large centralised mainframes, so the steady evolution of more sophisticated tools and techniques, combined with the power of user-friendly graphical interfaces, has greatly reduced the need for traditional specialist computing skills. Until just a few years ago, in order to be able to use computer programs for their work, engineers either needed to be highly 'computer literate' or required the support of a number of specialists.

Today, they have a wide choice of 'off-the-shelf' components, covering aspects ranging from data preparation and modelling to graphical visualisation and analysis, which can be selected in the most appropriate combination for each task to be performed.

Distributed computing infrastructure

The in-house network

The above-mentioned wide choice of applications, which can often be distributed over a variety of hardware resources on the network, can lead, on the other hand, if not adequately supported by a reliable and flexible infrastructure, to a staggering growth in overall complexity.

One such case occurred a few years ago when, in the absence of consistent support for 'open' communication protocols such as TCP/IP (the central support being traditionally focussed on 'proprietary' protocols of mainframe computers, such as IBM's SNA and Digital's DECnet), simple operations like exchanging files, redirecting printed outputs to another host computer, or exchanging electronic-mail messages with external institutions were not yet provided as standard network services, and engineers had to expend considerable efforts in getting these capabilities established, maintained, or fixed when not working properly.

Today's ESTEC network infrastructure is seen, by general admission of those interviewed by TNO–TPD, as an essential resource for the everyday work of engineers and scientists, which can be maintained at the required service level only if centrally managed and coordinated.

High-performance computing

The migration of computing power to the user's desktop – or even laptop! – thanks to VLSI (Very Large Scale Integration) chip technology has undoubtedly turned fast processing into a portable commodity. Together with the exponential growth in processing power per unit of cost, a whole collection of multimedia devices have also been added to the core functionality of PCs and work stations in order to enhance the user interface.

The integration of a group of engines (graphics cards, modem connections, network adapters, fax, phone, wireless devices) together with a powerful processor has created a new type of multipurpose machine that has unlimited resources virtually built-in, thanks to its connectivity possibilities.

Although a first level of computing power is available in a compact form, however, the multitasking essence of these computers does not allow the provision of the computational power necessary for aerospace simulations and studies. When it comes to advanced calculations, computing resources with orders of magnitude of extra power are needed. Examples at ESTEC are the mainframe three-vector processor and the recently installed 'High-Performance Cluster Facility', a cluster of fast work stations which can be used as a single computing resource.

The goal with these mid-range computing facilities is to provide the ESTEC engineering community with access to high-performance computing as an enabling technology for advanced applications. They are not intended to fulfil all the computing requirements resulting from the application of advanced simulation techniques within the major space projects. In line with the Agency's Industrial Policy, large-scale 'production work' of this sort will be executed primarily by Industry in the ESA Member States.

In addition to the obvious benefits of the faster response of the high-performance computer facilities, the user is relieved of the burden of having to cope with the time-consuming activities associated with the maintenance and administration of a computer server. The opportunities for time savings and cost reductions inherent in the distributed-computing model are easily quantifiable beforehand when defining a financial plan for a large space project.

Data management and security

In an effort to provide transparent and cost-effective data-management services to the desktop, storage technology has evolved in parallel with the basic network infrastructure. The possibility of storing huge amounts of data on ever more complex and denser media has led to the proliferation of 'repositories' containing hundreds of gigabytes of data. These are basically used for interactive work and reflect the need for essential associated services such as database management, file administration, backup, archival and security.

Despite the fact that these services have reached an important level of automation, professional support is needed to ensure the necessary continuity and maintenance that turns these high-performance storage resources into a transparent enabling facility for the aerospace engineer.

The current trend observed in most research centres – e.g. NASA, CalTech and CERN – seeks to establish a harmony between the network topology and the distributed high-performance storage system where basic high-volume resources (tape silos, optical disks) are logically linked to the fast-access local data servers and monitored by highly specialised coordinating staff.

In addition to the obvious economies of scale that a meta-storage system provides, both capacity and flexibility are orders of magnitude greater than with isolated storage on office machines. As long as the site storage system is treated as a single entity, the possibilities of synergy in a single-headed control team offer substantial savings in operating costs.

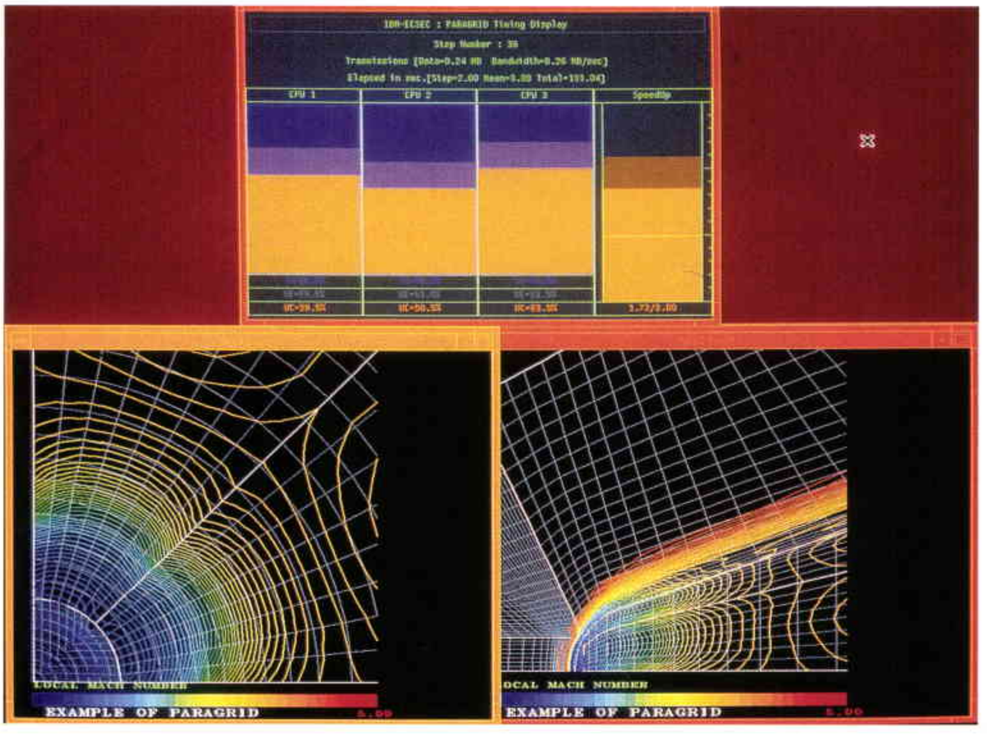


Figure 3. Application of parallel computing to CFD simulation

Special facilities and resources

The impressive growth in computer technology in recent years has generated a number of 'niche' activities with tremendous potential for the aerospace industry. New opportunities (network integration, parallelisation, computer art, scientific visualisation) have offered new and better ways of dealing with old problems and unresolved questions. In this context, some high-level computer services are uniquely adapted to a vertically integrated strategy meant to address the production of finished products and complete services.

Figure 4. Computer-animation frame of the Hubble Space Telescope from the ISD VisuLab

One such example is the ISD VisuLab, which offers a unique suite of computer-animation skills which the engineers can call upon to enhance the quality of their technical presentations. The parallelisation of computer programs for faster execution, consultancy and assistance on integration issues, and remote work-station management are other examples of new areas where great benefits can be gained from a clustering approach.

Future prospects

Despite the rapid changes that have occurred in the computing industry over the last three decades – the price/performance ratios of processors and storage technology dropping by an order of magnitude every 2–3 years, and at the same time the life-span of hardware products shortening to some 3–5 years – information technology has until recently maintained a comparative degree of continuity. The typical information-technology infrastructure was dominated by a large centralised computer complex, and the evolutionary path was focused on maintaining operational stability while planning the growth of the deployed resources according to a relatively predictable growth in user requirements.

Only since the 'desktop revolution' in the late eighties have stability and homogeneity given way to diversity and heterogeneity. The role of the information-technology centre has changed from that of managing hardware and software platforms, which were completely under its own control, to one of providing support to a distributed environment that is largely determined by the independent choices of the users; from that of being the sole provider of information-technology resources in a monopoly position, to that of being the provider of the 'enabling technology platform' which permits a number of logical services to be distributed over different physical resources.

In the old centralised model, the user was confronted with a single, stable and professionally maintained environment. The migration of computing power to his desktop gives him/her completely new opportunities, unimaginable until just a few years ago, but it also poses new threats. An engineer might be able to perform more analysis locally, but may also be spending considerable time attending to the details of the system itself, instead of concentrating on his/her prime task.

Products and tools are beginning to be available from many vendors which adhere to the Distributed Computing Environment standards defined by the Open Software Foundation (OSF-DCE). They provide a wide range of support functions previously available only for central mainframes, such as:
- single-point user registration, authentication and security
- a single filing system distributed across the network and on different storage media, but centrally administered and maintained
- tools and facilities for performing typical system-management tasks, such as software installation, from a central location.

ISD has already started pilot installations of some such products, and will soon be offering end-user services based on them. The challenge for ISD is to create, by deploying new technology and at the same time by preserving its legacy of professional experience, the conditions needed for successful 'centrally supported decentralisation'.

The ESA Earth-Observation Guide and Directory Service

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The ESA Earth-Observation Guide and Directory Service (GDS) is a new on-line information resource describing Earth-observation data, systems and applications. It carries details about ESA's remote-sensing programmes and satellite missions and provides material of interest to those working with the data products from these missions. GDS also carries information for newcomers who are interested in the science and exploitation potential of Earth observation.

The information gathered in GDS is accessible in the form of full-text documents, images, graphics, audio and animated image sequences. The Service is also a network entry point from which a number of other information systems can be located and, in several cases, also accessed.

Introduction

A growing number of international satellite systems are providing ever-expanding capabilities for observing the Earth and its environment. The consequence thereof is a growth in the variety and volume of the valuable geophysical data produced. The systems that are converting the data into useful information and making it accessible to users are also increasing in both number and complexity.

There is extensive knowledge about how these systems work and how to apply the available Earth-observation data both scientifically and operationally. The problem, however, is that this knowhow still resides with a comparatively small group of specialists. It is critical to the future success and continued development of Earth observation from space that a wider multidisciplinary community be made aware of the potential of Earth-observation technology and the usefulness of the information being derived from satellite data.

ESA has developed and is currently operating the ERS-1 and Meteosat series of satellites, together with the ground infrastructure for the generation and distribution of related data products. The Agency also acquires, processes and distributes data from the non-ESA Landsat, MOS, JERS, NOAA and other missions. For all of these missions, ESA has the mandate to provide information services that help users in accessing the data products and support their utilisation.

These services use various channels to communicate this information to users: publications in the form of journals, brochures and articles; user-services staff informing on a person-to-person basis; mailing of newsletters; bulletin-board services; CD-ROM-based information packages; conferences and training courses, etc. The existing ESA 'on-line' information systems represent an essential information resource and the Earth-Observation Guide and Directory Service (GDS) has been newly established as an important addition to them.

GDS is a multimedia database, accessible via the major wide-area computer networks. It provides the comprehensive information needed for a better understanding of the essential characteristics of today's Earth-observation programmes, satellite missions, sensing instrumentation, and data products and their utilisation/application. The current emphasis within GDS is on missions handled by ESA, and on ERS-1 in particular.

Finding, understanding and ordering data

A primary function of GDS is to help users find the Earth-observation data of particular interest to them. It therefore contains a *directory of data sets* that allows a quick determination of their nature and availability. In addition, it contains a *guide* that offers more detailed information suitable for evaluating the potential usefulness of a particular data set.

Figure 1 shows how these directory and guide functions relate conceptually to the 'inventory' and 'browse' facilities of more conventioanal information bases.

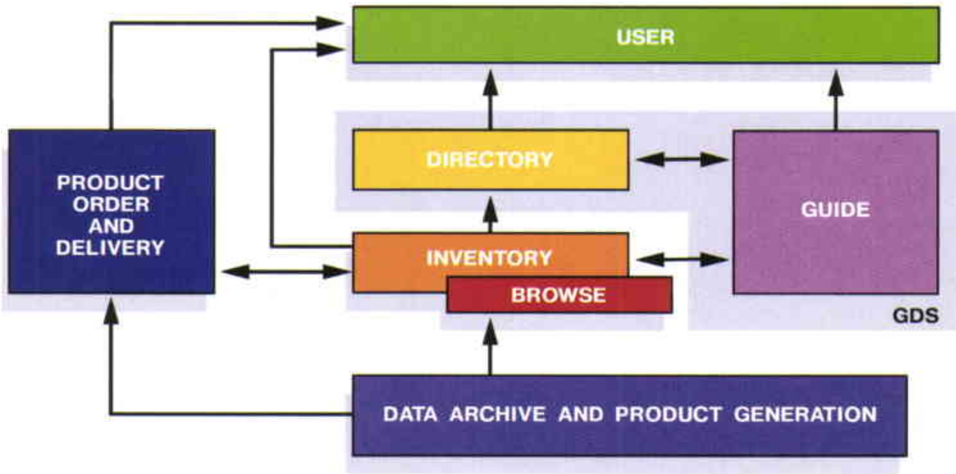

Figure 1. Relationships between Earth-observation user information services (guide, directory, inventory, browse) which help the user in finding data and understanding its usefulness before ordering the data products

Data-set and data-product information

As already mentioned, the GDS information base includes a directory of Earth-observation *data sets*. All Landsat images stored in ESA archives, for example, are considered to be a single data set. There are currently more than 2500 data-set descriptions stored in GDS, collected in an on-going international effort (the CEOS International Directory Network initiative) from data producers all over the World.

A search in GDS using keywords from controlled-keyword category lists or using just any text word(s) will provide a full-text description of relevant data sets (Fig. 2).

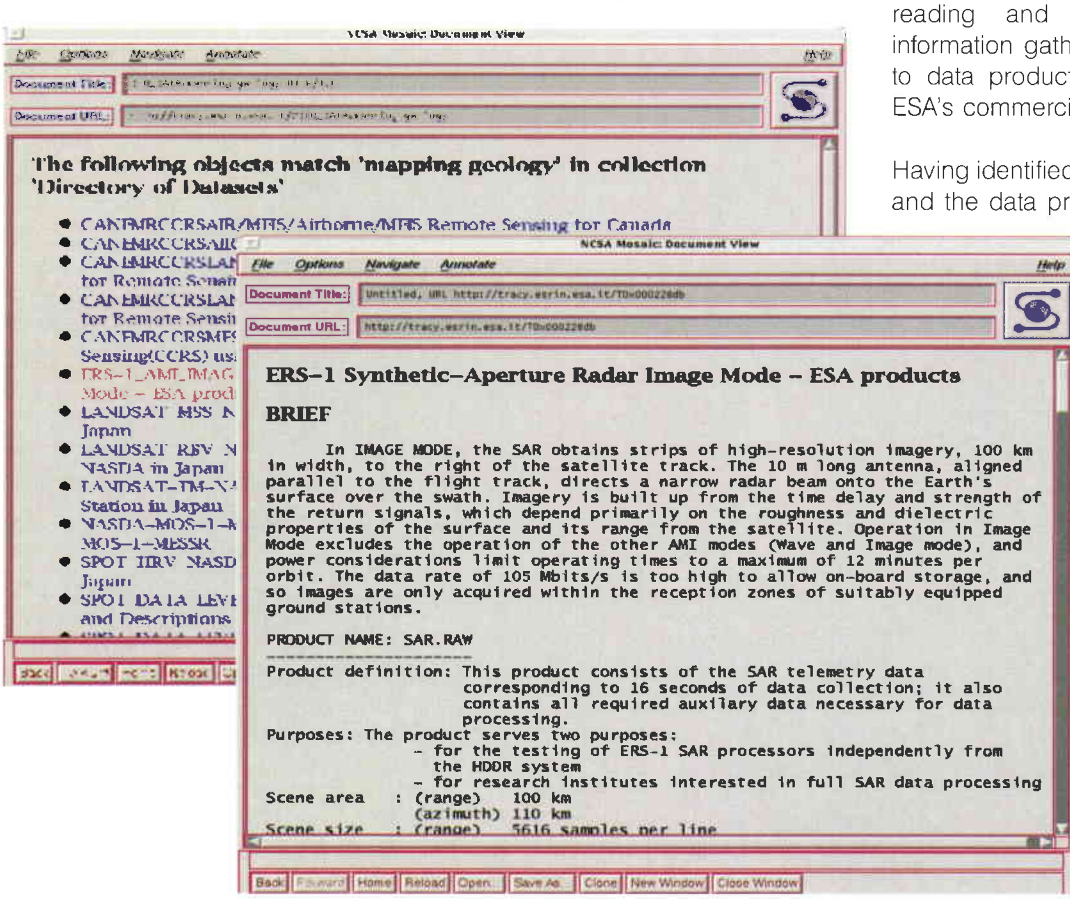

Figure 2. Information contained in 'directory of datasets': results from a search using keywords and a brief description of a dataset containing information on associated data products (Document viewer software: NCSA Mosaic for X-Window system)

This description includes the attributes of the data set, an indication of its geophysical application potential, associated data-centre information, names of contact persons knowledgeable about the data set, and key literature references for further reading.

Normally, Earth-observation data are delivered to users in the form of specific 'data products'. GDS therefore provides data-ordering information in the form of product lists, prices, order and delivery conditions and processes, etc. It also contains the product media and format specification documentation and information about any available software for reading and analysing the data. The information gathered in GDS relates primarily to data products that can be ordered from ESA's commercial data-distribution partners.

Having identified in GDS the data set of interest and the data products associated with it, it is essential before ordering to check whether the raw data required for the generation of a particular data product have been acquired by the satellite, e.g. if an individual satellite image, covering a particular geographical area, was taken at a particular point in time, and what percentage of the image was cloud-covered.

The 'inventory' databases collect this information in a systematic manner by storing often millions of records, each containing the parameter values that characterise the individual data 'granule'. GDS itself is not an inventory service, but provides information on how to access such services. Currently, some 60 on-line inventory services operated by different institutions around the World are referenced in GDS. This directory of on-line services is collected and maintained within the CEOS International Directory Network coordination initiative. For a number of inventory services, GDS can also establish a telecommunication connection to the service, if the user so wishes.

In addition to providing easy access to inventory services and information about data-product ordering and delivery, GDS offers a wealth of other very useful information, as outlined below.

Satellite, sensor and ground-facility information

GDS contains information on the spacecraft and platforms that carry the remote-sensing instrumentation for Earth observation. A knowledge of these instruments and their operating principles is often useful for understanding the characteristics of data sets and for the proper application of related data products. The GDS information base includes two directories containing source/spacecraft/platform and sensor/instrument descriptions. Photographs, technical drawings and occasionally animations of satellite/instrument operating principles supplement the descriptions.

Earth-Observation User Information Services

Information provided by individual services, defined according to recommendations of the Committee on Earth-Observation Satellites (CEOS):

Directory – brief 'data set' descriptions (no information about individual data 'granules' in set, but of the set as a whole), suitable for identifying data and the data 'products' offered

Guide – detailed information suitable for assessing the application value or usefulness of data sets (not of individual granules)

Inventory – attributes of individual data granules required for data-product ordering.

Browse – visualisations of individual data granules, typically limited in size or resolution, for assessing their type and quality prior to ordering the full data granule

The European ERS-1 satellite, its payload and the distributed ground facilities are described in great detail in a special multimedia document collection within the GDS information base (Fig. 3). Further information about the European Earth-observation space and ground infrastructures is in preparation.

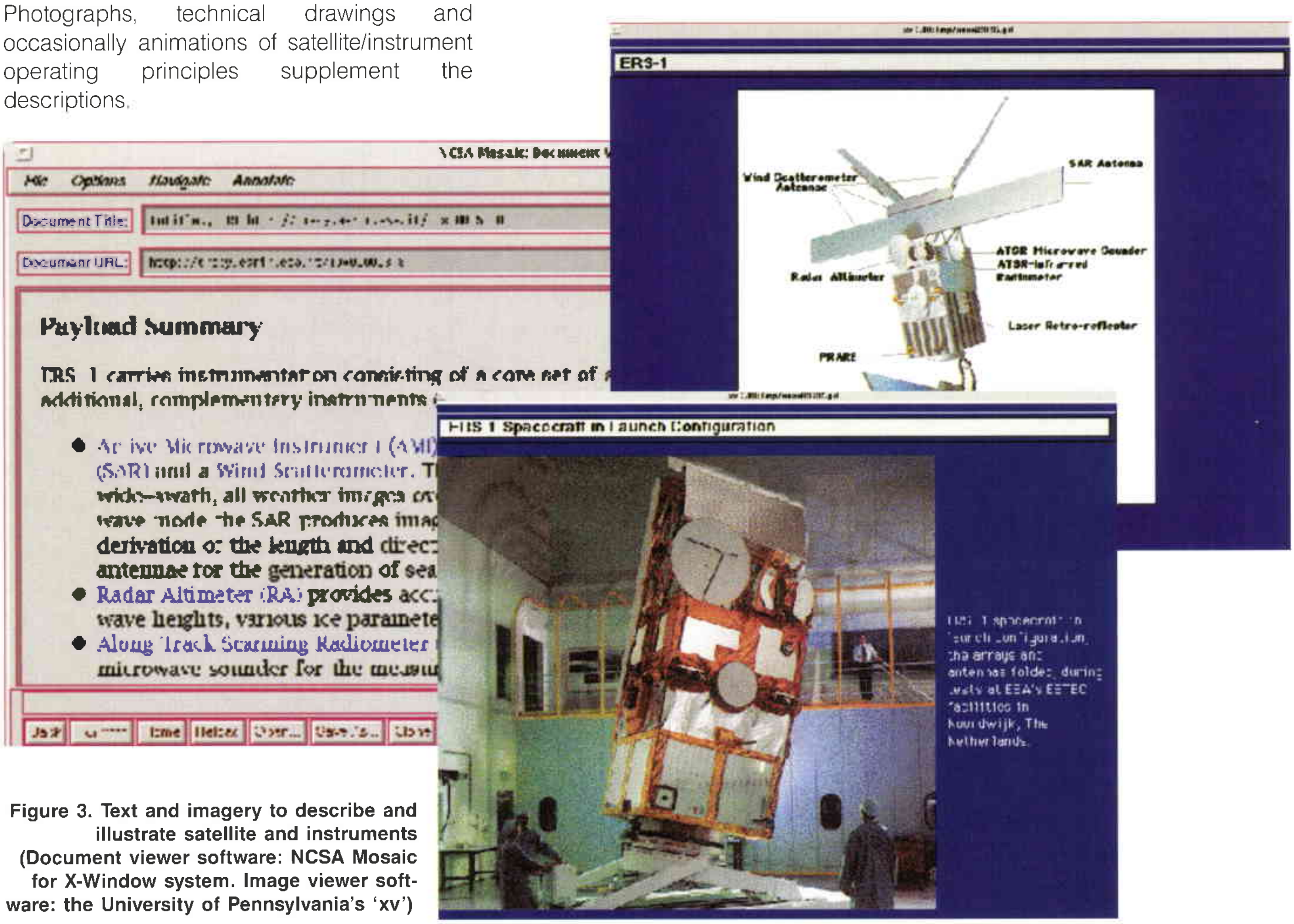

Figure 3. Text and imagery to describe and illustrate satellite and instruments (Document viewer software: NCSA Mosaic for X-Window system. Image viewer software: the University of Pennsylvania's 'xv')

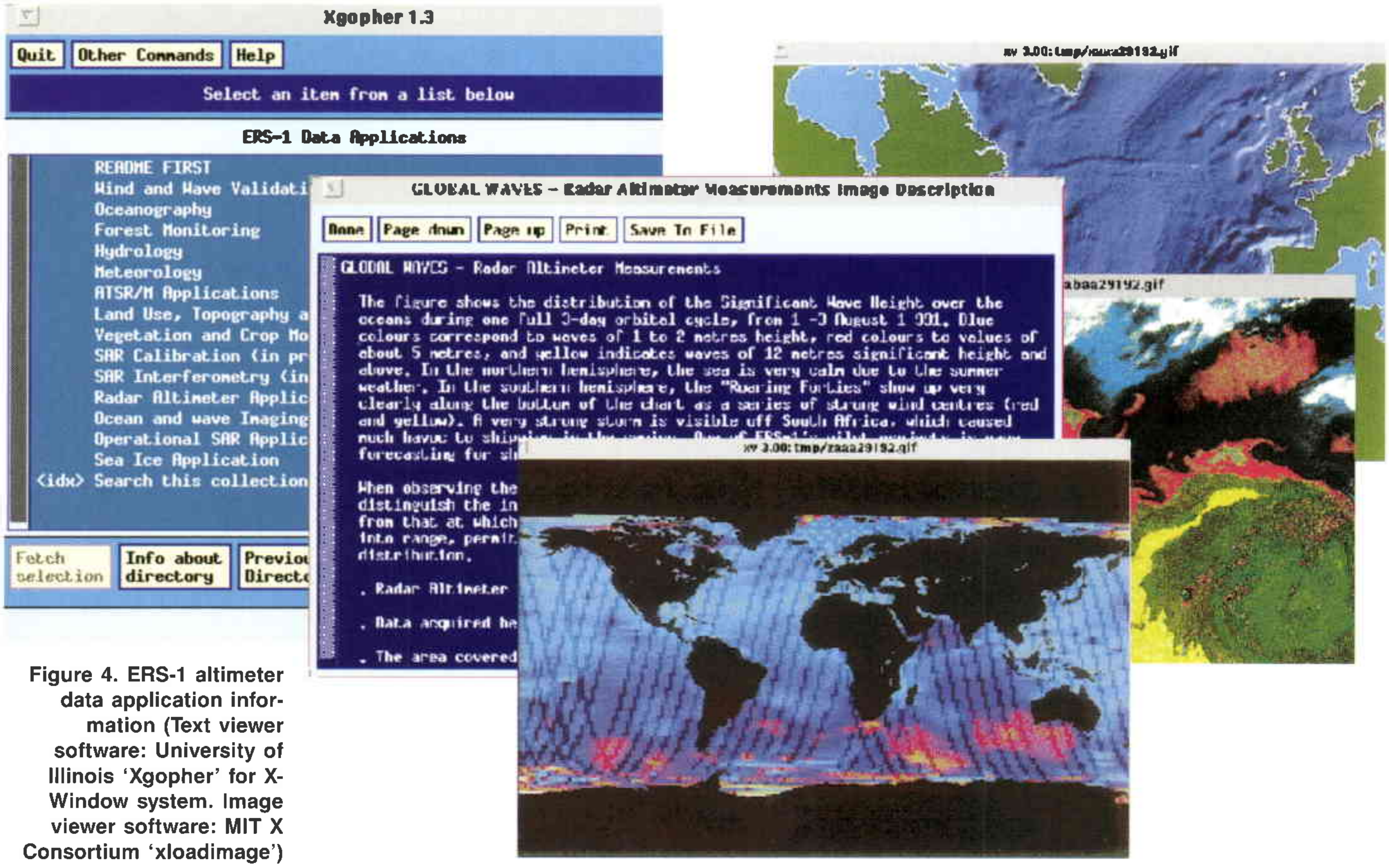

Figure 4. ERS-1 altimeter data application information (Text viewer software: University of Illinois 'Xgopher' for X-Window system. Image viewer software: MIT X Consortium 'xloadimage')

Data application information

A further role of GDS is to serve as a 'data user guide', communicating achievements in all areas of Earth-observation data application. GDS is assembling expert judgements on the usefulness of existing 'Earth system' data products, exclusively or partially derived from satellite observations and available to the wider user community. Full-text documents are to be found in the GDS information base which are written in a tutorial style, introducing terms and concepts important for both understanding and using the data. Technical papers on specific data applications will be included at a deeper level.

Special sections in the GDS information base will contain summary documentation on processing algorithms, calibration and validation procedures being applied to the satellite measurements. Other sections will contain demonstrations of typical and widely accepted applications of this information in a number of fields, together with illustrative examples. There could also be a place in the GDS information base for proposals for pilot demonstration projects aiming to develop operational applications.

Currently, the GDS 'data user guide' information is somewhat fragmented and mainly covers descriptions of ERS-1 data applications (Fig. 4). The collection of further data-application information for GDS is envisaged as a cooperative project involving the identification and critical assessment of related technical literature by international scientific programmes and by agencies interested in informing a broad audience about Earth and space data applications. ESA wishes to encourage these programmes and institutions to participate in the initiation and coordination of such an information cooperative.

Institutional and organisational information

A 'data centres directory' in GDS describes currently some 80 organisations providing Earth-observation data products. It describes each data centre's focus, contact information, access procedures, and data ordering, price and distribution policies.

Information in GDS

- Dataset and data-product descriptions at various levels of detail.
- Satellite, sensor and ground-facilities descriptions
- Data application information, tutorials, scientific papers
- Data user manuals and full ancillary and auxiliary data
- Institutional and project information
- Mission news and help-desk information.
- Product ordering instructions and order-form templates
- Shareware software
- Pointers to relevant internationally shared information sources
- Inventory log-in information and user manuals
- Calendars of events.

GDS gives information about ESA itself and about ESA's establishment in Italy, ESRIN, from which the GDS service is managed and operated. Newsletter-type information will be regularly updated by ESRIN's Earth-Observation User Services to inform customers about the latest status of the ERS and other, non-ESA missions.

Descriptions of international scientific research, validation and exploitation programmes will also be incorporated into the GDS information base. This data will be complemented by descriptions of scientific campaigns or projects.

GDS has already started to collect names of and contact information for researchers and institutions actively participating in the ERS-1 project. Potentially, GDS could become an on-line 'yellow pages service', systematically providing descriptions of European laboratories and institutes active in Earth observation, the people involved, their specialisations and the available research capabilities and facilities.

Software repository
GDS is also providing descriptions of public-domain software products made available by ESA or its partner organisations to the Earth-observation community. Screen dumps showing the user interface and processing results are presented to illustrate the software's functionality. The software itself is stored in specific file-transfer directories, from which it can conveniently be copied to the user's own computer.

ESA will also use GDS to announce the availability of its CD-ROMs containing, for example, systematic collections of browse images and display tools.

ERS-1 information in GDS
GDS is intended to be a multi-mission information service, but at present the primary focus is on the European ERS-1 mission. GDS is used by the ERS Help Desk as its main on-line publishing and announcement system. It contains digital versions of the ERS-1 System and Product-Specification Manuals, as well as the ERS User Handbook and material from various ERS-1 brochures and articles. Very importantly, GDS will carry regularly updated mission and Help Desk news, as well as the complete set of 'ERS User Sheets' (also distributed by mail).

The top-level GDS menu of the current collection of ERS-1 information items is shown in Figure 5.

A first special-interest group, the ERS-1 Fringe SAR Interferometry Working Group, has started to exchange and publish news and research results in a coordinated manner via GDS. To support this group, ESA is loading into GDS all 'INSAR orbit listings' (currently some 10 000 files), thereby affording convenient access to up-to-date information.

The on-line ERS CUS (Central User Service) system contains the inventories for the European ERS and the Japanese ERS-1 missions. For the European mission, CUS also delivers mission-planning information and

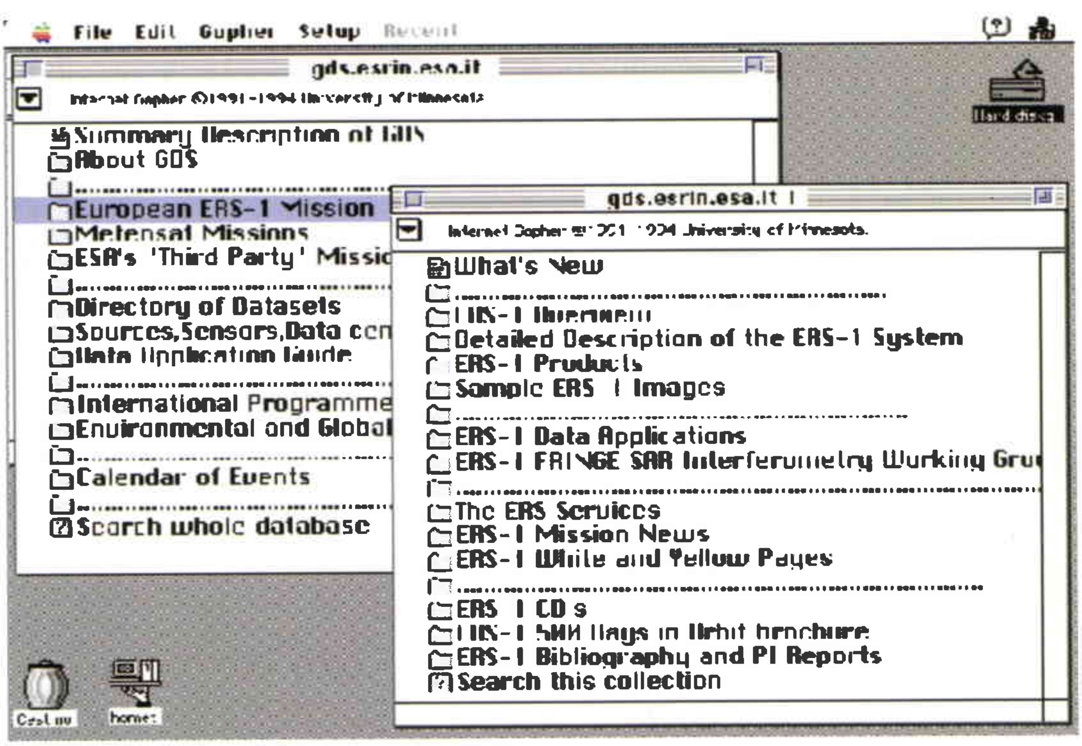

Figure 5. ERS-1 menu called from the GDS Main Menu (Viewer software: University of Minnesota's 'Turbo Gopher' for Macintosh)

offers product-ordering functions. Since CUS can be accessed by authorised users only, GDS does not support direct computer links to CUS, but does provide all user-handbook information for CUS users and for all those who want to order ERS-1 products.

Relationships with other ESRIN services
In addition to the ERS systems mentioned above, GDS also has 'links' to other existing services at ESRIN. One of these is the well-known LEDA service (on-Line Earthnet Data Access), which has a long tradition of providing on-line access to ESRIN's Landsat, NOAA, MOS and Nimbus-7 inventories. LEDA is now linked under GDS and is therefore available to all in a non-restricted way. The LEDA User Manuals are also available via GDS for on-line browsing or downloading.

The 'ESA Prototype International Directory' (ESAPID) is the forerunner service of GDS with regard to the 'directory of datasets' and some supplementary information. ESRIN will continue to operate ESAPID as the agreed mechanism for the automatic exchange of directory updates between ESRIN, NASA and NASDA. Direct user access to the ESAPID service will, however, be disabled soon, when the new GDS service takes over this role.

The 'European Space Science Information System (ESIS)' has many things in common conceptually with GDS, and is even partially built around identical technology. ESIS has been aimed exclusively at space-science users, e.g. astronomers, whereas GDS is targetted at the Earth-observation community.

The 'ESA Information Retrieval Service' (ESA-IRS) delivers on-line bibliographical references and factual data which may also ultimately be of interest to the Earth-observation data user. This ESA-IRS information is therefore complementary to the information contained in GDS. Consequently, users can find descriptions in GDS of ESA-IRS, summary information on Earth-observation-relevant files offered by ESA-IRS, as well as instructions on how to gain on-line access to this particular information.

Pointers to internationally shared information
GDS is targetted to maintain information primarily on Earth-observation programmes and satellite missions in which ESA is actively involved. The GDS information database therefore contains 'pointers' to networked external information sources on other missions provided by other organisations. GDS is designed to help users establish computer access to these resources at the highest possible level of 'inter-operability'.

Where proper inter-operability protocols have been implemented by the target service (e.g. the Internet World Wide Web protocol HTTP), the user connection is largely transparent. Otherwise, GDS automatically performs a log-in to the target service and the user interacts with the alphanumeric user interface offered there. As GDS is a non-profit service and uses Internet or DECNet/SPAN networks that are free-of-charge for non-commercial traffic, this automatic log-in service can also be offered free.

GDS also contains many pointers to other Earth-observation user information services. There is a massive amount of information available on today's networks, most of which is not relevant for Earth-science applications. GDS only includes pointers to relevant external sources (currently about 100) and therefore offers a 'pre-digested' picture of the available information (Fig. 6).

WWW and Gopher
GDS employs a technology known as 'hyper-media', which makes it easy to combine text, graphics, sound and even video into a single electronic document. These documents can then be linked to each other so that a click on the mouse at the linking pointer in one document will cause a related document to appear. The collections of documents thereby form a so-called 'web'. This web is worldwide because the links between documents can exploit the Internet global network.

The web's technology was created in 1989 at CERN, Europe's high-energy physics laboratory, and was given the name 'World-Wide Web' (WWW). The software is freely available over Internet. The enthusiasm of thousands of volunteers who built WWW information servers and the availability of the client software 'Mosaic' developed by the US National Center for Super-computing Applications (NCSA), have made WWW one of Internet's most popular technologies.

Seen from WWW, GDS is just one of hundreds of information servers around the World. This offers the advantage, however, that the technology and user tools required to interact with GDS are already widely known and distributed on Internet.

A very similar wide-area information technology is the 'Gopher' system developed by the University of Minnesota. Since it has been available on Internet longer than WWW, it

Figure 6. Information on the World-Wide Web (WWW) relevant for Earth-observation data users. GDS provides pointers or access information for the on-line sources (Document viewer software: NCSA Mosaic for PC and MS-Windows)

serves an even larger community. GDS can also be interrogated without restriction by this community, using the common access tools.

The software needed by users to access GDS from the WWW or Gopher can be obtained as shareware or public-domain packages for a range of computer platforms (Unix/X Windows; PC/MS Windows, Macintosh, etc.). All the screen displays shown in this article are examples of the graphical user interfaces supported by the various free software packages. In order to use this attractive software, the user's computer must be connected to Internet.

GDS also offers 'log-in' access to users who are on the DECNet/SPAN or PSPDN (X.25) networks. This method of access is also available to users who are on Internet, but who do not have client software installed.

GDS server technology

Figure 7 shows how users interface with the GDS system via the access networks and the client tools or terminals that they are using. The 'Hyper-G' software developed for ESRIN by an Austrian–Italian university and industry team, forms the core of the hypermedia server. As well as making GDS look like a WWW or a Gopher server, depending on which software the user has, Hyper-G also includes the user interface module for terminal log-in. This allows the log-in users of GDS to access information on other Gopher, WWW and WAIS servers (WAIS stands for 'Wide-Area Information System' and is another Internet-based technology).

The second part of the GDS system is a server for file transfer using the standard Internet 'File Transfer Protocol' (FTP). Files provided by this server are downloaded to the user's computer either by entering FTP commands from a terminal or by using more comfortable client software, so-called 'ftptools'.

The NCSA Mosaic client software has the convenient feature of being both a hypermedia navigation tool and an FTP tool. Consequently, a Mosaic user can retrieve documents and data from both the GDS hypermedia server and the GDS file server without switching tools.

Status of the service and future plans

GDS has entered the initial operational phase and can be fully tried out by users. Many individuals within GDS's target user community have started to use the service in their daily work. The feedback being received from these people is very encouraging, indicating that the GDS concepts and implementation as a whole are on the right track.

It is ESA's plan to further develop the GDS information service in a flexible way, such that user feedback and information needs can be fully taken into account. Users are invited to provide their reactions as to how useful they find the GDS information base (assessment of quality and adequateness of information content, wishes for further material, etc.) and how they like the access methods and system features (getting into the network, using client software, quality of on-line help texts, etc.). The GDS user support staff (see accompanying panel for contact information) are keen to receive and act upon this user feedback.

On the technology side, the future development of GDS will be designed to keep up with

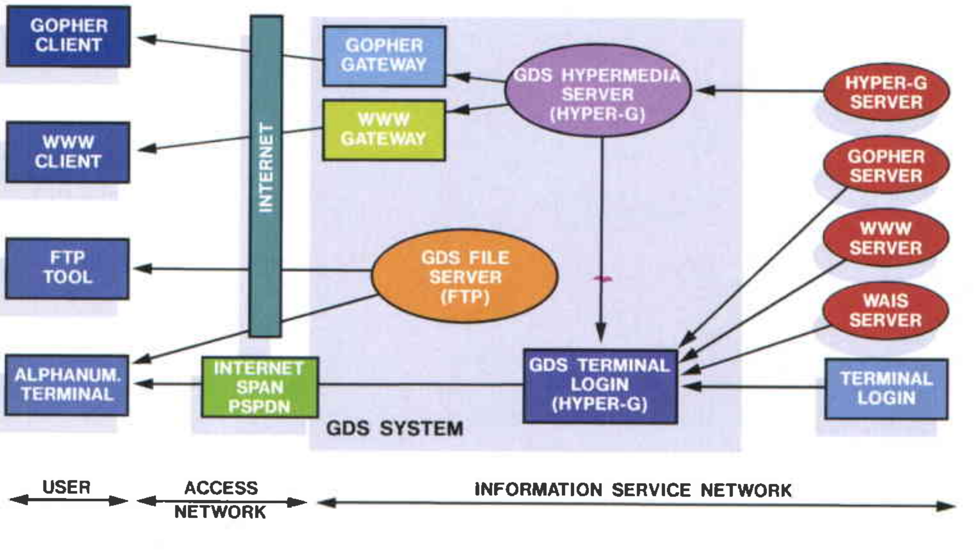

Figure 7. GDS system access tools, interoperable links to other servers and network connectivity

the rapid evolution in WWW, Gopher and similar technologies. A further challenge will be the more seamless integration of GDS with ESA inventory, browse, mission-planning, order and bibliographic services at ESRIN, and with Earth-observation user information services elsewhere.

Acknowledgements

The author would like to thank his colleagues in ESRIN's Environmental Data Network Section for their support during the GDS system-definition process. The technical design of GDS was an ESRIN Investment Plan activity, contracted out to Intecs Sistemi (Rome, Italy) and Joanneum Research (Graz, Austria). Particular thanks go to members of this industrial team, Z. Bjelogrlic, F.Mungo (both with Intecs), F. Kappe and G. Pani (both with Joanneum Research), and to S. Schiarini (VitroCiset) and P. Landart (Sisma), both of whom work at ESRIN, for their considerable efforts during the initial GDS database loading. The reviewing of this article by the members of the GDS Information Configuration Board is also gratefully acknowledged.

GDS Access Coordinates

Access via World-Wide Web (Internet) – Navigate to Document URL 'http://gds.esrin.esa.it/'

Access via Gopher (Internet)
– Open the following Gopher item: Gopher type '1', host 'gds.esrin.esa.it', port '70'

Access via FTP (Internet) – Type 'ftp gds.esrin.esa.it', username: 'anonymous', password: your e-mail address

Log-in access (Internet) – Type 'telnet gds.esrin.esa.it', username: 'gdsuser', no password required

Log-in access (SPAN) – Type 'set host 29526', user name: 'gdsuser', no password required

Log-in access (PSPDN) – Dial internat. NUA +2222641017461, user name: 'gdsuser', no password required. Please ask GDS User Support for your national NUA in Europe or Canada.

User support and help
ERS Help Desk, ESA/ESRIN, Via Galileo Galilei, I-00044 Frascati, Italy; Phone +39 6 94180 600; Fax +39 6 94180 510; e-mail helpdesk@ersus.esrin400.esrin.esa.it

The Columbus Utilisation Information System 'CUIS'

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The Columbus Utilisation Information System (CUIS) has been developed by ESA with the aim of offering the scientific community a tool to complement their existing means of communication, particularly for communicating, retrieving and exchanging information in preparation for space missions.

Introduction

From its early development, CUIS was designed as a user-friendly system that could be added to existing equipment, based on two major standards: the IBM PC and the Macintosh. To be complete, the system had to offer a global service ranging from simple message exchange, to the creation and exchange of comprehensive documentation. The two main components of CUIS, the General Communication Subsystem and the Documentation Retrieval Subsystem, are therefore based on an 'open architecture' that guarantees system flexibility and adaptability to a wide variety of users.

Other innovative features of CUIS cover such services as Electronic Questionnaires, which are extremely important in the context of 'Calls for Experiment Proposals' and 'Announcements of Flight Opportunities'.

Looking to the future, this community of space experimenters can be expected to evolve rapidly. Missions are becoming more and more interdisciplinary in nature and much of the equipment being taken into space is being developed in the form of multi-user facilities. The need for interaction and communication between the science and operation teams involved in such missions is therefore increasing rapidly, with a distinct trend towards the decentralisation of the experiment operations. The scientists are tending to work from their home institute or from the nearest 'User Support Centre', in contrast to the Spacelab-type scenario of the eighties when the participating scientists 'lived' at NASA's Payload Operation Center in Huntsville (USA) for the duration of the mission.

In addition to catering for the sophisticated remote operations scenarios that will characterise future missions, CUIS serves to enhance the dialogue between users in different time zones by incorporating a Bulletin Board and Electronic Conferencing Service. Last but not least, CUIS can provide quick access to hundreds of thousands of pages of operations guides and payload manuals that the payload scientists need to access before, during and after the missions.

What does CUIS offer?

CUIS has been designed to cope with the communication and information-sharing needs of those working on the Columbus Programme. The main goals currently being fulfilled are firstly to unite the Columbus User Community in communications terms, secondly to facilitate access to the Columbus technical documentation, and finally to collect and analyse the Columbus Experimenters' requirements or experiment proposals.

One of the characteristics of the Columbus community is that it is spread out all over Europe, and even around the World. These users have all kinds of computer infrastructures and networks, ranging from small stand-alone personal computers to powerful work stations connected to the major international networks.

CUIS provides the necessary tools to connect users with such disparate infrastructures, using the user's existing computer and communication equipment as much as possible. Therefore, what the user installs and uses depends on his current equipment. Users with little or no network infrastructure are connected

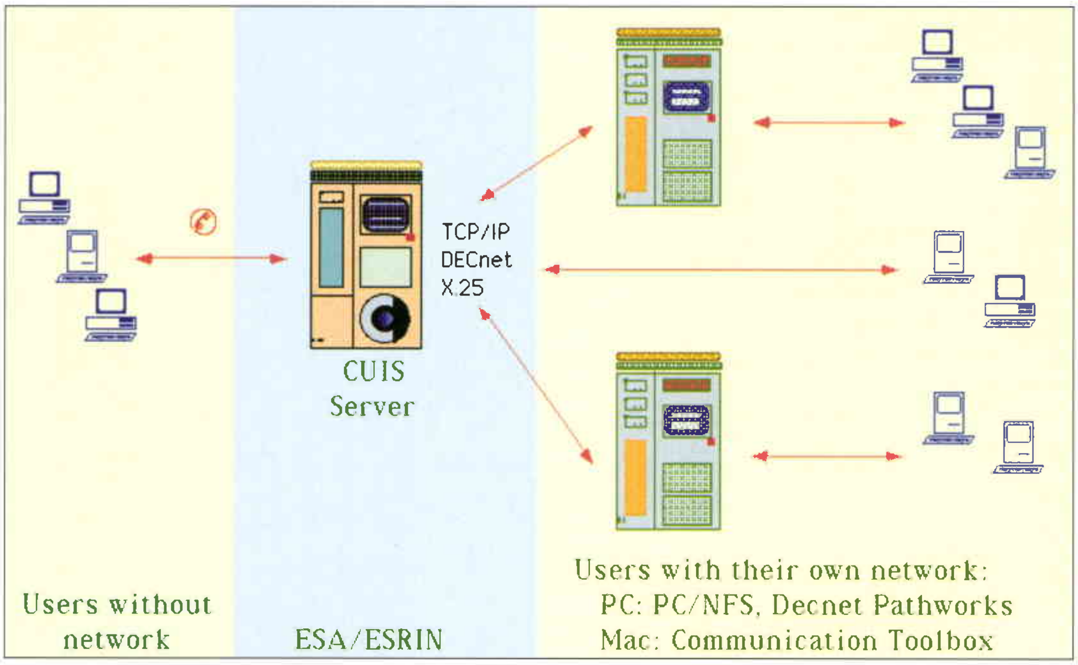


Figure 1. Different types of connection to CUIS

together with a complete system offering general communication services by means of a standard telephone line; users who already have their own network infrastructure and communication services generally prefer to use the CUIS Accessories only as a bridge.

The General Communication Subsystem is the core item for electronic communication between those not necessarily connected to ESA networks; these services include Electronic Mail, User Directories, Conferencing and Bulletin Board via a simple telephone line.

The CUIS Accessories are designed to link CUIS with off-the-shelf applications like mail systems or even simple terminal emulators: they allow the accessing and managing of CUIS and non-CUIS address lists for the user's own electronic mail infrastructure. Instead of providing an additional mail system, it offers all the tools necessary to use the CUIS User Directories. Moreover, users provided with off-the-shelf tools (e.g. 'Pathworks' from Digital) can access the CUIS Electronic Mail, Conference and Bulletin Board features directly through existing networks (e.g. Internet, SPAN).

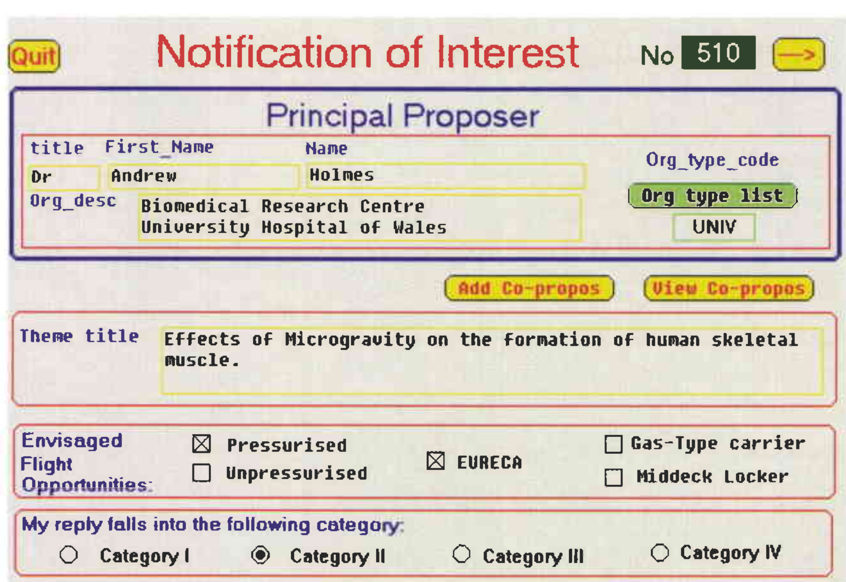
The Communications functions can also be used to exchange draft documents electronically. Then, once these documents have been reviewed by all those involved and the final version is ready, they can be made available via the CUIS Documentation Retrieval Subsystem, where the user can search and retrieve the information with the help of a powerful query system.

For a successful space mission, it is necessary for the space-facility providers to interact closely with the users, making sure that the planned experiments meet the latter's needs exactly. The General Communications Subsystem links the users together very effectively, so that they can prepare and coordinate their requirements and flight experiments.

The Electronic Questionnaires System (EQUS) is designed to automate most of the steps required from the preparation of a questionnaire up to the analysis of the responses. 'Calls for Proposal' are just one area in which an electronic questionnaire system is highly beneficial.

The end-user software is distributed free of charge by the Columbus Utilisation Office via ESRIN in Frascati (I). Aside from the hardware and software pre-requisites, the user bears only the costs incurred in accessing the nearest network.

Figure 2. Typical electronic questionnaire



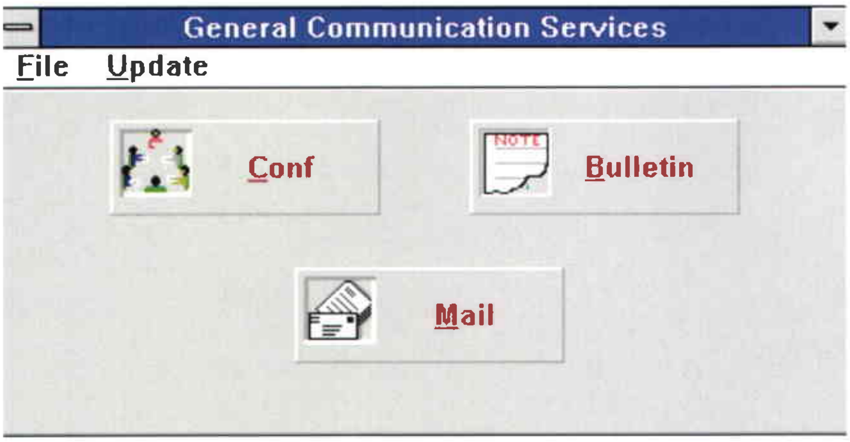


Figure 3. The General Communications Services

To access the General Communications Subsystem via a modem, users do not dial directly into the Central Computer in Italy, as this would lead to prohibitive telephone bills and unreliable links. Instead, they dial into an X.25 Public Access Point for which a monthly fee is usually payable to the national telecommunications services.

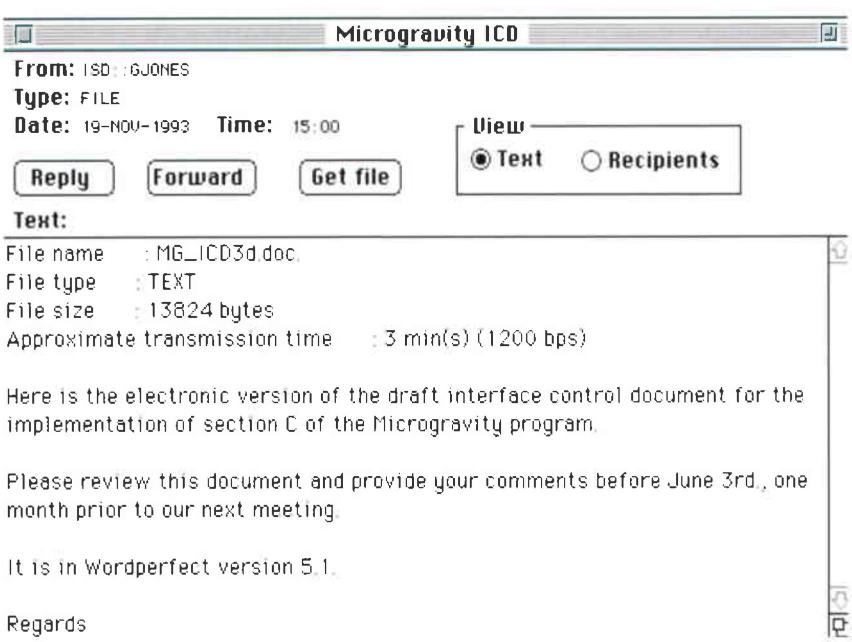
In order to use the CUIS Accessories, the user's TCP/IP or DECnet network must be connected to the Internet or SPAN worldwide networks.

The System is operated by ESRIN, where there is a Help Desk to answer questions about its usage. The Space Station and Microgravity Directorate at ESA Headquarters in Paris is responsible for the data on the System.

The General Communications Subsystem (GCS)

The General Communications Subsystem has four modules: Electronic Mail and File Exchange, User Directories, Conferencing and Bulletin Board.

Figure 4. Mail with attached file sent from DOS



Each CUIS user has a personal electronic mailbox on the CUIS Central Computer at ESRIN. CUIS users, as well as those connected to most of the world's electronic mail systems – ESA Profs/Office Vision, NASAMail, X.400, SPAN, Internet, etc. – can exchange messages via the CUIS GCS.

CUIS Electronic Mail supports all standard functions such as reply, forward, request automatic acknowledgment, search for mail containing given keywords, store copies on the personal computer, transfer mail to or from a local word processor, etc. One of its handiest features is that it supports files attached to an electronic message in a transparent manner. The appended files can range from pure text to a spreadsheet, word processor or even database documents.

In order to address electronic mail easily, the General Communication Mail module is integrated with the User Directories module. This allows the user to select the names and adresses of his correspondents from the Directories instead of having to compose them afresh each time. The User Directories support three types of addresses: CUIS users, external users and distribution lists. The latest list of CUIS users is supplied automatically by the CUIS Central Computer and is available to all CUIS users.

When a CUIS user corresponds with external users, their names can also be stored in a list. These external users can be on any mail system reachable from CUIS. Access to the most important mail systems is predefined, which means that the user does not need to know the addresses of each of these systems, but only how the intended correspondents are identified within their own mail systems.

When electronic mail is sent frequently to the same group of people, a distribution list can be created, including specific addresses as well as call-ups of other distribution lists.

Finally, the User Directories module supports simple queries in an on-line user directory in order to obtain electronic addresses. Currently, it contains about 60 000 users, including all ESA Profs and Quest users, NASAMail users, SSFPmail users and others.

In addition, the General Communications Subsystem provides for Electronic Conferencing, whereby people with similar interests can share their experience, opinions and information. CUIS supports two kinds of conferences: 'public' and 'private'. A 'public' conference is one that any CUIS user can open and contribute to; a 'private' one is restricted to invited participants only.

In parallel with the electronic conferences, where any member can read and write messages, CUIS also provides an electronic Bulletin Board, which all users can read but only authorised ones can write to. The CUIS Bulletin Board provides a way of keeping in touch with all the latest news and announcements on Columbus, including forthcoming events, progress reports on different areas of Columbus research and Calls for Proposals.

The Documentation Retrieval Subsystem (DRS)

One of the most important aspects of Columbus utilisation will be collecting and distributing the technical documentation, and facilitating and optimising access to this key information. The DRS, based on 'Ful/Text' software from the company Fulcrum, also ensures that the lastest version of a given document can always be accessed by the widest community of users. Documents like the Columbus Payload Accommodation Handbook (CPAH), the User Introduction to Columbus, and a number of documents relating to Eureca and Spacelab are already available.

Queries regarding Columbus documents can be performed using intuitive visual objects like menus, forms and dialogues. In addition, the system allows users to navigate through the database and through a document by means of hyperlink techniques, simply by pointing to existing correlations between sections of the various documents or by navigating into the Table of Contents of a specific document. Once a specific document has been retrieved and displayed, the user can receive and immediately browse through all the information related to it, including images and related documents.

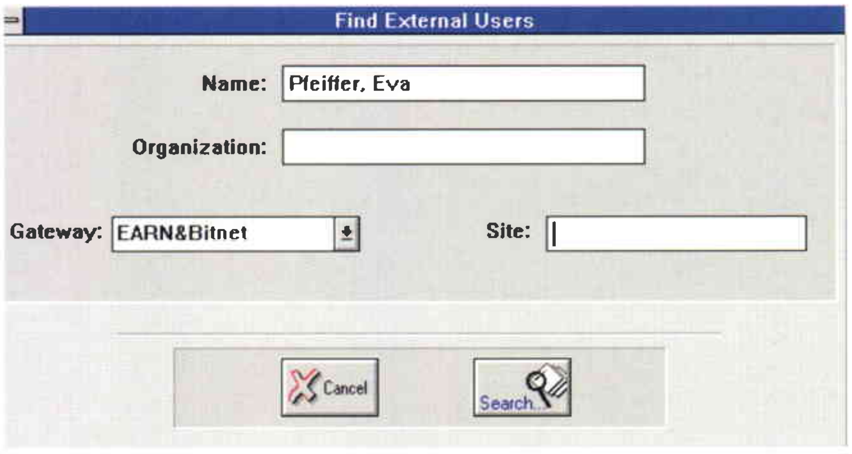


Figure 5. Find External Users screen

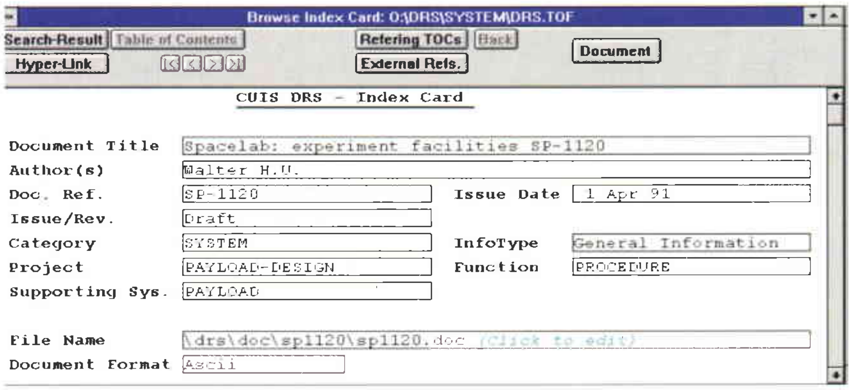


Figure 6. Query for a document. It is possible to query using more than one field of the 'form screen' or the 'text part' of the document simultaneously

The Electronic Questionnaires Subsystem (EQUS)

The lifecycle of an Electronic Questionnaire has three specific phases: the design of the questionnaire, the filling-in of the answers, and the analysis of the replies. Questionnaire forms can be of different levels of complexity, ranging from a simple questionnaire for addresses and telephone numbers to complex 'Calls for Proposals'. There are also two distinct types of Questionnaires possible in CUIS: those that can be filled in only once, and those that can be filled in a number of times. An example of a single-fill questionnaire is one that obtains responses on a seminar, with each participant

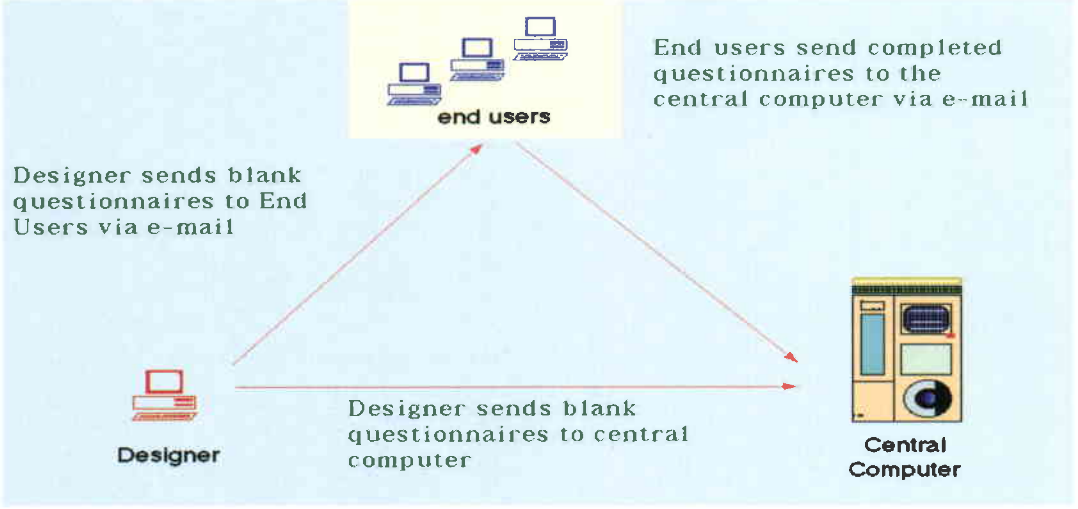


Figure 7. Questionnaire life cycle

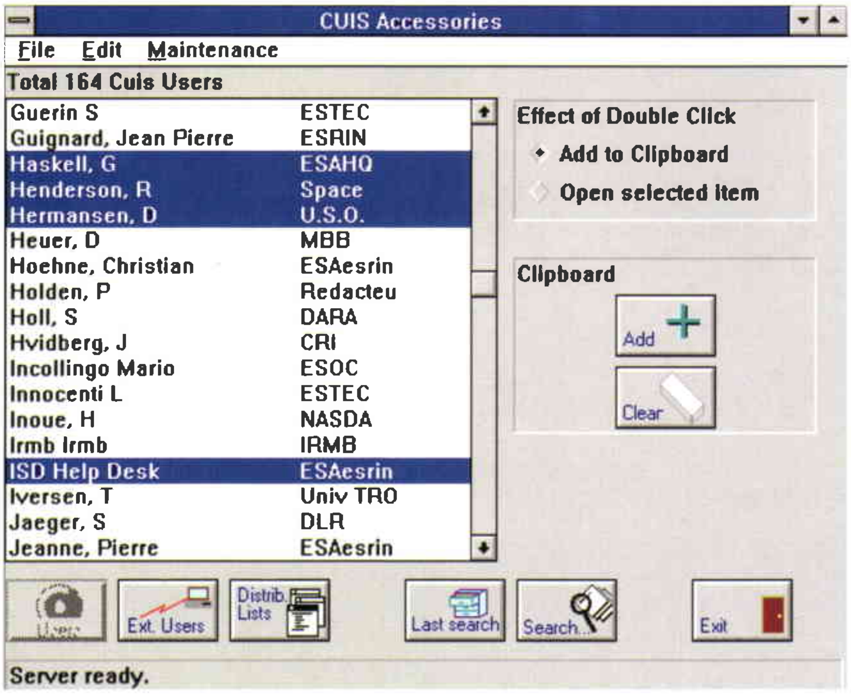


Figure 8. List of CUIS users in the CUIS Accessories

replying only once. Review Item Discrepancy (RID) forms used to comment on a document would be typical multiple-fill questionnaires.

To speed-up the reply process, the designer of an EQUS form can call upon a powerful user interface including pick-up lists, check boxes, etc. Validation checking can also be incorporated into the system if so desired.

Once the Questionnaire has been designed, blanks are sent to the users via electronic mail and to the CUIS Central Computer. The users then download the form to their personal computer and enter their replies offline. Once the questions have been answered, the end-users forward them to the CUIS Central Computer, again by electronic mail, where they are stored in an Oracle database.

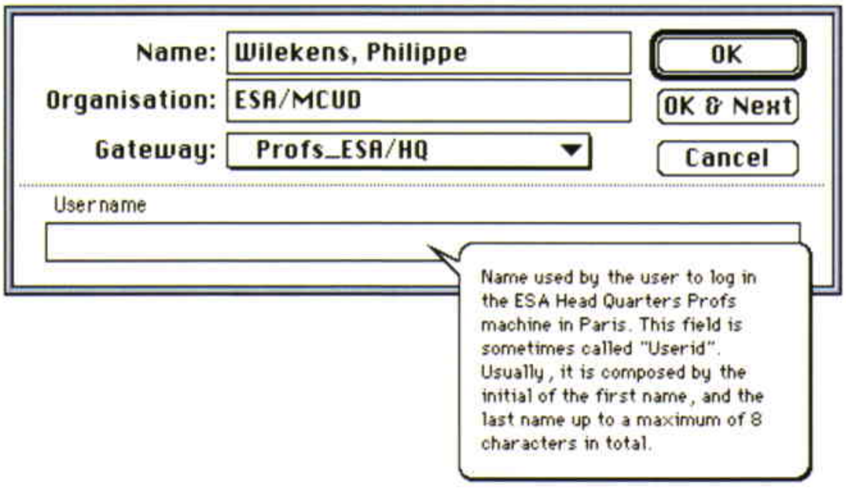
The CUIS Accessories

The CUIS Accessories provide the link between the Columbus user community and commercial electronic mail systems. Without such a link, it would be necessary to type the exact electronic address of the other Columbus users (these are often unintuitive addresses that are difficult to enter correctly). The CUIS Accessories use pick-up lists wherever possible to overcome this problem. A simple click copies the selected recipients' addresses to the standard clipboard, from which the user can paste them into his/her chosen electronic mail system. Virtually all electronic mail systems are supported, including VMS Mail, Profs, QuickMail and Microsoft Mail.

The CUIS Central Computer maintains a list of electronic mail systems designed to be used with CUIS Accessories. The user merely chooses one from a menu and CUIS Accessories automatically knows the electronic address format to be used for the CUIS users, the external users, and the distribution lists.

As in the General Communication Subsystem, the user needs only specify the intended recipient's mail-system identifier.

Figure 9. Create External User screen



The Communications

Computer-to-computer communication has traditionally meant all kinds of technical difficulties for the nonspecialist: complicated log-in procedures, different protocol arrangements, and primitive text editors. For many business or research users, it has often seemed easier to use the telephone, which is an expensive solution providing no written record. CUIS changes all that by offering an attractive, easy-to-use interface, so that the user does not have to remember complicated log-in procedures.

The CUIS Accessories and General Communication Subsystem offer different approaches for the communications: the former relies on existing communication systems, while the latter provides a complete communication system requiring only a telephone line and a modem, or an asynchronous serial connection (RS-232) to a local network.

For most users, the cheapest and most reliable means of connecting to the CUIS Central Computer for the General Communication Subsystem is via Packet-Switched Public Data Network (PSPDN) provided by their local telecommunications authority (PTT).

Compatibility and portability

CUIS has been developed with the aim of guaranteeing the greatest possible degree of compatibility and portability from one platform to another. Both IBM-compatible PCs and Macintoshes can connect to the same CUIS Central Computer without difficulty, and the document formats in the Documentation Retrieval Subsystem is identical for the PC, the Macintosh and the Central Computer.

What is the future of CUIS?
CUIS's development started with the distribution of an initial prototype in early 1988 in order to involve potential users well before any major architectural design effort started. Several subsequent prototypes have led to an 'Initial Version' of CUIS that has just been distributed.

The immediate exploitation of CUIS will be in the context of a Spacelab mission as it is being offered to the science and operation teams of for the laboratory's next two flights, namely the IML-2 mission (International Microgravity Laboratory) in June 1994 and the Atlas-3 mission (Atmospheric Laboratory for Application and Science) in October 1994. CUIS will be used for the distribution of Remote Operation Documentation before these missions and tested during the mission simulations. CUIS will play an essential role in the enhancement of communications between the five Operations Centres throughout Europe from which the instruments carried aboard Spacelab will be controlled.

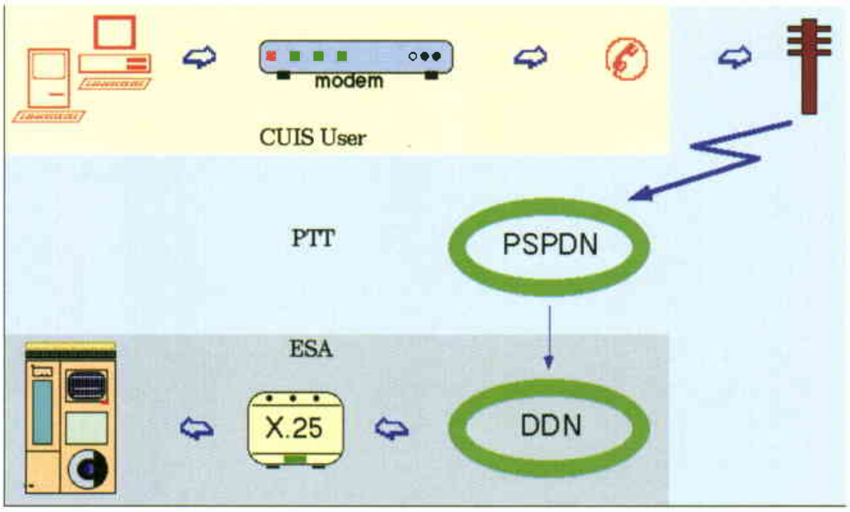


Figure 10. Connection via modem

The longer-term future of CUIS is linked to that of the Columbus Programme and the future of ESA's manned space activities in general.

Local Access Points

To use the General Communication Subsystem via modem, the user dials the nearest Public Access Point and from there the Central Computer. On the following networks, a direct access (Network User Address, NUA) is set up, which reduces the communications costs still further.

Country	Network
Austria	Datex-P
Belgium	DCS
Denmark	Datapak
Finland	Datapak
France	Transpac
Germany	Datex-P
Ireland	Eirpac
Italy	Itapac
Netherlands	DN-1
Norway	Datapak
Spain	Iberpac
Sweden	Datapak
UK	PSS
Canada	Datapac

Minimum System Prerequisites for CUIS

The minimum prerequisites common to all CUIS subsystems are:
- An IBM PC or 100%-compatible with MS-Windows 3, or
- An Apple Macintosh Plus with Operating System 6 or 7.

For the General Communication and remote Documentation Retrieval Subsystems:
- A modem and a telephone line
- A connection facility to a Packet Switched Public Data Network (PSPDN), such as TRANSPAC in France, ITAPAC in Italy or PSS in the UK

or
- A serial connection to a Local Area Network (LAN) with access to an X.25 PAD.

For the CUIS Accessories:

PC:
- TCP/IP via Sun PC-NFS (Version 4.0 or later), or
- DECnet via Digital Pathworks (Version 4.1 or later)
- Any network that supports either of these two protocols.

Macintosh:
- Apple Communication Toolbox (included in System 7)
- Any connection tool supporting Telnet, CTERM, LAT or X.25
- Any network that supports either of these protocols: a direct Ethernet connection or a gateway access through an AppleTalk network.

X-Windows (available second quarter of 1994):
- Sun or Vax Workstation with TCP/IP
- Motif or OpenLook.

For the Electronic Questionnaires:
There is no additional prerequisite for using the Electronic Questionnaires Subsystem. However, to receive the questionnaire and send the replies, the user needs either the General Communication Subsystem or CUIS Accessories.

A propos du Colloque
'La Convention de l'ESA à l'oeuvre – Enseignements du passé'

Florence, 25/26 octobre 1993

G. Lafferranderie & V. Kayser
Service juridique, ESA, Paris

Une Organisation se penche sur son passé

Une Organisation internationale repose avant tout sur une Convention, un Traité, qui en définit les objectifs, les ressources, les mécanismes. Il ne suffit pas d'y faire appel en cas de crise ou de l'examiner à l'occasion d'une conférence. 'Ce Colloque m'a permis de relire la Convention que je n'avais lue qu'une fois et que j'avais ensuite remise dans mon tiroir' a-t-on pu entendre. Une Convention est trop souvent vue comme une contrainte, un texte pour 'juristes'. Il serait sans doute excessif de dire que les succès spatiaux européens sont dus au texte de la Convention, mais elle y a contribué à sa manière et, très certainement, elle ne les a pas freinés.

Le contexte

En dehors même du contexte et des difficultés actuelles, certains avaient estimé utile pour la réflexion européenne sur les constructions juridiques, de jeter un regard rétrospectif, autant que prospectif, sur la Convention. Y trouve-t-on toujours les réponses pour continuer à avancer, quels sont éventuellement les nouveaux chaînons manquants, etc? Ce Colloque était donc à la fois un colloque à caractère historique sur l'origine et l'application des textes et un colloque de prospective, de réflexion entre les divers acteurs des activités spatiales européennes. Nul besoin de démontrer que l'Europe de l'Espace a considérablement évolué depuis 1960. Le contexte européen n'est plus le même; de nouvelles Organisations sont nées, publiques ou privées, dans le domaine des applications spatiales; le contexte international a été profondément modifié; l'environnement réglementaire des activités spatiales a lui-même considérablement évolué, tant pour ce qui concerne les activités publiques que les activités privées.

Ce passé, relativement récent, n'a pas été sans crise. Rappelons-nous la marche vers l'unité, la mise en place de la CSE, de la CETS, les efforts pour réunir l'ESRO et l'ELDO, efforts sur le plan pratique et institutionnel, les fameux 'package deals' de 1971, 1973, la rédaction d'une nouvelle Convention, les inventions juridiques (comme l'article VIII de la Convention ESRO), les 'ambiguïtés constructives', les avancées mais aussi les heurts dans la coopération transatlantique, tout cet humus qui permit à la Convention de l'Agence de germer. Mais ne soyons pas naïfs, ni optimistes, ni pessimistes. Les réponses alors apportées aux problèmes sur la table de négociation peuvent-elles continuer à s'appliquer dans le contexte actuel de profondes mutations?

Cette réflexion était devenue utile sans avoir bien sûr l'ambition de tout résoudre. Le débat est en lui-même déjà un début de réponse. Cet échange entre personnes de tous horizons, entre pères fondateurs et fils 'prodigues', entre personnes représentant les intérêts divers, qu'une Convention doit concilier, entre juristes, scientifiques, industriels, représentants d'autres Organisations publiques et privées, partenaires internationaux, tint ses promesses. La Badia Fiesolana et Florence n'ont pas été sans promouvoir une ambiance chaleureuse, amicale et studieuse. Le Colloque '*La Convention de l'ESA à l'oeuvre – Enseignement du passé*', organisé par l'ESA, l'Institut universitaire européen et le Centre européen de droit de l'espace, avec le soutien d'Arianespace et de la Commission des communautés européennes, a réuni une centaine de participants venant de tous les horizons de l'effort spatial européen.

Les sessions

Ce Colloque, le premier du genre, ne pouvait tout traiter. Les organisateurs avaient dû faire des choix et s'en tenir à l'examen de dispositions de la Convention qui soit caractérisent cette dernière, soit ont constitué des préoccupations permanentes au plan politique.

Après l'ouverture officielle du Colloque par le professeur Massimo Trella au nom du Directeur général de l'ESA, et par le Directeur de l'Institut universitaire européen, le professeur Reimar Lüst a présenté les principaux sujets qui seraient abordés au cours des débats, accompagnés de réflexions nées d'une longue pratique.

La première session, présidée par M. Harry Atkinson (ancien président du Conseil), était consacrée à la naissance de la Convention et à son évolution. M. John Krige (équipe Histoire ESA) a présenté le point de vue de l'historien. Les origines et les évolutions des programmes facultatifs ont été rappelées (G. Lafferranderie, conseiller juridique) ainsi que leur poids considérable au sein des programmes de l'ESA. M. Loosch (ancien délégué ESA) a exposé les procédures de décision et de vote au sein de l'ESA ainsi que leur pratique. Immédiatement le ton fut donné par les échanges entre l'auditoire et le podium. On retiendra la critique sur la **règle de l'unanimité** dont l'application est allée en s'amplifiant bien au-delà des textes, et qui est à la source de marchandages (on a même fait remarquer que l'unanimité ne devrait plus être de mise pour le vote du niveau de ressources). Les règles de la Convention ont traduit quatorze années de réflexion. Malheureusement elles ont été touchées par l'évolution et bien souvent les délégations ont institué, par une interprétation discutable, pour des motifs sans lien avec le texte lui-même, de nouveaux verrous. Or ces verrous 'artificiels' devraient sauter, car au lieu de contribuer à la stabilité des programmes, ils la mettent en péril et l'Agence avec eux. On aperçoit déjà le leitmotiv, la souplesse de la Convention qui permet telle quelle de faire face à diverses situations, mais en même temps le besoin de davantage de rigueur.

Cette ambivalence de la Convention transparaît tout particulièrement à travers l'examen des dispositions relatives au **retour géographique.** Un débat animé suivit les présentations par MM. Duran (chef de la division Contrats, ESTEC), Micklitz (prof. de droit, Berlin), Sacotte (conseiller du président, CNES) et Praet (Directeur général adjoint, Alcatel ETCA), au cours de la seconde session présidée par M. Van Reeth. Le 'retour industriel', quel mot magique! Quel bon génie pourra trouver la formule satisfaisant un retour industriel global proche de 1, les retours par programme de 1 ou de 0,95, les règles communautaires, etc. Un point à mettre à l'actif de ce Colloque fut la liberté de parole et de proposition. En dehors des interventions formelles au cours de séances du Comité de la

Politique Industrielle (IPC) ou du Conseil, d'aucuns ont avancé des propositions, tous se sont exprimés.

L'Annexe V de la Convention dont certains lecteurs se souviendront de l'élaboration difficile, a vu son décalage par rapport à la politique industrielle et aux règles communautaires particulièrement souligné. Certains industriels ont ainsi souligné que si le 'juste retour' était certes justifié à l'époque de l'apprentissage et du développement, et finalement celle de l'expansion, nous sommes actuellement dans une période de surcapacité industrielle dans laquelle il est permis de se demander s'il n'est pas anachronique de rendre la règle du juste retour de plus en plus rigide. La flexibilité qui doit être de rigueur dans ce domaine a été plusieurs fois mise en exergue par les participants.

Enfin, l'on a pu noter la remarque selon laquelle il existe au niveau de la Communauté et de la Communauté élargie, des instruments communautaires pour aborder le juste retour, par exemple les fonds structurels. Il a ainsi été suggéré, dans une perspective d'amélioration de la compétitivité de l'industrie européenne, d'utiliser les instruments existants et non pas de régler chaque problème au niveau structurel. Référence a été faite à l'ESA aujourd'hui et au CERN demain, et la question a été posée de savoir pourquoi il appartiendrait aux seules Agences de recherche de régler les déséquilibres nationaux qui peuvent être réglés par d'autres moyens. Cette session, particulièrement riche en discussions, a ouvert de nombreuses voies de réflexion dans une perspective qui irait au delà de l'Europe spatiale.

C'est sur la question de la **'commercialisation'** que s'ouvrit le deuxième jour du Colloque. L'occasion a permis de réunir sur le même podium, l'ESA (M. Trella, Inspecteur général), Arianespace (M. Bigot, remplacé par M. Bignier), Eutelsat (M. Payet, Directeur technique), Eumetsat (M. Morgan, Directeur général), Spot Image (M. Brachet, Directeur général) et Intospace (M. Von der Lippe)! On sait que la Convention s'est arrêtée en chemin sur la 'commercialisation', l'article V.2 n'en traçant qu'une ébauche, et pourtant l'Agence a parfois avec amertume porté de nouvelles structures en elle. Pas assez loin, pas assez fort, dira-t-on. L'Europe spatiale a besoin d'une politique qui sache prendre en compte dès le départ l'exploitation des produits en développement, si besoin est, par de nouvelles structures. Le temps est venu d'être plus créatif, plus imaginatif. En particulier, il a été souligné au cours des discussions qu'une telle dynamique devait particulièrement être recherchée en matière d'observation de la Terre, où un état d'esprit de type partenariat entre l'Agence et un distributeur devrait être recherché, du même type que celui auquel l'Agence est parvenue avec Arianespace, ou le CNES avec Spot Image. Enfin, d'une façon plus générale, l'accent a été mis sur l'importance du rôle de la communauté des utilisateurs dans le processus de décision de l'Agence afin de mieux l'aider à se déterminer pour les différents développements à entreprendre dans le futur.

Dans une dernière session, conçue dans l'esprit d'une table ronde et présidée par M. Lopez-Aguilar (ancien délégué ESA et ancien président du Comité de relations internationales), fut abordé le contexte international, au cours d'une série de présentations de M. Vereshchetin (Académie des Sciences de Russie), M. Créola (chef de la délégation suisse à l'ESA), M. Pedersen (ancien administrateur adjoint chargé des relations internationales, NASA), M. Paillon (chef unité 'Espace', DGXII), contexte tout à fait différent aujourd'hui de celui qui existait lors de la conception ou de la naissance de la Convention de l'Agence. Une Europe spatiale ne peut se concevoir aujourd'hui en dehors de ce contexte mais sans pour autant y perdre son âme. Une discussion passionnante s'en est suivie illustrant les différents aspects d'une coopération internationale qui a beaucoup changé mais où la cohésion est plus que jamais nécessaire et où l'importance du message à faire passer à l'opinion publique et aux décideurs politiques a été plusieurs fois soulignée.

Enfin, le professeur Atkinson tira les conclusions de ces deux journées. Des images, des propos resteront dans l'esprit de ceux qui ont participé à ce Colloque: le souhait de revenir à une Convention sans rigidités; être plus imaginatif pour répondre à de nouveaux défis; au fond, instituer un meilleur dialogue entre juristes, scientifiques, ingénieurs; enfin re-convaincre les politiques. La Convention est née de l'intégration, de la fascination du public pour l'Espace et de l'intérêt du monde politique pour cette nouvelle frontière. L'Espace était la démonstration d'une 'bonne' construction européenne, d'une 'bonne' autonomie et le gage d'une coopération internationale solide, et qui doit le demeurer en affrontant de nouvelles difficultés.

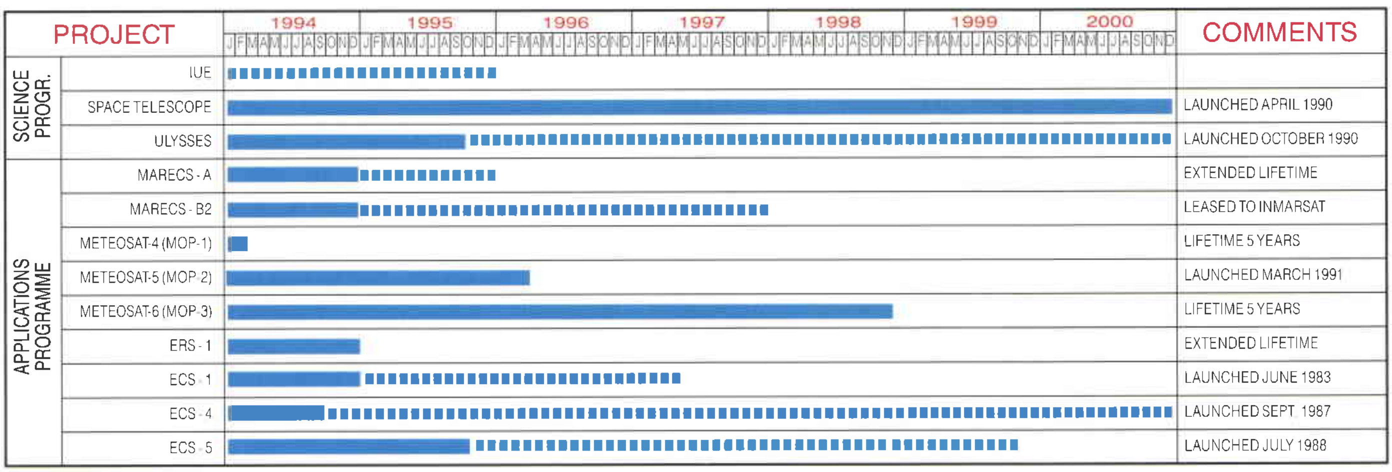
La Convention par sa souplesse ne s'est pas opposée à la réalisation de ces objectifs. Mais qui la lisait? Trop souvent on sort le 'petit livre bleu' à l'appui d'un intérêt particulier. Ce Colloque a ravivé l'intérêt pour ce texte, pour une Convention apte à canaliser l'intérêt de tous vers des réalisations communes et à relever les défis à venir. De nombreuses suggestions ont été reçues, notamment d'organiser un nouveau Colloque dans le même esprit, traitant d'autres aspects de la Convention de l'Agence.

Les Actes du Colloque, reprenant également la transcription des discussions, sont disponibles. Pour tous renseignements, contracter:

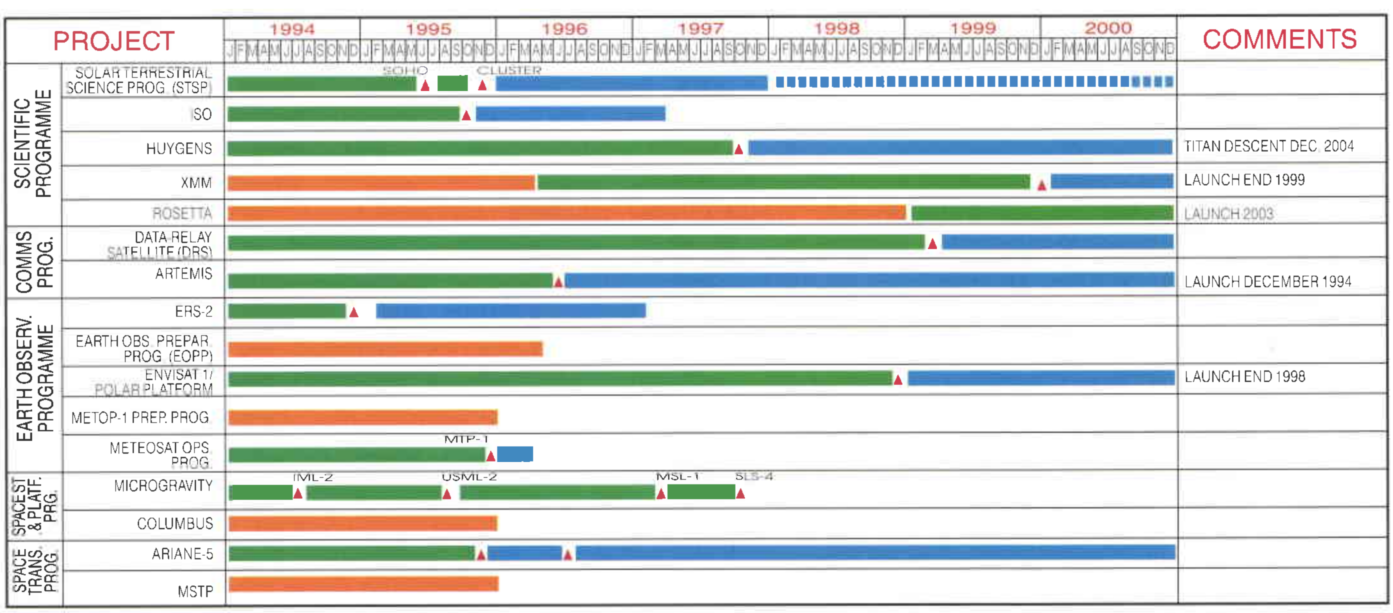
Mme E. Vermeer
ESA, 8–10 rue Mario-Nikis
75738 Paris Cedex 15

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

In Orbit / En orbite



Under Development / En cours de réalisation



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

Soho

Industrie

Les activités relatives au modèle d'identification se sont achevées début février par une série d'essais de compatibilité électromagnétique couronnée de succès. Un essai de séparation avec l'adaptateur d'interface d'Atlas IIAS avait été précédemment réalisé à la mi-décembre, selon le calendrier prévu.

L'intégration du modèle de vol du module de servitude s'est poursuivie en janvier et février avec les sous-systèmes de régulation thermique et d'alimentation. Le sous-système AOCS était en cours d'essais et sa livraison était prévue pour la mi-mars.

L'intégration des expériences du modèle de vol du module de charge utile a commencé début décembre, après certains travaux d'optimisation sur le matériel de régulation thermique. Cette intégration a progressé de manière satisfaisante, malgré les problèmes rencontrés par certaines expériences qui ont dû être renvoyées aux équipes responsables pour mise au point supplémentaire.

Coopération ESA/NASA

Une revue de définition des opérations de la mission s'est déroulée à la mi-février au Goddard Space Flight Center de la NASA. Les représentants de l'ESA ont participé à cette session de deux jours qui a permis de confirmer que des progrès avaient été accomplis dans ce domaine. Un certain nombre de secteurs réclament une attention particulière et les activités à entreprendre à cet effet ont été identifiées.

La première fusée Atlas IIAS (la version équipée de quatre propulseurs d'appoint à poudre qui doit être utilisée pour Soho) a été lancée avec succès le 15 décembre du Kennedy Space Center.

Deux enregistreurs à bande supplémentaires (destinés à Cluster) ont été livrés en février. La conception et la réalisation des enregistreurs à mémoire à état solide a progressé selon les plans prévus.

Expériences

Six expérimentateurs avaient livré leurs modèles de vol fin février, ce qui a permis de les intégrer et de les essayer sur le module de charge utile. A la suite de ces opérations, plusieurs éléments ont été retournés afin d'apporter une solution à des problèmes rencontrés lors de l'intégration ou déjà identifiés sans avoir pu être résolus avant la livraison. Ceci nécessitera certaines activités de réintégration, qui entraîneront un décalage général du programme. Pour le moment, ces éléments ont pu être intégrés dans les marges du calendrier prévu.

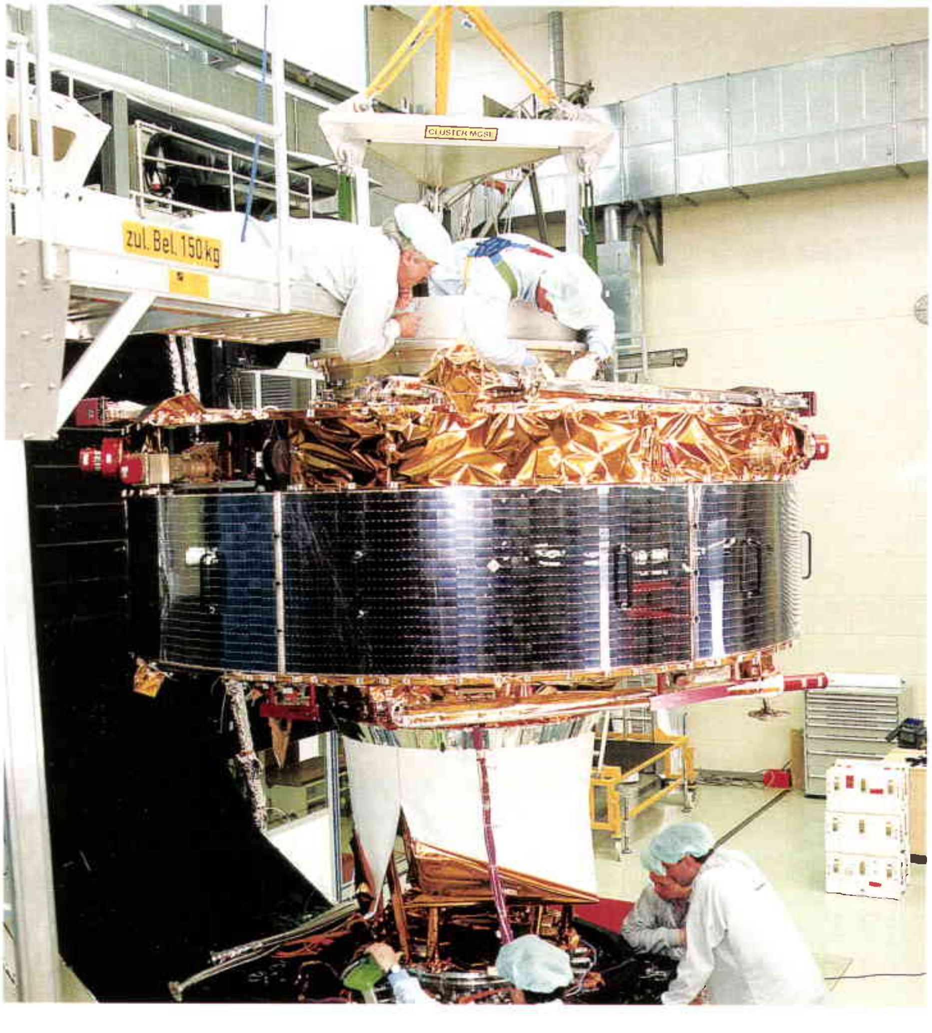
Les responsables de l'ESA et de la NASA se sont penchés avec une attention particulière sur la situation de l'expérience UVCS. Un certain nombre de mesures spécifiques ont été adoptées afin d'offrir à cet instrument les meilleures chances de viabilité.

La réalisation des détecteurs à lignes de retard croisées (XDL) pour les instruments UVCS et SUMER, conçus et fabriqués à l'Université de Californie, à Berkeley, progresse de manière satisfaisante. Ces détecteurs ont franchi le stade de la revue critique de définition.

Cluster

Le prototype de vol du satellite (PFM) vient d'achever avec succès ses essais d'équilibrage thermique et ses essais thermiques sous vide chez IABG, à Munich (D). Les résultats de ces essais doivent être à présent analysés et comparés au modèle thermique afin de permettre de fournir les prévisions de vol. L'ultime série d'essais d'ambiance sur le PFM comprend des essais en vibrations en empilement avec la deuxième unité de vol F2 qui seront suivis d'essais en vibrations acoustiques. La séquence d'essais sur le PFM sera alors achevée.

L'unité de vol F2 a été entièrement intégrée avec sa charge utile, et son



Thermal testing of Cluster spacecraft at IABG, Munich (D)

Le satellite Cluster aux essais thermiques chez IABG, Munich (Allemagne)

Soho

Industry

The engineering-model activities were concluded in early February with a successful electromagnetic compatibility test campaign. A separation shock test with the Atlas IIAS interface adapter had previously been completed on schedule in mid-December.

The Service Module flight-model integration has continued during January and February with the thermal-control and power subsystems. The AOCS subsystem is currently being tested and its delivery is planned for mid-March.

The Payload Module flight-model experiment integration started in early December, after some optimisation work on the thermal-control hardware. The integration effort has been progressing smoothly, within the constraints of the problems encountered with the experiments, some of which have had to be returned to their teams for further work.

ESA-NASA cooperation

A Mission Operation Design Review was held in mid-February at NASA Goddard Space Flight Center. ESA representatives participated in this two-day event, at which it was confirmed that positive progress has been made on this part of the mission. A number of areas needing attention and further effort were also identified.

The first Atlas IIAS vehicle (the version to be used for Soho with four solid boosters) was successfully launched from Kennedy Space Center on 15 December.

Two more tape-recorder units (destined for Cluster) have been delivered in February. The design and manufacturing of the solid-state recorders has progressed according to plan.

Experiments

By the end of February, six experimenters had delivered their flight models and these have been integrated and tested on the Payload Module. Several units have subsequently been returned for the correction of problems that showed up during the integration or which were known but could not be resolved before their initial delivery. This will necessitate some re-integration activity which is causing an overall programme slippage. So far, however, this is being contained within the available schedule contingency.

The UVCS experiment situation has been under specific scrutiny by ESA and NASA management. Some specific measures have been agreed in order to give this instrument a maximum chance of reaching a viable verification status.

The Cross Delay Line (XDL) detectors for the UVCS and SUMER instruments being designed and manufactured at the University of California at Berkeley are progressing well and have passed their Critical Design Review stage.

Cluster

The protoflight (PFM) spacecraft has just successfully completed the thermal-balance/thermal-vacuum test sequence at IABG in Munich (D). The results from the test have now to be analysed and correlated with the thermal model to enable the flight predictions to be produced. The final environmental test sequence on the PFM are a stack vibration test with the flight 2 (F2) spacecraft, followed by the acoustic vibration test. This will complete the test sequence for the PFM.

The F2 spacecraft has been completely integrated, including its payload, and electronically tested. It now awaits transportation to IABG to join the PFM for the stack vibration test. Subsequently, the F2 will undergo thermal, acoustic and magnetic tests.

The third flight spacecraft (F3) has been fully integrated, including payload, and is ready for full system-level electrical testing at Dornier (D).

The fourth flight model (F4) is in the process of integration at subsystem level, with the payload due for delivery after Easter.

The solid-state memory units intended as a back-up to the tape recorders are progressing on schedule. To date, two engineering models have been delivered and successfully integrated on PFM and F2, together with the tape recorders. Flight-model production is on schedule for deliveries to commence in late 1994.

The ground segment is progressing on schedule, with the first system validation test being planned for early 1995. This will be an end-to-end test from the operations centre to the spacecraft via the ground network.

The Cluster Science Data System has successfully completed its Architectural Design Review and is now in the implementation phase. First delivery to the data centres of the user interface software is scheduled for mid-1994.

ISO

Scientific instruments

The flight-model scientific instruments have been installed in the flight-model satellite hardware and thoroughly tested. They performed well in general. The ISOPHOT focal-plane unit, however, showed some anomalous movements of the filter wheels, and it was therefore decided to replace it with the spare unit, which is of improved design and behaves perfectly.

Satellite

The payload module with the scientific instruments has been fully tested and performed well. A major project hurdle was crossed when the straylight test showed that the 'darkness' inside the payload module is better than specification, viz. darker than one tenth of the zodiacal background. The successful outcome to this very critical test is a major confidence booster within the programme.

The payload module was opened to remove hardware needed to perform the straylight test and to exchange the ISOPHOT focal-plane unit. The payload module will now be re-integrated, closed, cooled and tested before final delivery to ESTEC at the end of June.

The service module has been in storage, but it will soon be built up and made ready for mating with the payload module during the summer. The complete flight-model satellite will then be subjected to a final series of system tests.

The satellite work remains on schedule for the September 1995 launch date.

Ground segment

The spacecraft-operations development effort is proceeding satisfactorily. The *électronique a été soumise à des essais. Elle doit être transportée à présent chez IABG pour subir les essais en vibrations en empilement avec le PFM. Elle subira ensuite ses essais thermiques, acoustiques et magnétiques.*

L'intégration de la troisième unité de vol F3 avec sa charge utile a été elle aussi achevée. Le satellite se trouve prêt à subir des essais électriques complets au niveau système chez Dornier (D).

La procédure d'intégration de la quatrième unité de vol (F4) est en cours de réalisation au niveau des sous-systèmes. La charge utile du satellite devrait être livrée après Pâques.

La réalisation des unités de mémoire à état solide, venant en appoint des enregistreurs à bande, progresse selon le calendrier prévu. Deux modèles d'identification ont été livrés à ce jour et intégrés avec succès sur le PFM et sur F2 avec les enregistreurs à bande. La réalisation des modèles de vol se poursuit comme prévu et leur livraison devrait intervenir à partir de la fin 1994.

Les travaux du secteur sol progressent normalement. Les premiers essais de validation au niveau système sont prévus pour le début 1995. Ils seront réalisés de bout en bout, du centre des opérations au satellite, en passant par le réseau au sol.

La revue de définition architecturale du système d'accès aux données scientifiques de Cluster a été réalisée avec succès et la phase de mise en oeuvre du système a été lancée. Les premières livraisons des logiciels d'interfaces utilisateurs aux centres de traitement des données sont prévues pour la mi-1994.

ISO

Instruments scientifiques

Les modèles de vol des instruments scientifiques ont été mis en place sur le modèle de vol du satellite et ont fait l'objet d'essais approfondis. Les résultats de ces essais ont été généralement bons. Les disques à filtre de l'unité au plan focal de l'ISOPHOT ont cependant révélé quelques anomalies de mouvement et la décision a été prise de remplacer cet instrument par le modèle de réserve dont la conception est améliorée et qui fonctionne parfaitement.

Satellite

Le module de charge utile équipé des instruments scientifiques a subi avec succès des essais complets. Une étape importante a été franchie avec les essais en lumière parasite qui ont révélé que 'l'obscurité' à l'intérieur du module était supérieure aux spécifications, c'est-à-dire supérieure à un dixième de la lumière zodiacale. Les résultats positifs de ces essais particulièrement critiques sont très encourageants pour le programme.

Le module de charge utile a été ouvert pour permettre d'enlever le matériel nécessaire à la réalisation des essais en lumière parasite et pour changer l'unité au plan focal de l'ISOPHOT. Le module doit être à présent réintégré, fermé, refroidi et essayé avant sa livraison définitive à l'ESTEC, à la fin du mois de juin.

Le module de service, qui était entreposé, sera bientôt monté et préparé pour être assemblé durant l'été avec le module de charge utile. Le modèle de vol complet du satellite sera alors soumis à une ultime série d'essais système.

Les travaux d'avancement du satellite se poursuivent conformément au calendrier qui prévoit son lancement en septembre 1995.

Secteur sol

Les travaux préparant l'exploitation du satellite se poursuivent. L'équipe de développement des opérations scientifiques a été renforcée et de gros efforts sont accomplis pour respecter le calendrier. La prochaine étape importante, au mois d'avril, comprendra une série d'essais d'interface entre le satellite et les logiciels d'opérations scientifiques. Ces essais seront reconduits durant l'été, entre l'ESOC et la station sol de Villafranca, près de Madrid.

Huygens

Les livraisons d'éléments de matériels entre les membres du consortium industriel Huygens progressent de manière très satisfaisante. Les activités de conception ont été largement menées à bien, l'industrie se concentrant à présent sur la fabrication et les essais des unités mécaniques et thermiques aux normes de vol et des unités électroniques aux normes techniques.

La majorité des unités et sous-systèmes sont en cours de réalisation selon le calendrier prévu; toutefois, divers scénarios ont été imaginés pour répondre aux éventuels délais qu'entraîneraient au niveau système des retards dans la livraison d'éléments ou d'unités devant être intégrés dans la sonde.

L'assemblage et l'intégration du modèle structurel, thermique et pyrotechnique de la sonde (STPM) commencera comme prévu au mois de mai. Cette activité a été précédée et autorisée par une revue de définition du matériel au niveau projet.

Un certain nombre de problèmes et de questions techniques se sont toutefois posés au cours des derniers mois. L'analyse détaillée d'une éventuelle contamination des fenêtres optiques de l'expérience DISR lors de l'entrée dans l'atmosphère de Titan a abouti à envisager plusieurs options permettant d'incorporer à la sonde des éléments de protection déployables. L'instabilité possible de la sonde dans les pires conditions d'entrée a conduit à modifier la conception du parachute principal et à reprendre un certain nombre d'essais en soufflerie. La rupture de certains éléments de batteries au cours des essais aux vibrations est un problème préoccupant qui n'a toujours pas été résolu (les éléments de batteries sont identiques à ceux qui équipent actuellement la sonde de la NASA Galileo).

A l'heure actuelle, selon des informations en provenance des Etats-Unis, la NASA envisage de modifier le mode de lancement prévu pour Cassini/Huygens, passant d'un véhicule de référence Titan ou Centaur, à un lancement double par la navette. L'assemblage de Cassini et du dernier étage de lancement serait alors réalisé en orbite. Des études ont été immédiatement entreprises pour évaluer l'incidence éventuelle de ces changements sur le projet.

science-operations development team has been strengthened and great efforts are being made to keep to schedule. The next key milestone is a series of interface tests between spacecraft and science operations software to be performed in April. These tests will be repeated in the summer between ESOC and the ground station at Villafranca, near Madrid.

Huygens

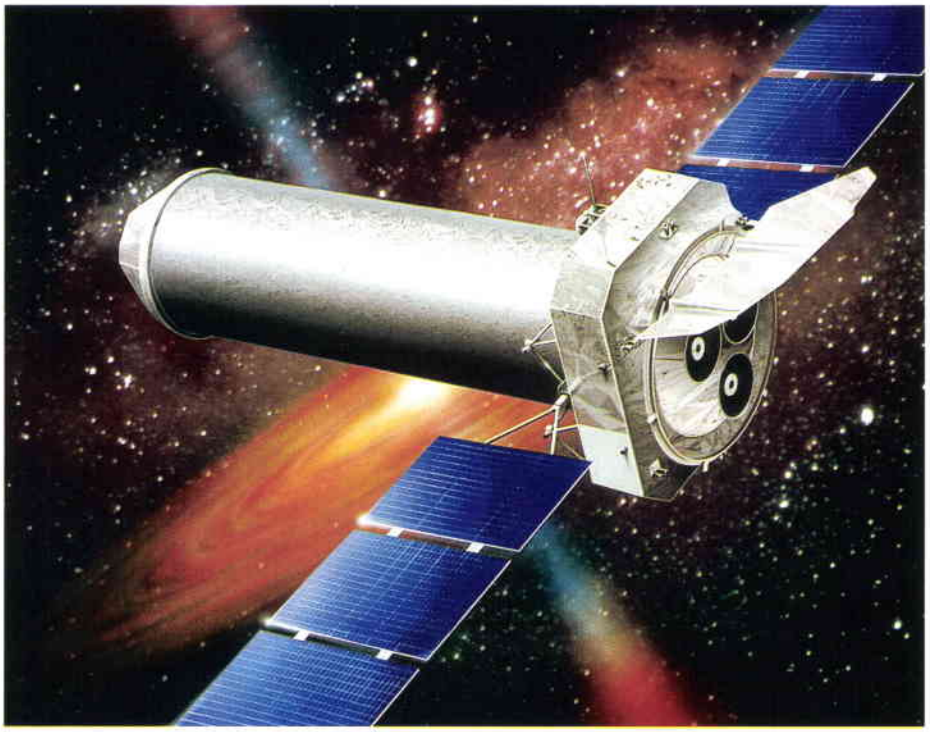
Deliveries of hardware items between the Huygens industrial consortium team members are providing the most visible signs of progress. The design activities have largely been completed, with industry now concentrating on the manufacture and testing of flight-standard mechanical/thermal units and engineering-standard electronic units.

The majority of the units and subsystems are being built to the nominal schedule, but various scenarios have nevertheless been devised to overcome potential system-level delays where items or units could perhaps be delivered late for integration into the Probe.

Assembly and integration of the Structural/Thermal/Pyro Model (STPM) Probe will start in May as scheduled, an activity preceded and authorised by a project-level hardware design review.

The past few months have not been without their technical problems and issues, however. Potential contamination of the DISR experiment's optical windows during the entry into Titan's atmosphere has been analysed in depth, resulting in several options for deployable covers to be incorporated on the Probe. Potential instability of the Probe under worst-case entry conditions has led to modification of the main parachute's design and the re-running of a number of wind-tunnel tests. Breakage of battery components during vibration testing is a serious concern which is still being resolved (the battery units are identical to those currently flying on NASA's Galileo spacecraft).

At the time of writing, there is news from the USA that NASA is considering a change of launcher for Cassini/Huygens from the presently baselined Titan/Centaur vehicle to a dual Shuttle launch, with assembly of the upper-stage launch vehicle and the Cassini spacecraft to take place in orbit. Work has started immediately on evaluating the impact that this might have on the project.



Artist's impression of the XMM spacecraft

Le satellite XMM (Vue conceptuelle)

XMM

The recent period has been marked by an extensive evaluation of industrial offers for the project's Phase-B. The results of this evaluation were presented to the Agency's Industrial Policy Committee (IPC) on 14 March 1994, together with a revised procurement proposal which takes account of the unacceptability of the offers that were evaluated. It was decided to re-issue a competitive Invitation to Tender to European industry for XMM Phase-B proposals, after which the Agency intends to initiate the resulting Phase-B activities no later than the beginning of October 1994. The new ITT therefore stresses the need to maintain a tight programme schedule in order to still meet the planned June 1999 launch date.

A number of activities associated with mirror production for XMM's telescope have already been started and continue to be on schedule. The production of flight-mirror mandrels, which are used as masters to replicate the individual nickel mirror shells, is so far advanced that the first batch is already available at Carl Zeiss, Oberkochen (D). They will be delivered to Medialario in Como (I), where they will be used to manufacture the first flight mirror-shells.

On the XMM payload side also, significant progress has been made. The Reflection Grating Spectrometer (RGS) experiment team has successfully completed a ten-week X-ray calibration test on their instrument's Electro-Optical Bread-Board (EOBB) model, at the Max Planck Institute's 'Panter' facility in Neuried, near Munich (D). The European Photon Imaging Camera (EPIC) team started their calibration activities on 18 January and the scientific data obtained so far are already showing satisfactory results.

All of the ground-segment activities being carried out by ESOC are continuing according to the XMM programme schedule requirements. These activities are directed primarily towards finalisation of the XMM Mission Interface Requirements Document.

Meteosat

During the commissioning of Meteosat-6, which was launched by Ariane (flight V61) on 20 November 1993, an anomaly was observed in the infrared images from

XMM

Une évaluation approfondie des offres de l'industrie pour la phase B du projet a été récemment conduite. Les résultats de cette évaluation ont été présentés le 14 mars 1994 au Comité de la politique industrielle de l'Agence (IPC), conjointement à une proposition d'approvisionnement révisée prenant en compte l'irrecevabilité des offres évaluées. Il a été décidé de lancer un nouvel appel d'offres ouvert à l'industrie européenne pour la phase B du projet XMM, à la suite duquel l'Agence se propose d'entamer les activités en rapport, au plus tard début octobre 1994. Le nouvel appel d'offres souligne en conséquence la nécessité de maintenir un calendrier très strict afin de respecter la date de lancement prévue en juin 1999.

Un certain nombre d'activités liées à la production de miroirs pour le télescope XMM ont été déjà entamées et se poursuivent selon le calendrier prévu. La production des mandrins des miroirs de vol, dont on se sert comme modèles pour reproduire les différentes coquilles des miroirs en nickel, est suffisamment avancée pour que l'on puisse déjà disposer du premier lot chez Carl Zeiss, à Oberkochen (D). Ces mandrins seront livrés chez Medialario, à Côme (I), où ils serviront à la fabrication des premiers exemplaires de vol des coquilles de miroirs.

Des progrès significatifs ont été également accomplis dans le domaine de la charge utile XMM. L'équipe d'expérimentation du spectromètre à grille de réflexion (RGS) a mené avec succès — pendant dix semaines dans l'installation 'Panter' de l'Institut Max Planck de Neuried, près de Munich (D) — des essais d'étalonnage aux rayons X du montage de table électro-optique de l'instrument. L'équipe de la caméra photonique européenne (EPIC) a entamé ses activités d'étalonnage le 18 janvier et les résultats scientifiques obtenus jusqu'à présent sont d'ores et déjà satisfaisants.

L'ensemble des activités du secteur sol sont menées par l'ESOC selon le calendrier prévu. Ces activités visent en premier lieu à permettre la mise au point définitive du document sur les impératifs d'interface de la mission XMM.

Météosat

Lors de la mise en service de Météosat-6, lancé le 20 novembre 1993 par Ariane (vol V61), les images dans l'infrarouge provenant du satellite ont présenté une anomalie. Alors que la qualité géométrique des images de la Terre est correcte, le niveau de gris qui indique les températures affiche une instabilité de l'ordre de 5% pouvant varier par intermittence entre 0 et 30%. Une enquête menée par l'ESA et par l'industrie semble indiquer que le défaut est d'ordre mécanique et se situe dans la partie infrarouge du radiomètre. Une commission d'enquête ESA/Eumetsat livrera prochainement ses conclusions.

Les travaux se poursuivent dans le cadre du Programme Météosat de transition afin de permettre un lancement fin 1995. Eumetsat a parallèlement demandé à l'ESA de lui fournir une proposition permettant de repousser le lancement à la mi-1997.

MSG
L'accord de coopération ESA/Eumetsat sur les satellites Météosat de deuxième génération (MSG) a été officiellement signé après avoir été approuvé par le Conseil de l'ESA. Sa mise en oeuvre dépend encore de son approbation définitive par le Comité directeur du programme MSG d'Eumetsat et de l'état des souscriptions au sein de l'ESA qui, conformément à la déclaration du programme MSG, doit atteindre le niveau requis pour lancer les activités.

Metop
Le Programme préparatoire Metop, approuvé lors de la réunion du Conseil de l'ESA en décembre dernier, a débuté avec la réalisation des modèles de démonstration du radiomètre imageur hyperfréquences multibande (MIMR) et du diffusiomètre vent de technologie avancée (ASCAT). La réalisation possible d'un modèle supplémentaire du MIMR est à l'étude pour une occasion de vol sur la plate-forme EOS PM de la NASA.

La préparation des activités de la phase B de Metop au niveau système a commencé sur la base des résultats de l'étude de phase A, lancée en octobre 1993.

Des discussions programmatiques ont été entreprises avec Eumetsat afin de mettre au point le plan d'action qui doit conduire à la phase C/D.

ERS

ERS-1
ERS-1 a subi sa première panne en orbite depuis sa mise en exploitation régulière, avec la perte d'un tube à ondes progressives dans le système de transmission de données vers le sol. L'utilisation du tube de secours a cependant permis de reprendre rapidement une exploitation normale. Une commission d'enquête a conclu que le tube défaillant était proche, en fait, de la fin de sa durée normale de vie. Quelques mesures correctives mineures ont été recommandées et mises en oeuvre pour prolonger la durée de vie du satellite.

ERS-2
Le programme d'intégration au niveau satellite a été lancé à la suite de l'achèvement du programme d'intégration du modèle de charge utile et de sa livraison en décembre. Au nombre des étapes importantes déjà franchies figurent les premiers essais de validation du système, menés avec succès à l'ESOC. Ces essais ont démontré que les adaptations du système de contrôle d'ERS-1 et les modifications sur ERS-2 étaient compatibles.

Les préparatifs pour les essais acoustiques et vibratoires au niveau satellite, qui doivent avoir lieu en mai à l'ESTEC, sont désormais bien avancés.

Le modèle de vol de l'instrument GOME en est à présent aux ultimes étapes des essais de recette. Il sera intégré à temps au satellite pour les essais acoustiques et vibratoires.

Les préparatifs pour le lancement d'ERS-2 à la fin de l'année et pour son exploitation ultérieure progressent de façon satisfaisante. Une analyse préliminaire de la mission a été réalisée avec Arianespace au début du mois de mars. Ces résultats ont été concluants. La préparation du secteur sol progresse également de façon normale.

the satellite. While the geometrical quality of the image of the Earth is correct, the grey level that indicates temperatures exhibits an instability of the order of 5%, but which also varies intermittently between 0 and 30%. An investigation by ESA and industry seems to indicate that the fault is mechanical in nature and is located in the infrared part of the radiometer. An ESA/Eumetsat Enquiry Board will present its first conclusions shortly.

Meteosat-5 is currently the operational spacecraft, with Meteosat-4 on standby.

Work continues on the Meteosat Transition Programme for a launch in late 1995. Meanwhile, Eumetsat has asked ESA to provide a proposal that would allow for delaying the launch until mid-1997.

MSG
The ESA/Eumetsat Cooperation Agreement on the Meteosat Second Generation (MSG) has been formally signed, afer approval by the ESA Council. Implementation of this Agreement is subject to the full approval of the Eumetsat MSG Programme Board and to the ESA subscriptions reaching the required level to allow activities to commence in accordance with the MSG Programme Declaration.

Metop
The Metop Preparatory Programme, approved at the ESA Council's December meeting, has started with the development of instrument demonstration models (Multi-frequency Imaging Microwave Radiometer (MIMR) and Advanced Wind Scatterometer (ASCAT)). An optional MIMR model is being studied for a flight opportunity on the NASA EOS PM platform.

Preparation of the Metop System Phase-B activities has now started based on the results from the Phase-A study, which had been running since October 1993.

Programmatic discussions have been initiated with Eumetsat in order to work out the plan of action leading up to Phase-C/D.

ERS

ERS-1
ERS-1 has suffered its first in-orbit failure since the start of regular operations, with the loss of a travelling wave tube in the data-transmission link to the ground. Nominal operations could, however, be quickly recovered by switching to the spare tube. An Enquiry Board concluded that the failed tube was in fact approaching its natural end-of-life. Some minor operational countermeasures were recommended and these have been implemented to extend the remaining lifetime of the satellite.

ERS-2
Following completion of the payload-model integration programme and the delivery in December of the plaform, the satellite-level integration programme has started. Major milestones already achieved include successful completion of the first System Validation Test with ESOC, which has demonstrated that the adaptations to the ERS-1 control system and the modifications on ERS-2 are compatible.

Preparations are now well in hand for the satellite-level vibration and acoustic testing planned to take place in ESTEC in May.

The flight model of the GOME instrument is now in the final stages of acceptance testing and will be integrated into the satellite in time for the vibration and acoustic testing.

Preparations for the launch of ERS-2 at the end of the year and the subsequent operations are well advanced. A preliminary mission-analysis review was held with Arianespace at the beginning of March, with good results. Preparation of the ground segment is also proceeding satisfactorily.

Envisat-1/Polar Platform

The Envisat-1 and Polar Platform Declarations were approved at the ESA Council Meeting of 15 December 1993 by an Act of Council which financially links both Programmes.

On the industrial side, activities have progressed towards finalisation of the accommodation of the Envisat-1 instruments on the Polar Platform and ensuring the coherence of the technical and management interfaces between the two Programmes.

A mission/system-level Preliminary Design Review (PDR) will take place in June/July 1994, covering all aspects of the Envisat-1 mission, including the Polar Platform and the ground segment.

Polar Platform
Development activities are proceeding to plan. The service-module structural-model test programme has been successfully completed at CASA (E) and the structure will now be shipped to British Aerospace (UK) for further integration. Manufacture of the payload-module structural-model is in progress. Engineering models for most payload-module equipment and protoflight models for the service-module units are being manufactured or assembled.

Final negotiation of the majority of the subcontracts has been completed and the goal is to finalise the negotiation of the main development contract (Phase-C/D) in the second quarter of 1994.

Envisat-1
A major step forward has been achieved with the approval of the full space-segment Phase-C/D by ESA's Industrial Policy Committee at its 14 March meeting.

Work is now proceeding to consolidate all of the industrial activities and firm up the detailed definition of the present technical baseline. To this end, the development status of all the Envisat instruments is being scrutinised through a series of PDRs, which are due to be concluded in May.

Ground segment
Following several iterations to define its exact scope and content, the proposed Envisat ground segment has been presented for approval to the Earth Observation Programme Board.

The ground-segment consolidation phase has been the subject of an Invitation to Tender (ITT) and the corresponding industrial activities are planned to start early in June. The objective of this consolidation phase, which will last ten months, is to finalise the architectural design, and define all necessary subsystem and internal/external interface specifications before the start of the implementation phase.

Envisat-1/Plate-forme polaire

Le 15 décembre 1993, le Conseil de l'ESA a approuvé les Déclarations Envisat-1 et Plate-forme polaire par un 'Acte en Conseil' qui lie financièrement les deux programmes.

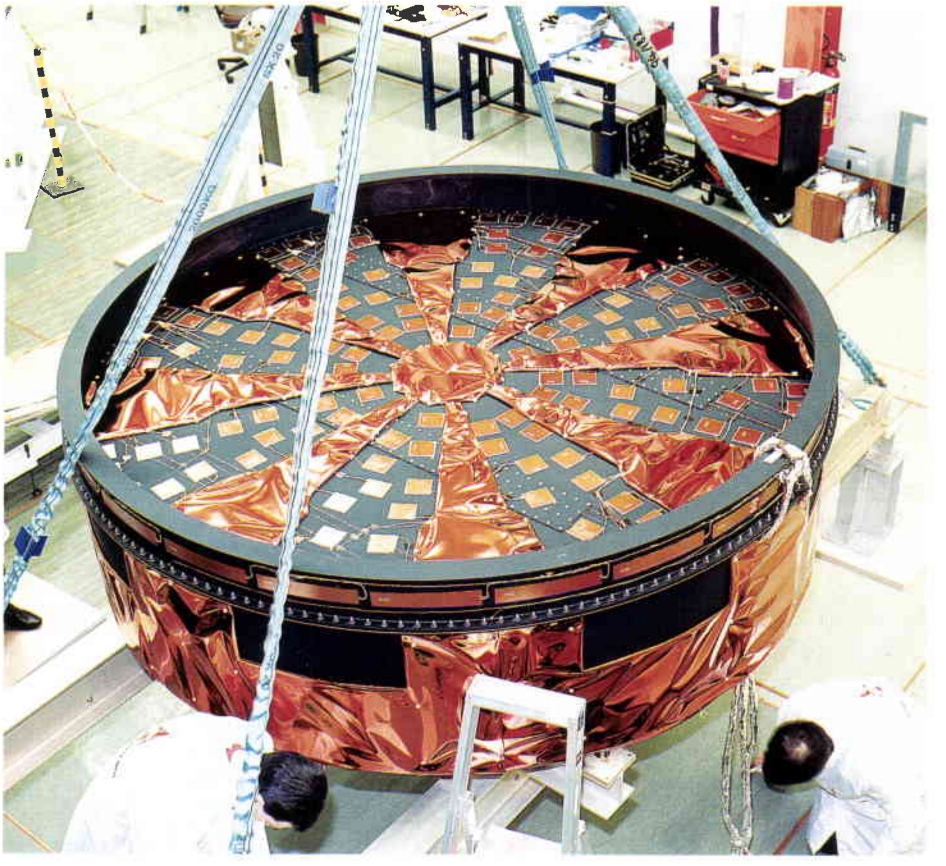
Sur le plan industriel, des progrès ont été accomplis dans la mise au point finale de l'aménagement des instruments d'Envisat-1 sur la Plate-forme polaire, de même que dans la recherche d'une cohérence entre les interfaces des deux programmes dans le domaine technique et dans celui de la gestion.

Une revue de définition préliminaire (PDR) aux niveaux mission et système se déroulera en juin/juillet 1994, couvrant tous les aspects de la mission Envisat-1, Plate-forme polaire et secteur sol compris.

Plate-forme polaire
Les activités de développement se déroulent selon le plan prévu. Le programme d'essais du modèle de structure du module de servitude s'est achevé chez CASA (E) et la structure doit être envoyée à présent chez British Aerospace (UK) pour la phase suivante d'intégration. La fabrication du modèle de structure du module de charge utile progresse. Les modèles d'identification de la plupart des équipement du module de charge utile et les prototypes de vol des unités du module de servitude sont en cours de fabrication ou d'assemblage.

La négociation de la majorité des sous-contrats a été achevée et l'objectif est aujourd'hui de faire aboutir la négociation du contrat de développement principal (phase C/D) au second trimestre de 1994.

Envisat-1
La phase C/D du secteur spatial complet a été approuvée par le Comité de la politique industrielle de l'ESA, réuni le 14 mars, ce qui a constitué une étape importante. On s'emploie désormais à consolider toutes les activités industrielles et à établir la définition détaillée de la base de référence technique actuelle. A cette fin, une série de PDR ont été entreprises afin d'évaluer précisément le stade de réalisation de tous les instruments d'Envisat. Cette procédure doit s'achever en mai.



Thermal testing of the Polar Platform's battery compartment at ESTEC (NL)

Le compartiment des batteries de la Plate-forme polaire aux essais thermiques à l'ESTEC (Pays-Bas)

Secteur sol
Une proposition de configuration du secteur sol d'Envisat a été soumise pour approbation au Conseil directeur du programme d'observation de la Terre, après plusieurs itérations pour définir sa composition et son étendue exacte.

La phase de consolidation du secteur sol a fait l'objet d'un appel d'offres, et les activités industrielles correspondantes devraient être lancées début juin. L'objectif de cette phase de consolidation, qui doit durer dix mois, est de mettre définitivement au point l'architecture de l'ensemble, et de définir tous les sous-systèmes nécessaires et les spécifications des interfaces internes et externes avant le début de la phase de mise en oeuvre.

MSTP

Technologie
La préparation des activités dans le domaine technologique, adaptée aux besoins des véhicules ATV et CTV, a progressé et les travaux industriels débuteront prochainement. Le programme technologique comprend un démonstrateur de rentrée atmosphérique (ARD) dont la faisabilité est à présent démontrée de manière suffisante. Cette capsule ayant été conçue pour être emportée comme passager APEX sur le vol V502 d'Ariane, les contraintes de planification sont critiques. Une décision concernant les passagers du vol V502 sera prise prochainement.

Etudes système conjointes Columbus/MSTP
A la suite des décisions du Conseil, les travaux relatifs aux activités conjointes Columbus/MSTP ont débuté fin février avec la mise en place de l'équipe commune au sein de l'ESA et la première session de travail avec l'industrie après attribution des contrats en rapport.

Etudes système
Les études système actuellement en cours portent sur l'exploitation et l'utilisation des éléments MSTP dans le scénario de Station spatiale et sur la détermination des contraintes dans les conditions de rentrée.

MSTP

Technology
Preparation of the technology activities, adjusted to the needs of the ATV and CTV vehicles, has progressed and industrial work will start shortly. The technology programme includes an Atmospheric Re-entry Demonstrator (ARD), the feasibility of which has now been sufficiently established. As this capsule has been conceived as an APEX passenger for Ariane flight V502, the planning constraints are critical. A decision on the V502 passengers will be taken shortly.

Joint Columbus/MSTP system studies
Following the decisions taken by Council, the work related to Columbus/MSTP joint activities started at the end of February with the setting up of ESA's internal 'core-team', and with the first working session with industry after the awarding of the related contracts.

System studies
System studies that are in progress address the operation and utilisation of the MSTP elements in the Space Station scenario, and the determination of environmental re-entry constraints.

CTV (Crew Transport Vehicle)
The two parallel industrial Phase-0 studies are in progress; the first step, to determine, for four different missions, which have been specified as study cases, the most suitable system concept, has been achieved. Both Phase-0 contractors have arrived at valid solutions, which will be further consolidated in the coming months.

ACRV (Assured Crew Return Vehicle)
The Phase-A extension studies have been completed. Apart from a joint evaluation with NASA, ACRV activities will be discontinued. Aspects of crew return will now be dealt with in the framework of the CTV studies.

Servicing elements
The ERA and EVA
Following the discussions with Canada concerning the complementary roles of their manipulator and the ERA (European Robot Arm), a joint study has been performed which has established the technical basis for deciding on the need, or otherwise, for developing both systems.

Regarding Extra-Vehicular Activity (EVA), despite a good understanding with the Russian Space Agency (RSA) on the need for a common suit, a trilateral agreement including ESA, NASA and RSA still needs to be reached.

ARC (Automated Rendezvous and Capture)
ARC, which forms a crucial link in the development and verification of European rendezvous technology required for the ATV and CTV vehicles, is still not receiving the necessary support from NASA for the demonstration flight of the Astrospas/Minispas configuration. Alternative solutions are therefore being investigated.

ATV (Automated Transfer Vehicle)
The ATV industrial team, covered by extensions to the Phase-A contract, has continued to consolidate the vehicle concepts. The Request for Proposal (RFP) for Phase-B is being prepared for release to industry in March. An effort is being made to integrate the ATV into the Space Station operation and utilisation plans.

Cooperation with Russia
The studies being performed on the use of MSTP elements and technologies for the Russian part of the Space Station have arrived at a point where the the items of interest to be procured in Europe have been identified. ESA and RSA have now to establish an agreement concerning their deliveries, including also items for bartering. The MSTP elements concerned are EVA, ERA and rendezvous sensors. Russia still aims to launch its elements starting in 1997, which imposes very tight schedule constraints on the European contributions.

Cooperation with the USA
In view of the increasing importance of including the MSTP programme in the Space Station development scenario, the exchange of information with NASA has been intensified. MSTP members are participating in the on-going Space Station reviews.

Ariane-5

System
The dynamic environment tests on the launcher upper section, with the vehicle equipment bay, L9 stage and Speltra, have been successfully completed. The next and final step concerning this section will be the acoustic testing of the system.

P230 stage
Following the propellant heterogeneity problems identified in the two main M2 booster segments, it was decided not to use these segments; the test has therefore been cancelled.

The M3 booster, now built, is undergoing checks and final assembly for a hot test scheduled for June 1994.

The metal booster casing has successfully undergone burst tests for its qualification.

H155 stage
Integration of the battleship stage teststand in Guiana is proceeding apace and, with the thrustframe and Vulcain engine already assembled, it is possible to envisage carrying out the first hot tests over the summer.

Tank development work is continuing at a sustained rate. There are two very important events to report:
- burst tests on the qualification tank as predicted
- pressure-proof testing of the tank intended for the 501 flight.

The Vulcain engine has now undergone 173 tests, bringing total firing time to over 43 000 seconds. The first flight-standard engine has now been test-fired for over 10 000 seconds — 16 times the flight burntime.

L9 stage
The L9 stage is integrated on the Lampholdshausen stand but the modelling concerning the Pogo phenomenon has shown that modifications need to be made before proceeding with the hot test, which is now planned for April.

CTV (véhicule de transport d'équipage)
Les deux études industrielles parallèles de phase 0 progressent; la première étape, qui vise à déterminer le concept système le plus approprié pour quatre missions différentes — présentées comme cas d'étude — a été menée à bien. Les deux contractants de cette phase 0 sont parvenus à des solutions valables qui seront consolidées au cours des mois à venir.

ACRV (véhicule de secours pour le retour de l'équipage)
Les études d'extension de la phase A ont été achevées. Mis à part une évaluation commune entreprise avec la NASA, les activités liées à l'ACRV seront interrompues. Les différents aspects de la question du retour des équipages seront désormais traités dans le cadre des études sur le CTV.

Eléments de desserte ERA et EVA
Une étude conjointe a été réalisée à la suite des discussions conduites avec le Canada sur les rôles complémentaires du bras télémanipulateur canadien et de l'ERA (le bras télémanipulateur européen). Cette étude a fourni les bases techniques permettant de décider du besoin de développer ou non les deux systèmes.

Dans le domaine des activités extra-véhiculaires (EVA), un accord tripartite reste encore à conclure entre l'ESA, la NASA et l'Agence spatiale russe (RKA), bien que la RKA se soit montrée favorable à l'idée d'une combinaison spatiale commune.

ARC (rendez-vous et capture automatiques)
En ce qui concerne l'ARC, élément essentiel du développement et de la mise à l'épreuve de la technologie européenne en matière de 'rendez-vous' qu'impose la réalisation des véhicules ATV et CTV, la NASA n'a toujours pas apporté le soutien nécessaire au vol de démonstration de la configuration Astrospas/Minispas. D'autres solutions sont étudiées en conséquence.

ATV (véhicule de transfert automatique)
Dans le cadre d'une extension du contrat de phase A, l'équipe industrielle de l'ATV a poursuivi la consolidation des concepts du véhicule. L'appel d'offres pour la phase B était en préparation et devait être adressé à l'industrie au mois de mars. Un effort a été accompli pour intégrer l'ATV dans les plans d'exploitation et d'utilisation de la Station spatiale.

Coopération avec la Russie
Les études entreprises sur l'utilisation d'éléments et de technologies du MSTP pour la partie russe de la Station spatiale ont permis d'identifier ceux dont la fourniture par l'Europe présente un intérêt. L'ESA et la RKA doivent maintenant conclure un accord sur la livraison de ces éléments, dont certains feront l'objet d'accords de troc. Font partie de ces éléments l'EVA, l'ERA et des capteurs pour les rendez-vous. La Russie entend toujours lancer ses éléments à partir de 1997, ce qui impose des délais très stricts aux contributions européennes.

Coopération avec les Etats-Unis.
Les échanges d'informations avec la NASA se sont intensifiés. Les membres du MSTP participent aux revues en cours sur la Station spatiale.

Ariane-5

Système
Les essais en ambiance dynamique de la partie haute du lanceur, comportant la case, l'étage L9, et la Speltra, sont terminés avec succès. La prochaine et dernière étape système concernant cette partie sera l'exécution des essais acoustiques.

Etage P230
Suite à des hétérogénéités identifiées dans le propergol des deux gros segments du propulseur M2, il a été décidé de ne pas utiliser ces matériels et donc de supprimer cet essai.

Le propulseur M3, aujourd'hui fabriqué, est en cours de contrôle et d'assemblage final, pour un essai à feu prévu en juin 1994.

L'enveloppe métallique du propulseur a subi avec succès les essais de qualification à rupture.

Etage H155
L'intégration du banc d'essai de l'étage lourd en Guyane se poursuit activement, le bâti-moteur et le moteur Vulcain sont déjà asssemblés, ceci permet donc d'envisager les premiers essais à feu au cours de l'été.

Les activités de développement du réservoir se poursuivent avec un rythme soutenu et l'on doit signaler deux événements très importants:
- *essais à rupture du réservoir de qualification conformément aux prévisions*
- *timbrage du réservoir destiné au vol 501.*

Le moteur Vulcain en est à 173 essais cumulant plus de 43 000 s de fonctionnement. Il faut remarquer que le premier moteur conforme en standard de vol vient de réaliser plus de 10 000 s de fonctionnement soit plus de 16 fois la durée de vol.

Etage L9
L'étage L9 est intégré sur le banc de Lampoldshausen, mais les modélisations concernant le phénomène 'Pogo' ont montré la nécessité d'y incorporer des modifications avant de procéder à la mise à feu, qui est désormais prévue en avril.

Ariane-5 upper stage (L9) AESTUS engine nozzle

Tuyère du moteur AESTUS de l'étage L9 d'Ariane-5

In Brief

Finland Becomes Full ESA Member State

On 22 March, Finland signed an Agreement for its accession to the ESA Convention. Under the Agreement, which must first be ratified by the Finnish Parliament, Finland will become a full ESA Member State on 1 January 1995.

Finland has been an Associate Member of the Agency since January 1987, and has been increasingly involved in ESA's science, Earth observation and telecommunications programmes.

This brings the number of full Member States to 14. The thirteen others are: Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

Matti Vuoria (seated right), Secretary General of the Finnish Ministry of Trade and Industry, acting on behalf of the Finnish Government, and Jean-Marie Luton, Director General of ESA (seated left), finalise the Agreement making Finland the 14th ESA Member State, as various Finnish representatives and ESA officials look on

ESA Structure Changes

The ESA Council on 22/23 March approved a new internal structure for ESA's manned spaceflight and launcher programmes. The restructuring results from the redefinition of manned space programmes decided at the Council's previous meeting.

There will be two new directorates and their responsibilities will be:

- Manned Spaceflight and Microgravity Directorate: the preparation and management of ESA's manned spaceflight activities, including studies with a view to Europe's participation in the International Space Station and negotiations with the other partners, and ESA's microgravity programme.

- Launcher Directorate: the Ariane-5 programme, the monitoring of Ariane-4 exploitation, and future launchers.

The Council appointed two current ESA Directors to these new posts: J. Feustel-Büechl as Director of Manned Spaceflight and Microgravity, and F. Engström as Director of Launchers.

Frederik Engström, Director of Launchers

Jörg Feustel-Büechl, Director of Manned Spaceflight and Microgravity

ESA Astronauts Training at Star City

Four ESA astronauts are currently training at ZPK, the Russian training centre in Star City near Moscow, in preparation for the EuroMir missions. The first mission, EuroMir-94, will last 30 days and will take place this October. The second one, EuroMir-95 will last up to 135 days and will begin in August 1995.

Training for the EuroMir missions on board the Russian IL-76 aircraft (the ESA astronauts are wearing white suits)

Work on Meteosat Second Generation to Begin

On 17 February, Eumetsat and ESA signed a cooperative agreement on the Meteosat Second Generation (MSG) programme, which will ensure the continuity of Meteosat data into the next century.

The current Meteosat satellites have been collecting and distributing meteorological information since 1977 and are planned to be operated until the end of this decade. However, long-term meteorological requirements as well as satellite technology have evolved and European needs for the next decade will have to be met by a new series of satellites.

ESA will develop the first prototype satellite, a high-technology geostationary satellite, based on preparatory activities that have been underway since 1987. It is expected to be launched in 2000, by an Ariane launcher. A series of such satellites could subsequently be developed.

The Meteosat Second Generation mission is being undertaken by ESA in close cooperation with Eumetsat, in the same way as the current Meteosat Operational Programme (MOP) is being carried out.

John Morgan (seated left), Director of Eumetsat, and Jean-Marie Luton (seated right), Director General of ESA, sign the cooperative agreement for the Meteosat Second Generation programme

ESA to Open Liaison Office in Moscow

Preparations are currently underway for the establishment of a permanent ESA mission in the Russian Federation. This office is planned to be located in the centre of Moscow. It will provide official representation of ESA in Russia, and will serve as a base to support ESA project teams conducting joint programmes with Russia.

Alain Fournier-Sicre, an ESA staff member since 1973 and most recently Manager of ESA's POEM-1 Preparatory Programme, has been nominated as Head of the Office.

ESA has two other liaison offices, one in Washington D.C. and the other in Brussels.

Ariane Launches to Resume in June

Ariane launches are expected to resume on 4 June, with the launch of Flight V64. All launches had been postponed pending the results of an investigation into the loss of Flight V63 on 24 January. The cause was an abnormal heating of the engine's liquid oxygen (LOX) pump bearing soon after it began operating.

Flight V64, which will use a 44 LP launcher, will carry IntelSat 702 as its main passenger, as well as the STRV 1A and 1B satellites.

This launch plan assumes that the new configuration of the HM7-B engine's LOX pump is declared qualified. That decision is expected by the end of May. The qualification tests performed to date have demonstrated that the improved bearing (with a Ni/Ag/MoS2 coating) has a greater resistance to severe working conditions.

Two HM7-B test engines have respectively accumulated 4600 and 3100 seconds of operation time to date. In addition, eight bearings, which have been tested at Liège University (Belgium), have run for more than 40 000 seconds (with 8000 seconds successfully achieved on two units) and with large variations in the main parameters such as the axial load, LOX flowrate and temperature.

At the same time, the other activities in the action plan implemented in response to the loss of Flight V63 are also progressing.

The hardware for the upcoming Flight V64 is also now being prepared. The third stage is being integrated at Aerospatiale (SIL, Les Mureaux, France), and it will then be transported to French Guiana. The launch campaign is expected to restart on 6 May for the launch on 4 June.

Go Where No Student Has Gone Before!

For the first time, students will be able to experience weightlessness ... and carry out scientific experiments. Thirty places have been reserved for students on board a parabolic flight — an airplane flight in which near-zero or microgravity conditions are produced, causing everything in the cabin to be free-floating.

The airplane is flown on a special trajectory so that microgravity conditions are produced for about 20 seconds, with up to 30 parabolas during each flight. Such flights are used to carry out scientific experiments under microgravity conditions.

To win one of the places on the flight, students are invited to submit a proposal for an original experiment that could be carried out in microgravity conditions on board an aircraft and which would complement experiments conducted in ground laboratories. The competition is open to students at European universities and institutes. Cooperation between student groups at several universities in one or several countries is encouraged.

The competition is sponsored by ESA and VSV Ruimtevaartdispuut, a society of engineering students specialising in space technology at Delft University of Technology in The Netherlands.

Proposals must be submitted before 13 June. The flights will be conducted as part of the Second European Week for Scientific Culture, from 18–27 November.

For more information, contact:

VSV Ruimtevaartdispuut
Kluyverweg 1
2629 HS Delft
The Netherlands

ESA C-15
April 1994

Go where no student has gone before

Are you prepared for an out-of-this-world challenge ?

Parabolic Flight Competition
closing date 13 June 1994

Thirty places for students have been reserved on board the Caravelle used for parabolic flights; and you can win one of the places. This is a unique opportunity not only to experience short spells of weightlessness, but to carry out experiments whilst on board under microgravity conditions.

Space Communications by Laser One Step Closer

ESA is pushing ahead with very advanced technology to transmit data directly from one satellite to another using lasers. As part of this effort, ESA will set up an optical ground station in Tenerife, Canary Islands, Spain, to receive laser optical signals from ESA's Artemis satellite. On 29 April, ESA signed an agreement with the Instituto de Astrofisica de Canarias (IAC) on the installation of the ground station at the Teide Observatory in Tenerife.

A one-metre telescope forms the heart of this ground station. The Tenerife site chosen is at an altitude of 2400 metres and observations will be almost completely undisturbed by stray light. It is also particularly well suited to simulate and test laser optical communications with a satellite in geostationary orbit.

The ground station is expected to be installed in the second half of 1995 in anticipation of the launch of the Artemis satellite in 1996. Artemis is an advanced satellite for testing and operating new telecommunications techniques. It will carry a Satellite Inter-orbit Laser Experiment (SILEX) optical terminal that will enable Artemis to exchange data both with other satellites and with ground stations.

Under the agreement, the IAC will also be able to use the telescope for astrophysical research in return for making the site and its infrastructure available to 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 on the second last page of this issue, and using the Order Form on the last page.

ESA Journal

The following papers were published in ESA Journal Vol. 18, No. 1:

SPACE POWER ELECTRONICS — DESIGN DRIVERS
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SPACE-PLATFORM IMPACT PROBABILITIES — THE THREAT OF THE LEONIDS
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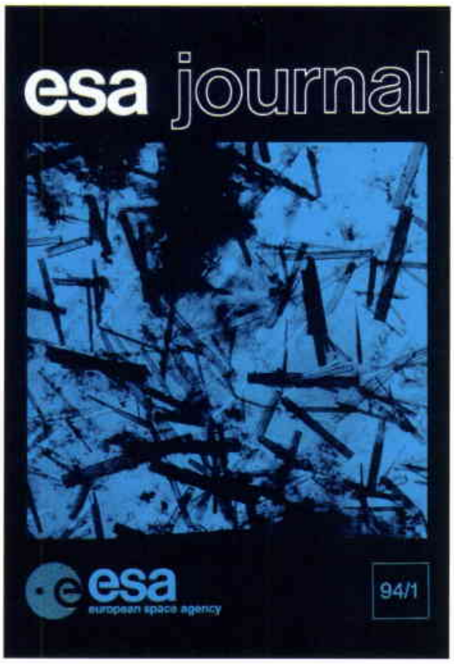

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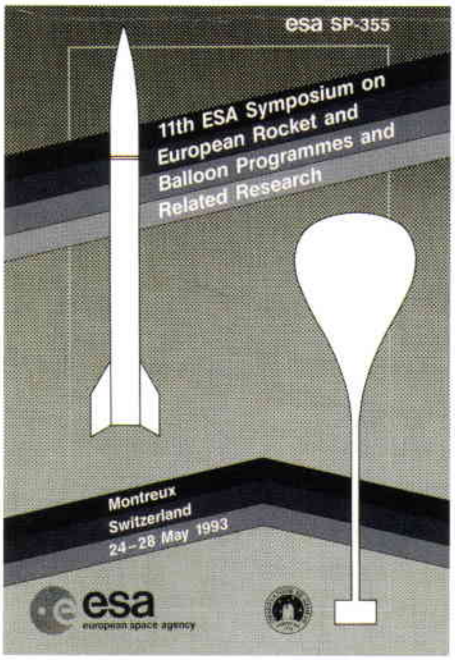

ESA Newsletters

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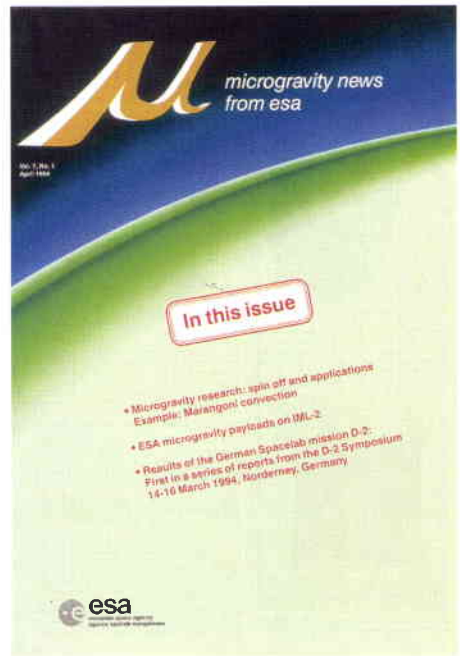
(EDS. N. LONGDON & T.D. GUYENNE)

EUROPEAN CENTRE FOR SPACE LAW
NEWS — No. 13, MARCH 1994
(NO CHARGE)
(EDS. N. LONGDON & T.D. GUYENNE)

MICROGRAVITY NEWS FROM ESA
— VOL. 7, No. 1, APRIL 1994 (NO CHARGE)
(ED. B. KALDEICH)

NEWS & VIEWS (on ESA's Information
Retrieval Service) — VOL. 19, No. 1,
APRIL 1994 (NO CHARGE)
(ED. N. LONGDON)

PREPARING FOR THE FUTURE
(Technology Programme Quarterly)
— VOL. 4, No. 1, MARCH 1994
(NO CHARGE)
(ED. M. PERRY)



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