esa bulletin

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august 1985

european space agency

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

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

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

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

The Directorate of the Agency consists of the Director General; the Director of Scientific Programmes; the Director of Applications Programmes; the Director of Space Transportation Systems, the Technical Director, the Director of Operations, and the Director of Administration.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Dr. H.H. Atkinson.

Director General: Prof. R. Lüst.

agence spatiale européenne

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

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

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

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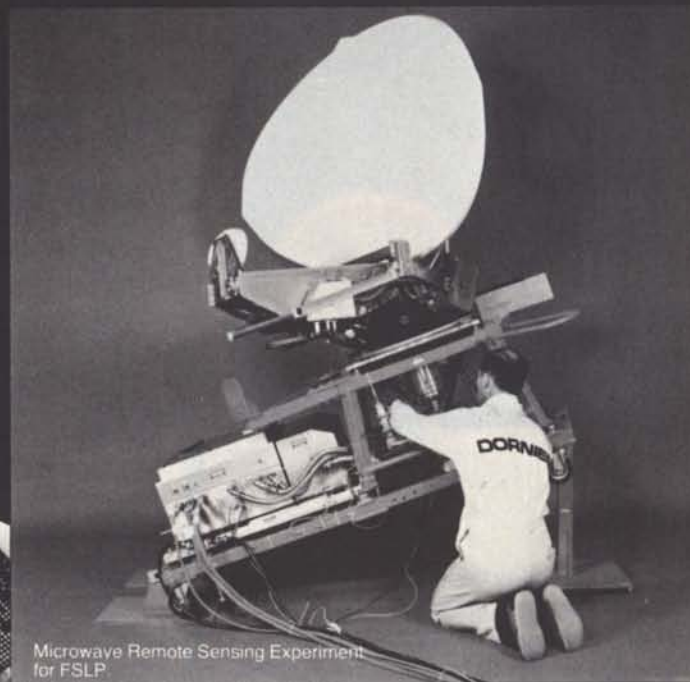
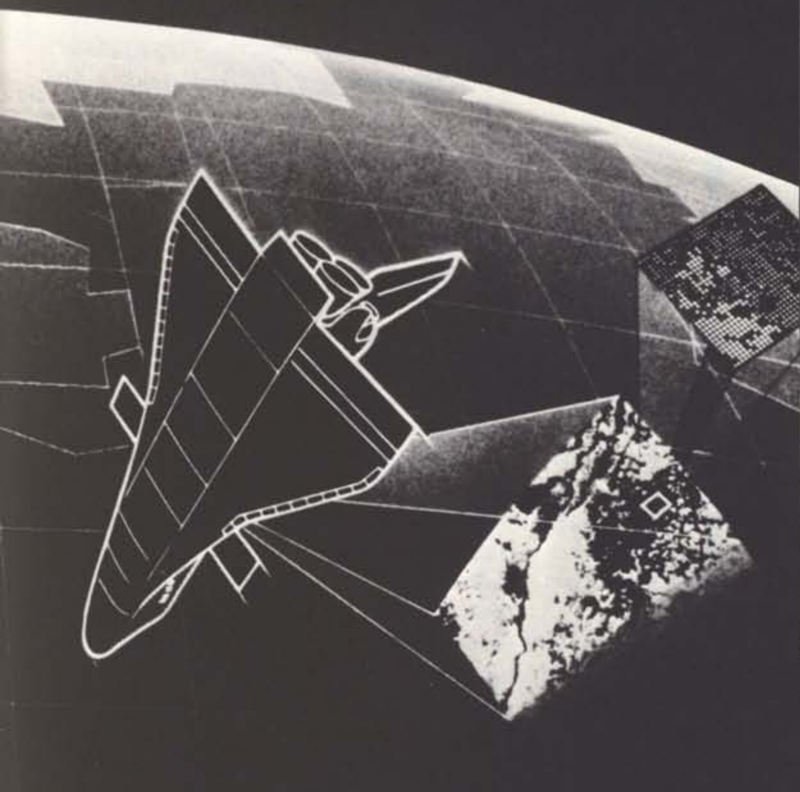


Microwave Remote Sensing Experiment for FSLP



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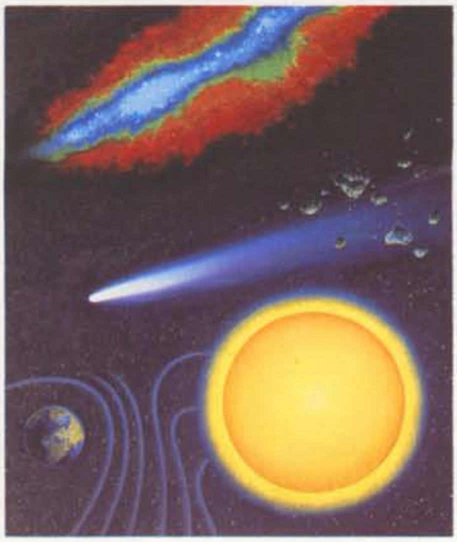


The New Mandatory Scientific Programme for ESA

R.M. Bonnet, Director of Scientific Programmes, ESA, Paris

No-one can deny that the recent Ministerial Meeting in Rome on 30 and 31 January was a total success. One element of this success was the decision taken by the 11 Ministers to gradually increase the budget for the mandatory Scientific Programme by 5% each year until 1989. It is the first time since 1971, when the budget for the Programme was fixed at an annual level of 27 MAU, that the level of the Programme has been changed*. This in itself represents a remarkable success, even though the absolute level of the increase finally adopted may look somewhat meagre in comparison with the anticipated increase in ESA's overall expenditure by a factor two. Although modest, the progression of the Science Programme has to be seen in the context of the financing situation for fundamental science in each country which, at best, is levelling off and more generally does not keep pace with inflation. In addition, the Agency's basic Scientific Programme is a mandatory activity which, with the contribution to the general budget of the Agency – also mandatory – represents the entrance fee to all activities for each Member State, and everyone knows that mandatory payments are not usually joyfully accepted!

* ESA's basic Scientific Programme is a mandatory programme for all Member States and is fixed for periods of five years, reviewed every three years. It funds the development, launching, operation and management of scientific satellites in the domain of space science, with the exception of Earth-oriented, life- and material-sciences in space. In principle, the experiments carried by the satellites are developed by national research institutes using their own resources.

The reasons for success

The reasons are diverse. The first is certainly political. The spirit of the Ministers in Rome was clearly success-oriented. At the time of taking such decisions as the start of new ambitious programmes such as the development of new launchers, participation in the Space Station and in enlarged application programmes, it would have been strange, to say the least, not to increase also the level of one of the large potential users of such huge facilities, i.e. basic sciences. The major question to be discussed by the Ministers was the amount of the increase. NASA, for example, has up to now deviated little from its policy of maintaining the level of its science activities at a constant 15% (approx.) of the total. ESA has no such policy and its capability for introducing optional programmes, which usually induce strong fluctuations in the total budget, does not necessarily automatically reflect the level of the mandatory programme. For example, in spite of the 5% annual increase agreed in Rome, the proportion of the ESA budget devoted to basic science will fall from 14% in 1984, to less than 10% in 1989, and may even go below that level if the progression of the science budget is stopped at that time. This is due to the maximum foreseen in the budget because of the Columbus and Ariane-5 development programmes.

Another reason is that it was not too difficult to argue for an increase in the Scientific Programme because, since 1971, the objectives, nature, size, complexity and lifetimes of science missions have evolved dramatically. Satellites weighing one ton or more, which is considered a low average today, were thought to be beyond the realms of possibility in the early 1970s. This evolution has of course been paralleled by an increase in the cost of the missions, but has not been followed by a parallel increase in the budget of the Scientific Programme. The direct consequence of this was the constant decrease in the number of scientific missions, as can be seen in Figure 1. Between 1968 and 1983, ESRO/ESA launched 13 scientific satellites (the same number as Japan) and will launch only five missions between now and 1993.

This marked reduction in the number of flight opportunities for the scientific institutes was of course of great concern to the scientists themselves, but also to European industry, which is facing a lack of continuity in its activities. Hence, the mandatory Scientific Programme was running the risk of slow extinction, a risk the Ministers finally refused to take. Almost everyone was therefore convinced that something had to be done to save the Programme. The surprise, however, was that final agreement was reached in Rome on the best possible compromise. This success was due in no small part to the existence of a well-prepared and documented Long-Term Plan.

Prior to the existence of this plan, the method used by ESA for incorporating new scientific missions into its Programme was to ask the scientists in Europe to provide new ideas for missions on a regular basis. These were analysed by the various advisory bodies of the Agency,

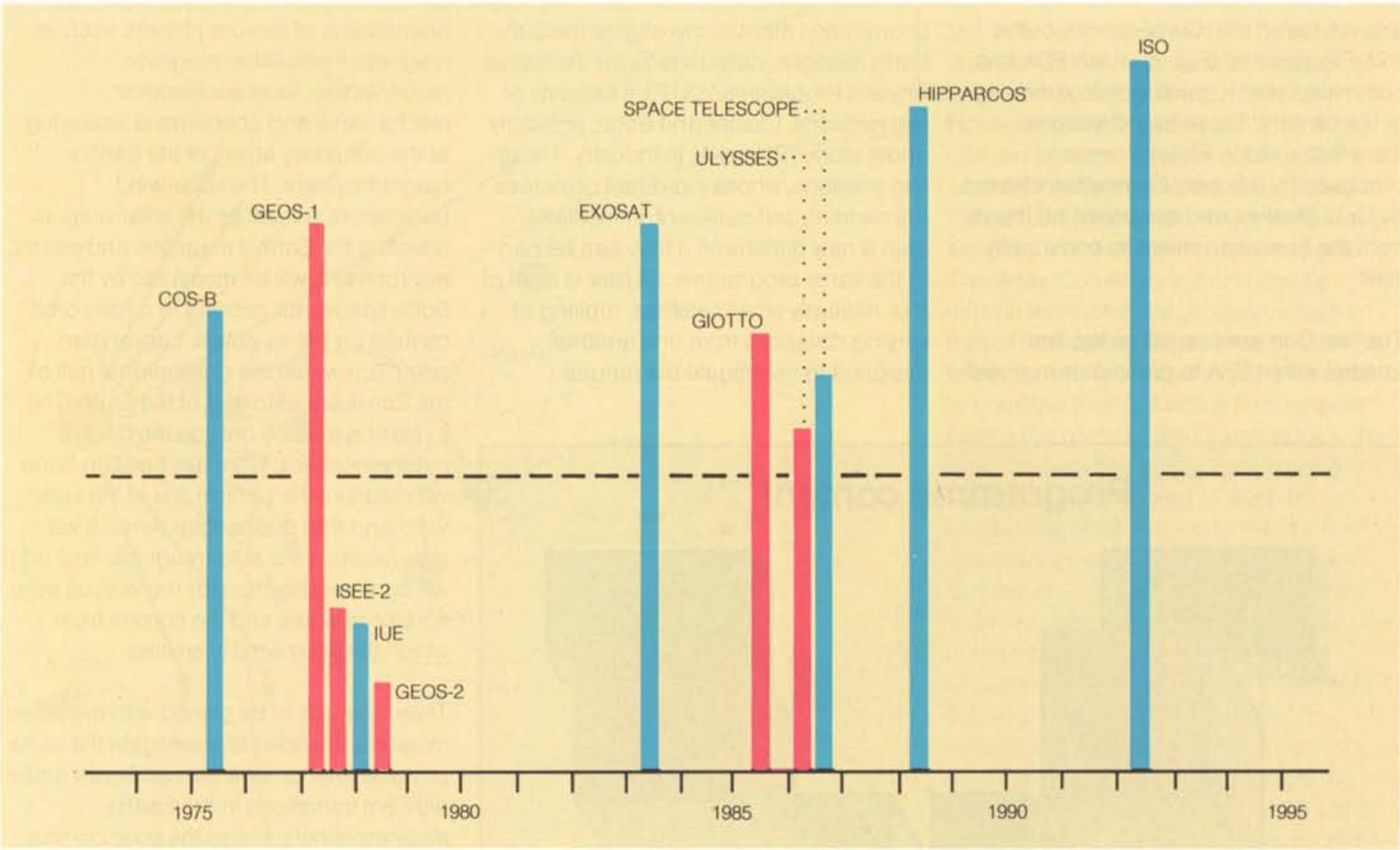


Figure 1 – Total costs of ESA scientific missions launched after 1975, at the time of launch (calculated for the same financial year). The horizontal dotted line is the budget level of the mandatory programme per 30 January 1985. The cheapest missions are either those conducted in cooperation with NASA, such as ISEE-2, IUE, Ulysses and Space Telescope, or replicas of former spacecraft, such as Geos-2. Astronomy missions (blue bars) tend to be more expensive than the others.

before being assessed scientifically and technically. Their final selection was the result of generally fierce competition, after an extensive study phase had been performed by industry. This method was very successful in providing a continuous injection of new ideas into the Programme and keeping up with the rapid evolution in the various areas of space science. In addition, the competitive selection usually led to a good end product. The method proved to be well-adapted to the class of missions characteristic of the early 1970s and which ESA could undertake in fairly good conformity with its programme. It also had some disadvantages.

The first was that ESA and the scientific community were not in a position to know what their programme would be before the competitive selection had been accomplished. Consequently, the Agency was not able to give solid undertakings in discussions at international level which took place regularly on long-term planning, nor was it able to undertake the necessary preparatory technological developments sufficiently ahead of time. The Agency was therefore in a somewhat weak position and could not be the more aggressive partner that its technical and scientific capabilities could well justify it to be.

The second disadvantage really became apparent at the time of the last call for ideas issued in the summer of 1982, which resulted in very ambitious mission proposals that ESA could not realistically consider. They required advanced technological research activities not yet started and their anticipated cost would have absorbed a substantial fraction of ESA's resources for several years, further reducing the number of flight opportunities.

It therefore became all the more evident that something had to be done in order to give a new impetus to the mandatory Scientific Programme, while maintaining it within realistic limits. This was the rationale for undertaking the long-term planning exercise that led to the publication of the by now well-known 'Space Science, Horizon 2000*'. The exercise was also very timely in view of the preparation of ESA's future 'global' plan in the light of the more ambitious space developments, such as the heavy launcher Ariane-5, Columbus/Space Station, and the starting of studies in some Member States of an independent space shuttle.

Horizon 2000

The major difference between the new programme method proposed in Horizon 2000 and that in use up to now is the pre-identification of four major directions in

* ESA Special Publication SP-1070, December 1984 (copies available from ESA Scientific & Technical Publications Branch)

science called the 'Cornerstones of the ESA Programme' (Fig. 2), which ESA has committed itself to pursue before the end of the century. These four directions, identified in red in Figure 2, were proposed by a Survey Committee, chaired by Dr. J. Bleeker, and are based on inputs from the European scientific community itself.

The first Cornerstone will be the first attempt within ESA to participate in a well-coordinated effort to investigate the Sun–Earth relations, called the 'Solar Terrestrial Physics Programme' (STP). It consists of two missions, Cluster and Soho, presently under study (Phase-A) in industry. These two missions, whose individual objectives are certainly self-sufficient, immediately gain a new dimension if they can be part of the same programme. Cluster is a set of four relatively small satellites, orbiting at varying distances from one another, designed to investigate the natural phenomena of plasma physics, such as magnetic instabilities, magnetic reconnection, local acceleration mechanisms and phenomena occurring at the boundary layers of the Earth's magnetosphere. The solar-wind parameters, as well as the solar outputs affecting the Earth's magnetic and electric environment, will be measured by the Soho spacecraft, orbiting in a halo orbit centred on the so-called 'Lagrangian point' (L_1) where the gravitational pull of the Sun is equal to that of the Earth. The L_1 point is located outside the Earth's magnetosphere. From this position Soho will measure the particle flux of the solar wind and that due to solar flares. It will also measure the solar magnetic field and will continuously monitor the various solar surface features and the corona from which the solar wind is emitted.

There is much to be gained with these two missions, intended to investigate the same physical phenomena as manifested under different conditions in the Earth's magnetosphere and in the solar corona. This cross-fertilisation effect was outlined at a recent Workshop held at Garmisch-Partenkirchen.* The STP Cornerstone is one of the major components of the International Solar Terrestrial Physics Programme presently being planned by ESA, NASA and ISAS, the Japanese Institute of Space and Astronautical Science (Fig. 3).

The second of the four Cornerstones marks the first European attempt to take part in the internationally coordinated effort to explore the solar system. The Survey Committee identified the study of the so-called 'primitive bodies of the solar system', i.e. asteroids and comets, as a major means of understanding the origin of the solar system itself.

Europe has already taken the first steps in this direction with the Giotto mission, and has thereby gained precious experience

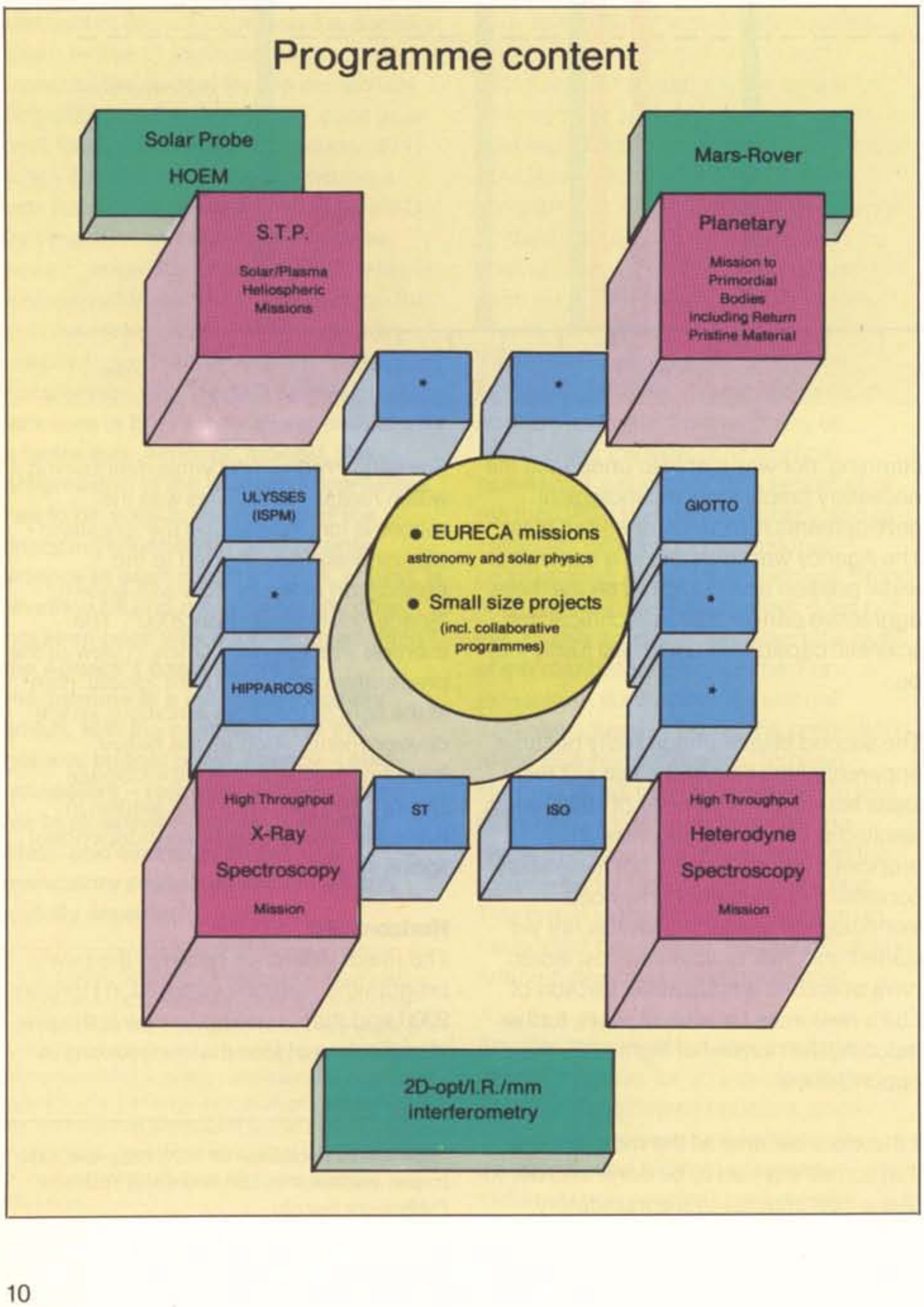
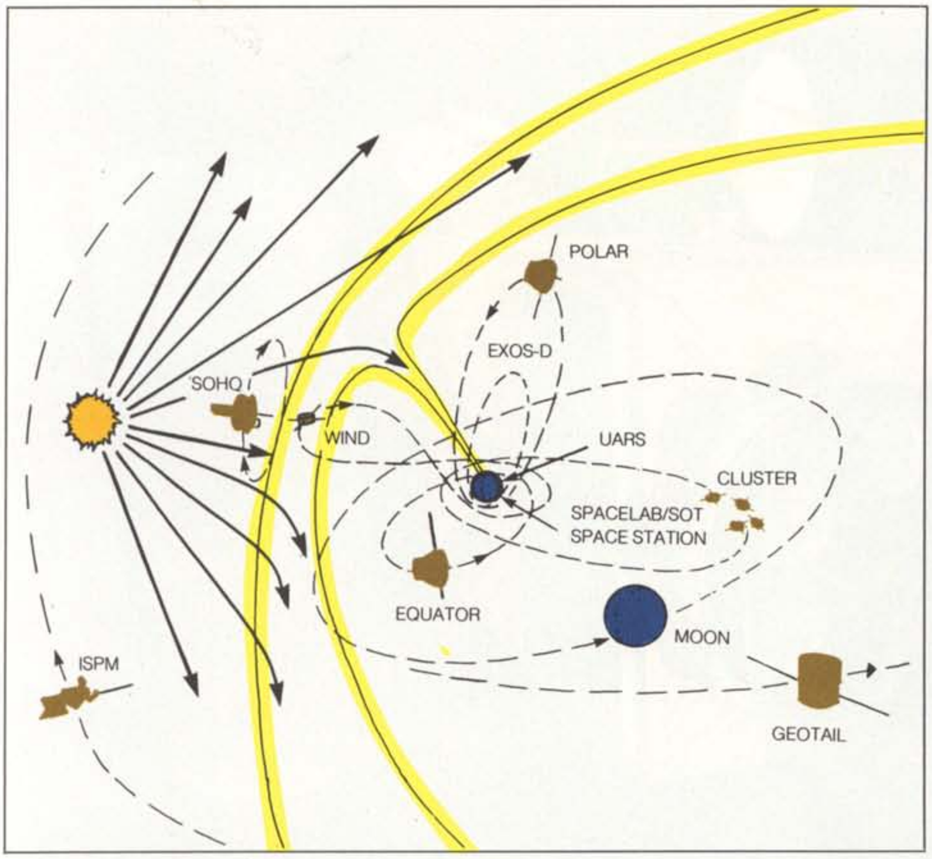


Figure 2 – The European Long Term Programme (as described in ESA SP-1070). The asterisks indicate such missions as the Solar and Heliospheric Observatory (Soho), Multipoint Probes (Cluster), Auroral Multiprobes, etc. in Solar/Heliospheric/Plasma Physics; Venus (Venture), Mars (Kepler), Lunar (Selene) Orbiters, etc. in Planetary Science; and Space VLBI, UV Spectroscopy, Stellar Seismology, etc. in Astronomy.

* Proceedings published as ESA SP-235, June 1985.

Figure 3 – The ISTP Programme concept presently being studied by ESA, NASA and ISAS. In this Programme, ESA would provide the Soho and Cluster missions and ISAS the Geotail mission. All other missions are those proposed by NASA. Ulysses (ISPM) is a joint ESA/NASA mission to be launched in May 1986 and which might be contemporaneous with the Wind mission.

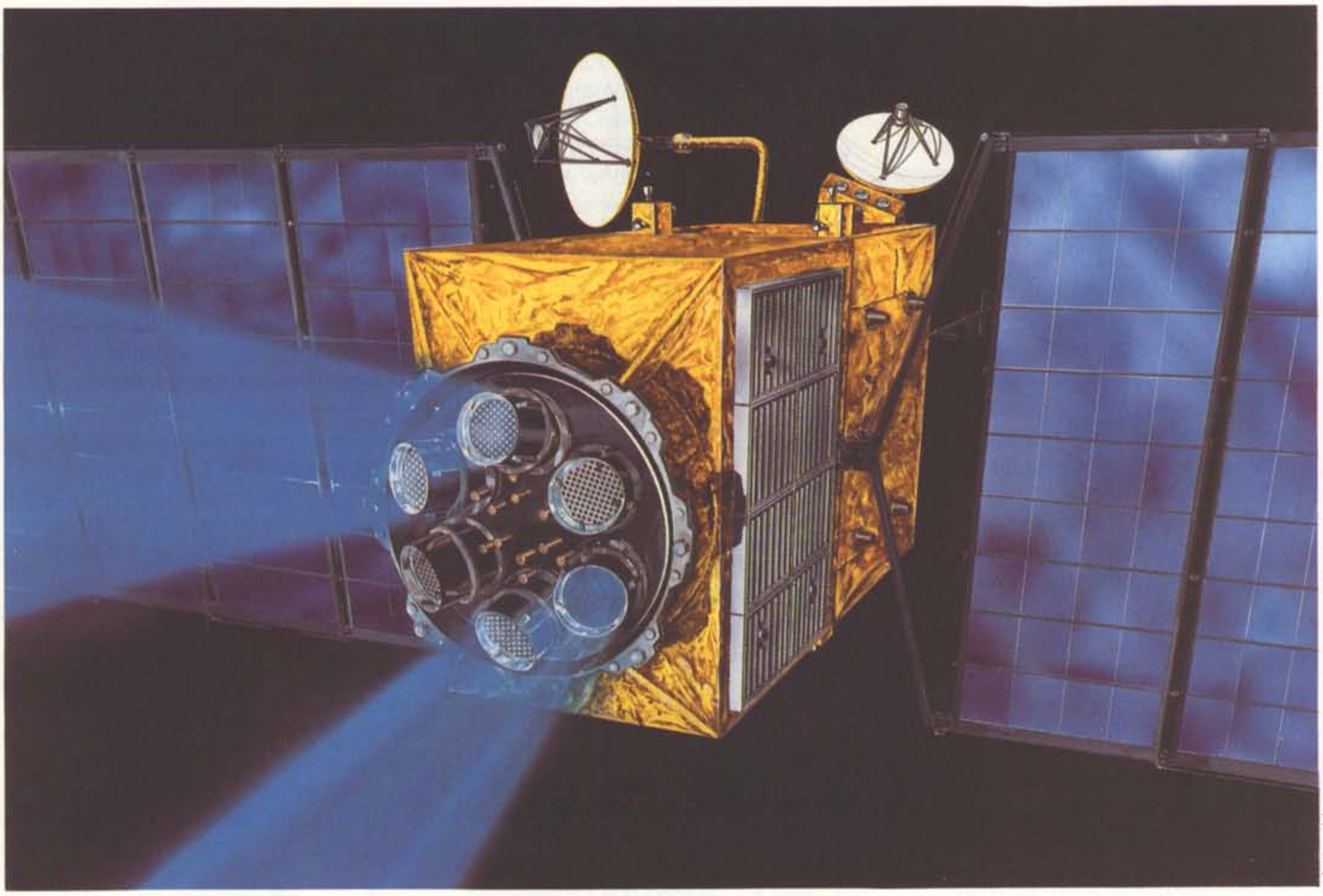


in the technology, instrumentation and navigation techniques necessary to undertake such ambitious objectives. The Survey Committee went one step further in recommending that ESA should attempt to return pristine material from these bodies, with more attention being paid to the nucleus of comets. The latter are considered to be the unchanged remnants of the solar nebula from which our star and its planets were born some 4.5 billion years ago. They are likely to reveal the composition of this nebula at the time when the solar system was formed and are in that sense a genuine jewel-case of our remote past, which we may be able to open up for the first time. The technology required for such missions lies essentially in the area of propulsion systems that will allow us to travel from place to place in the solar system, to brake the interplanetary vehicle, and to recommence the journey. They also require mastery of digging techniques and of returning the material intact to Earth. ESA has already undertaken the development of ionic propulsion systems (Fig. 4). These will soon be needing flight opportunities prior to being used in this ambitious programme, which will probably have to be conducted internationally.

Astronomy also has its part in this plan. The Survey Committee identified two major facilities and stressed the need to develop high-spectral-resolution instrumentation in two domains. The first lies in the high-energy part of the spectrum, i.e. the X-ray regime, where nearly all the violent manifestations of physical phenomena in stars, galaxies, quasars and clusters of galaxies are best observed. To conduct such high-spectral-resolution observations, the X-ray spectra of these objects must be sliced into tiny bands (the higher the resolution, the narrower the slices of the spectrum must be). In order to cope with the need to have sufficient photons in each of these slices, large collection areas are required. However, this is very difficult in the X-ray domain because the telescopes use grazing-incidence mirrors, as opposed to the visible-light domain where telescopes are used with normal incidence angles. The X-ray Cornerstone thus poses a difficult technological problem, which is that of fabricating large series of identical telescopes to be nested together in order to combine their individual throughputs. Hence the name of the Cornerstone – the High-Throughput X-Ray Spectroscopy Mission – and the need to start this technological development rapidly. It is important to note that NASA in its plan has the AXAF mission, which is in many ways complementary to the ESA project in that it emphasises the need for high angular resolution in the same spectral domain. This illustrates another advantage of having identified this direction of research early enough: the necessary coordination with NASA can start sufficiently early to avoid duplication, which could otherwise lead to a waste of resources on both sides.

The other astronomy Cornerstone will explore the only part of the electromagnetic spectrum that has not yet been completely studied, and which requires the use of space because of the absorption and emission of light by the Earth's atmosphere: namely in the range of wavelengths extending from 0.1 mm to 1 mm. In this domain, the 'cold' Universe can be observed, i.e. stars and planets in their first embryonic state. It is also here that we can best observe the remnant photons that were emitted in the very early moments of the Universe and which constitute the so-called 'cosmological background'. At these wavelengths, the deformation of the spectrum due to perturbations by large clusters of galaxies can also be studied, and it is therefore a very rich part of the electromagnetic spectrum indeed. As in the case of X-rays, high spectral resolution in this domain also requires the use of large collecting

Figure 4 – The RITA 35 ion engine, presently under development in ESA and Germany, which could be used for an interplanetary rendezvous with asteroids and comets.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areas to obtain as many photons as possible. However, contrary to the X-ray domain, normal mirrors can be used as long as their diameters are large enough. This Cornerstone, for which ESA intends to put a 10 m diameter mirror into space, is called the 'Heterodyne Spectroscopy Mission', because it employs the same technique that is used to detect radio waves, but applied here for photons with wavelengths of less than 1 mm. The detectors and part of the instrumentation must be cooled to very low temperatures, which necessitates the use of cryogenic liquids, such as liquid helium. The technological challenge of this mission obviously lies in the building and precise adjustment of large mirrors in space and the subsequent refuelling with cryogenic liquids for a long-duration mission.

The four Cornerstones have each been estimated to cost in the region of 400 MAU. They are not the only elements of the plan, however. In addition, it will be possible to continue the competitive-selection approach followed up to now and several possible 'moderate or smaller missions' costing in the order of 100–200 MAU per year can be incorporated in the Programme, calling on the scientific community for proposals at regular intervals, as in the past. In this category can be found such missions as:
- Kepler, an orbiter to Mars
- Cassini, a cooperative mission with NASA to visit Saturn and inject a probe into the atmosphere of Titan
- Lyman, an ultraviolet observatory, and
- Quasat, a radio-telescope in space

the last two missions also being conducted in cooperation with NASA.

Last, but probably not least, dependent upon the interest of the scientific community in Europe, ESA intends to fly a number of 'Eureca' platforms in order to increase the number of flight opportunities and to provide a test bench for new space technologies.

The above is in short, the content of 'Horizon 2000', and it is with the full knowledge of this content that several Ministers in Rome indicated that they would not accept a progression in the budget that would not allow the plan to be implemented. An increase above inflation of 5% per annum was therefore approved until 1989. What happens after 1989 will depend on several factors. Clearly, the rigour ESA adopts in implementing the plan will be one factor. By 1989, the progression in the budget will lead to an annual level of 162 MAU.

Horizon 200 is based on a level of 200 MAU, which has to be reached by continuous progression after 1989.

Implementation of the plan

If ESA wants seriously to implement its plan, it has to adopt a new approach of design-to-cost, so that each of the Cornerstones remains within a budget of 400 MAU. This can only be achieved if the Agency finds ways to keep its own internal costs, those of industry, and launch costs within strict limits. As far as the last of these is concerned, ESA has to find the most cost-effective means of launching. The degree of interest of the scientists and of the Member States in the objectives, and the confidence they place in the plan, will also play a major role.

A specialised Workshop is being organised for each of the four Cornerstones, to review the scientific definition of the project and the necessary technological requirements in depth, to assess the complementarity with missions that may be envisaged in other Agencies, to foster the interest of the scientific community, and to trigger potential cooperation. Scientists from all over the world are invited to these Workshops. The first in the series, mentioned earlier, was held recently in Garmisch-Partenkirchen. It was attended by nearly 200 scientists from ESA Member States, the USA, Japan and elsewhere, and was certainly a scientific success. By the summer of 1986, therefore, the four Cornerstones will have been reviewed and more detailed implementation plans will have resulted. The necessary technology development already identified will also have been started.

The Space Station

Horizon 2000 was conceived on the basis of scientific considerations alone, with no consideration being given to the means of launching the missions. In particular, the Space Station was not treated as a privileged means of launching. In the implementation plan, however, this must be considered and the efficiency of the Station thoroughly assessed. This has led us to propose recently that the Heterodyne Spectroscopy Cornerstone, as well as the Asteroid/Comet Cornerstone, should be considered as model payloads for the definition of Columbus. The first is an obvious candidate: the large mirror should be deployed and adjusted – probably with the help of astronauts – on the co-orbiting platform and the mission lifetime could be considerably increased by servicing from the Space Station. The Asteroid/Comet Cornerstone could use the Space Station as a transportation node for launching larger, deep-space missions than would be possible from Earth and for storing the collected samples of pristine material during the quarantine period.

It is possible that the Space Station could also prove to be a competitive and efficient facility for the smaller projects noted in blue in Figure 2, but yet to be identified. This will be assessed in due course.

The spin-off from Horizon 2000

The net result of the plan, following the successful Ministerial Meeting, has been to instill strong new momentum in the scientific community. The plan's existence has induced many ESA Member States, and also some outside Europe, to undertake a complete revision of attitude towards the ESA Scientific Programme. Obviously, the new Programme cannot satisfy everyone and voices are heard here and there which claim that, by eliminating a priori competition in the Scientific Programme, the chances of some missions being approved are now smaller than before the existence of the plan. Some may claim that it is better to have a large number of smaller missions competitively selected than a relatively small number of pre-identified larger missions. This, however, does not represent the global consensus. The success already encountered by the new Programme bears testimony to the fact that the new approach is fundamentally correct.

Is the plan definite?

Can we now say, however, that the plan is definitely in a final form? This would probably be too restrictive an interpretation of the whole exercise. The long-lead technological developments must, however, be undertaken now, and this is a somewhat irreversible step even if, for some reason, the objectives of the plan were to be modified in the future. Several reasons could be foreseen, which I will not review here as I do not consider that to be a very constructive approach. I have, however, one growing concern, related to the future of European launch capabilities and the continuously increasing costs for launchers. In addition, very little, if anything, is known about the operating costs of the Space Station. Will the limited budget of the new Scientific Programme allow the use of the new heavy launchers and of the Space Station? Should these costs prove prohibitive, will ESA be allowed to use launchers developed by other non-European organisations if they are cheaper? Or will the space policy in Europe at that stage have changed such that the necessary funds can be identified to allow use of these new heavy facilities? Although this is not of immediate concern when thinking of projects to be undertaken until 1994, it becomes critical for a Programme aimed at maintaining strong European leadership in the space-science domain at least until the beginning of the twenty-first century.

Giotto On-Course for Halley's Comet

D. Wilkins, Spacecraft Operations Division, Operations Department, European Space Operations Centre (ESOC), Darmstadt, Germany

On 2 July 1985, the Ariane-1 launch vehicle V-14 carried the Giotto spacecraft into orbit after some 15 minutes of powered flight. Lift-off from Kourou, French Guiana, occurred at 11:23:16 GMT. Twenty-two minutes later the first telemetry signals from Giotto were received at the Estrack station at Malindi in Kenya. From this point in the mission until the third perigee, some 32 h later, telemetry data acquired from Malindi and two other Estrack stations, at Carnarvon, Western Australia and Kourou, French Guiana, flowed via digital data links (for processing by the ESOC computers and display of engineering data to the Mission Control Team) to the ESOC Operations Control Centre at Darmstadt, West Germany, as Giotto orbited the Earth in Geostationary Transfer Orbit (GTO).

This period of 32 h was an extremely busy one, for the members of the ESOC Mission Control Team, the Giotto Project's spacecraft support team, and the staff of the tracking stations. It was also a stressful period because, for the first time, the newly designed and tested OCC was being used for active mission control together with newly installed S-band tracking stations plus a newly installed data-packet-switched communications network (see pages 24–31 of this issue). In the event, the new systems performed well and all flight events were carried out according to the Flight Operations Plan (FOP).

In order to place Giotto into the desired heliocentric interplanetary trajectory, it was necessary to determine the orbital parameters of the GTO and the attitude of the Giotto spacecraft precisely and to increase the spacecraft's spin rate prior to igniting its solid-propellant Transfer Propulsion System (TPS).

Between approximately 1200 GMT on 2 July and 19:23:47 GMT on 3 July, the following activities and manoeuvres were carried out using the telemetry, tracking and telecommand facilities of the Estrack S-band network:
- determination of GTO orbital parameters
- determination of spacecraft attitude
- three slew manoeuvres to place the spacecraft into the optimum attitude for firing the TPS;
- spin-up to 90 rpm, in two stages, in order to stabilise the spacecraft prior to TPS ignition.

The TPS firing took place precisely as planned by means of time-tagged stored commands, while Giotto was out of contact of the network during third perigee passage, and then confirmed by telemetry via the Kourou tracking station.

Within three hours, orbit determination revealed that Giotto was now speeding at some 12 km/s away from the Earth, exactly on course for its rendezvous with Halley's Comet. The orbit-insertion manoeuvre was so precise that the need for any orbital adjustment using the on-board thrusters was obviated. During the next four days, the Giotto spacecraft systems were checked out and configured for the long journey (700 000 000 km) to the Comet. The spacecraft's spin rate was adjusted to 15 rpm, and on 6 July 1985 at 10.47 GMT its high-gain antenna was mechanically released and despun. The telemetry signal received at the tracking stations increased in strength by a factor of more than 1000 as this antenna was activated. By 20.00 GMT on the same day, the testing of all Giotto platform systems was complete and the start of the mission's long 'cruise-phase' to the Comet had begun.

As of 15 July 1985, the Giotto spacecraft is 3 427 000 km from Earth and moving away from us at 13 000 km/h. On 15 July, a radio command transmission to Giotto required 11.5 s to reach the spacecraft from Earth. On 13 March 1986 a command sent to Giotto will travel at the speed of light for 500 s before arriving at the spacecraft. Europe's first interplanetary scientific probe is now on course for rendezvous with the Comet at 24.00 GMT on 13 March 1986.

The accompanying photographs capture the final preparations of the Giotto spacecraft and its Ariane launcher at ESA's launch base at Kourou in French Guiana.

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Figure 1 — Transportation of Giotto from the Kourou integration hall (building S1) to the safety building (S3)

Figure 2 — Arrival of the spacecraft in the safety building (S3)

Figure 3 — Giotto undergoing spin balance testing

Figure 4 — Fitting of the spacecraft's high-gain antenna

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Figure 5, 6 — Installation of the Mage apogee boost motor

Figure 7, 8 — Installation of the motor's nozzle-closure mechanism

Figure 9 — Filling of the spacecraft's tanks with hydrazine

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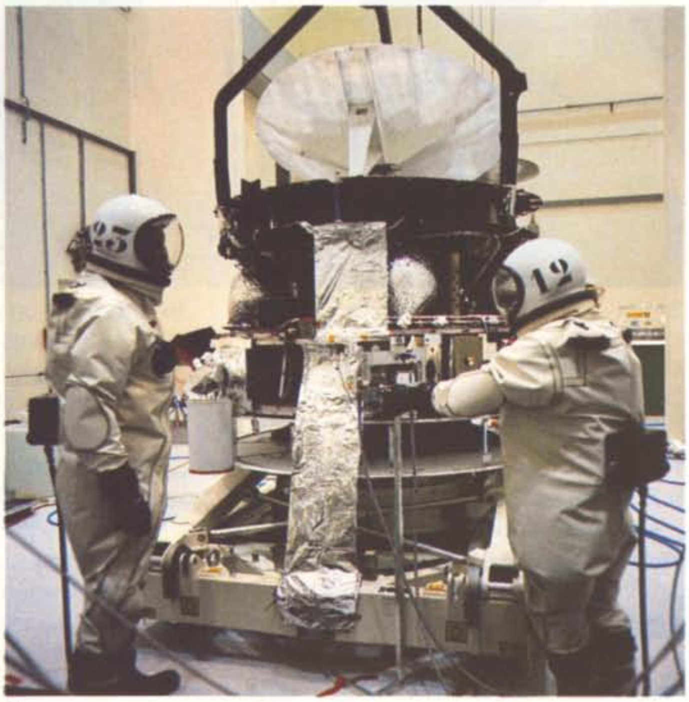

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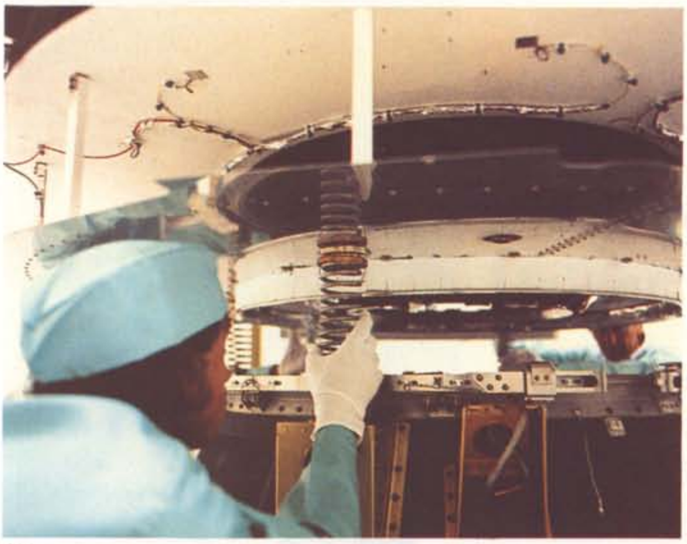

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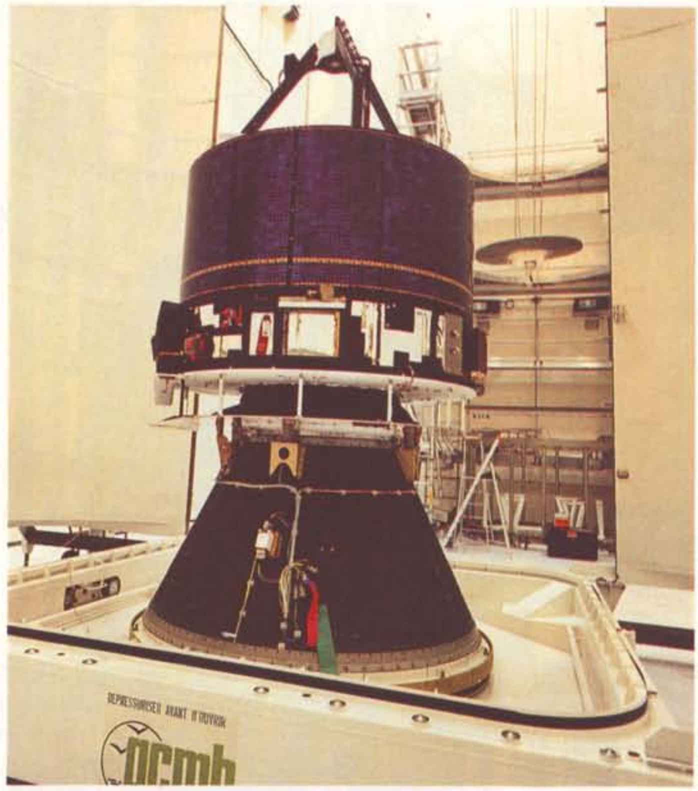

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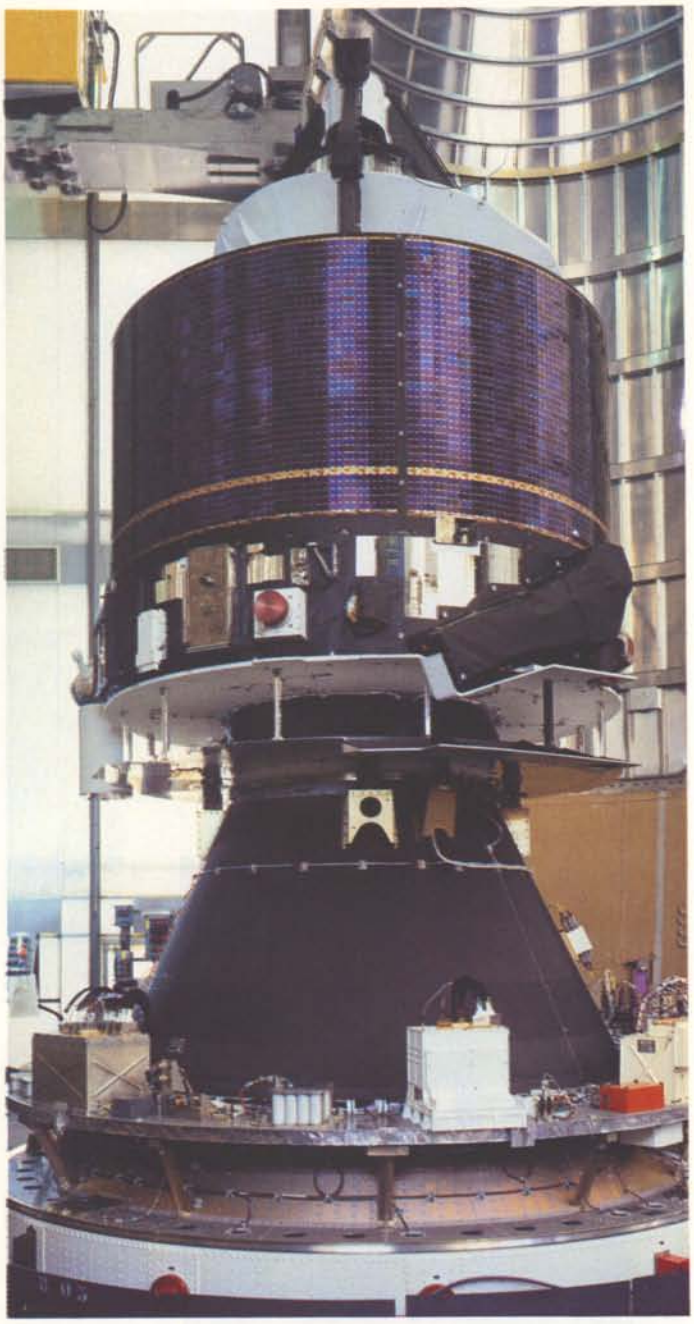
Figure 10 — One of the spacecraft separation springs

Figure 11 — Giotto mounted on the adaptor in the transport container

Figure 12 — Transport of the spacecraft to the launch vehicle

Figure 13 — Transfer of Giotto to the top of the launch vehicle



Astrometric Observation of Comet Halley

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Analysis of previous astrometric observations of Comet Halley has allowed proficient observatories and observers to be identified. These observers are being encouraged, and in some cases supported, to continue their observing campaigns over the next year, and especially during the difficult observing period in early 1986. The accuracy of the observations is discussed and the previous estimates of the comet's position uncertainty at the time of encounter by Giotto are reviewed. An extrapolation of the frequency and quality of the observations through to March 1986 leads to an estimated uncertainty of 300 km in the comet's position in the target plane at the time of encounter.

A cometary 'astrometric observation' is an accurate measurement of the comet's position (right ascension and declination) relative to the location of the observatory. An image of the comet is obtained – usually photographically but sometimes using a Charge Coupled Device (CCD) – together with the stars in the immediate vicinity. The 'plate' coordinates of the comet and stars are then precisely measured. The stars are identified and their positions in the sky determined from a modern star catalogue. With many reference stars, the system is 'over-determined', allowing corrections to be made, e.g. for asymmetry in the plate, as well as providing the comet's position and an estimate of the accuracy. This reduction process involves the use of high-technology hardware and software. Sometimes, image-processing software is also employed, for example to find the point of maximum light intensity in a diffuse image.

Theoretically, just three astrometric observations, taken at different times, are needed to provide a rough indication of the comet's orbit. However, to determine an orbit accurately, a large number of observations are needed, ideally many hundreds. For an active comet like P*/Halley, whose motion is perturbed by nongravitational forces caused by outgassing, observations spanning at least three apparitions are needed. In the case of Comet Halley, this means observations from the apparitions of 1835–36 and 1909–11 as well as from the present apparition. Once a good orbit has been established, a cometary ephemeris, which provides predicted positions (usually geocentric) for the comet at discrete times, can be set up.

On the assumption of ground-based observations only, the accuracy to which the comet's position can be predicted at the time of encounter by Giotto depends essentially upon three factors:

- the quality of the observations from the present apparition
- the quality of the observations from previous apparitions and
- the accuracy of the modelling of the cometary motion, for which the nongravitational forces are the most problematic.

The first of these factors is the most important. Moreover, observations at certain times have a higher information content than others. Observations obtained in late November 1985, when the comet will make its closest pre-perihelion approach to the Earth (Fig. 1) and its apparent motion across the sky will be greatest, are therefore among the most useful for pin-pointing the comet's position along its orbital path.

Observations obtained in early 1986 will also be important, for two reasons. First, perihelion passage will occur on 9 February 1986, at which time the comet will be entering its most active and least predictable phase. Secondly, observations obtained then and through into March 1986 will minimise the lead time up to the encounter (nominally zero hours UT on

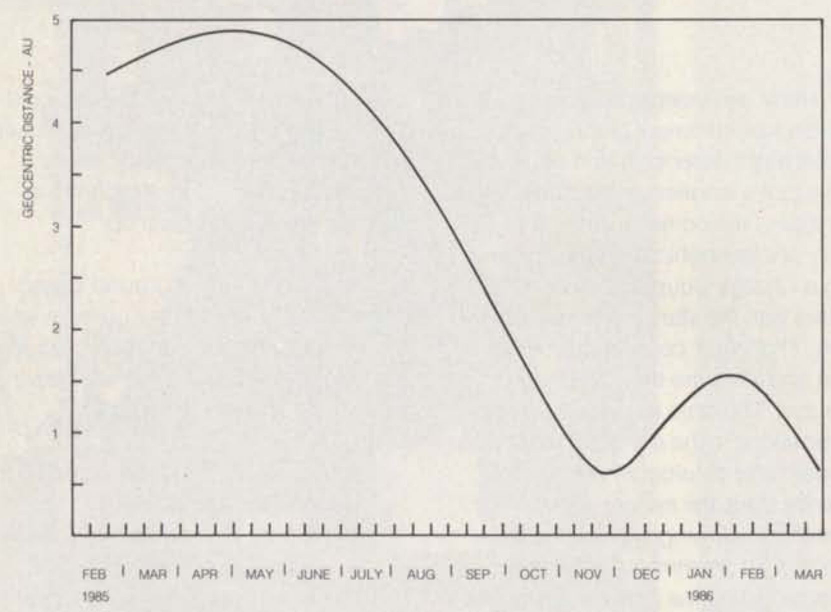
*The designation P/ is used for periodic comets with periods of less than 200 years.

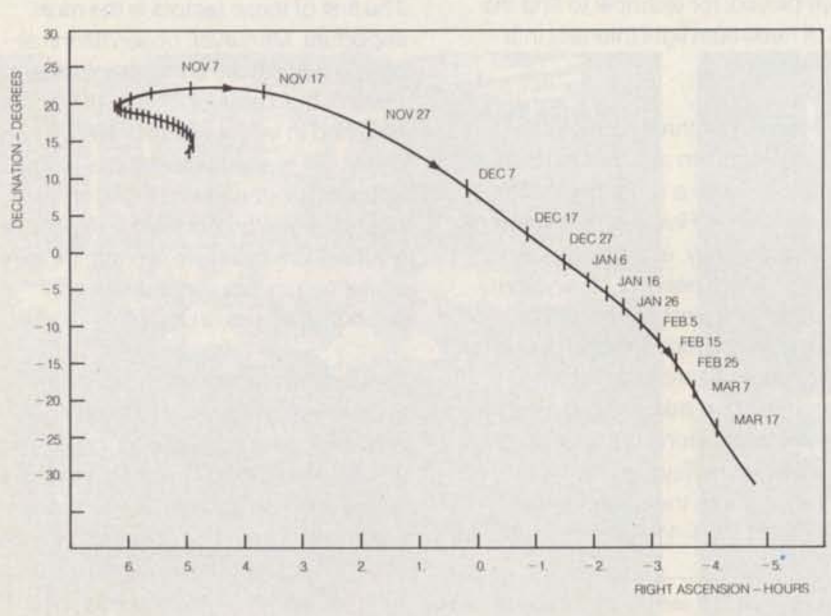
Figure 1a – Distance of Comet Halley from Earth during 1985 and early 1986

Figure 1b – Comet Halley's apparent motion across the sky in the months prior to the Giotto encounter

14 March 1986) for which the comet's motion must be predicted. Also, the 'pathfinder' data, expected from the Soviet Vega spacecraft at this time, must be cnecked to ensure that they are consistent with the ground-based observations.

Unfortunately, a solar conjunction will occur on 6 February 1986 and the closeness of the comet's direction to that of the Sun will preclude observations. Even two or three weeks away from solar conjunction, observing conditions will be very difficult, entailing observing close to the horizon in twilight. In this respect, an observatory located in the Northern Hemisphere will have more favourable conditions for observing in January 1986 and an observatory in the Southern Hemisphere is more favourably located for observing in late February and early March 1986.





The earlier solar conjunction in June 1985 means that no observations are likely around the time of the Giotto launch. The spacecraft will therefore be targeted at injection into a heliocentric cruise towards the predicted position of the comet based upon observations received up to April 1985.

Orbit determination and observation residuals

The quality of the astrometric observations obtained so far during Comet Halley's present apparition has been analysed, based upon observation residuals (the differences between the observed and computed values of the measurements), calculated using ESOC's comet-orbit-determination program. The magnitude of a residual is not an independent measurement of observation quality, since it also depends upon the accuracy of the modelling of the cometary motion within the orbit-determination process. However, the state-of-the-art of this modelling is such that, for a relatively small arc of an orbit, during which the comet was inactive from the point of view of nongravitational forces, the major part of a residual's value can be confidently attributed to observational error. Certainly, it is good enough to enable the accuracy of different observatories or observers (including the measurer and reducer) to be compared by comparing the residuals of their observations.

We can distinguish between the random element of observation errors and the systematic element. Biases in the residuals from one observatory or observer relative to another can be due to systematic errors made by one or both, but can also be due, at least in part, to systematic trends in the determined orbit away from the true orbit. On the other hand, random components of the residuals must be linked directly to random errors in the corresponding observations.

Random errors of a modest magnitude are not as troublesome as systematic errors, since their effect on the orbit-determination errors can be attenuated by using a large number of observations. Systematic errors, on the other hand, generally lead to systematic errors in the determined orbit. Every effort has to be made to remove the source of such errors. In this regard, a considerable effort has already been made to reduce the errors intrinsic in the old astrometric observations.

Old astrometric observations

To determine the comet's orbit, and consequently the residuals, observations from the previous two apparitions of Comet Halley were processed in addition to those from the present apparition. Originally, the old observations were assembled from various sources by Dr. D. Yeomans of NASA/JPL for the use of the International Halley Watch (IHW). Over the last eighteen months, ESOC has been instrumental in getting many improvements made to these observations. Dr. S. Röser of the Astronomisches Rechen-Institut in Heidelberg has re-reduced many of the visual observations from 1835–36 and some from 1909–11, in both cases including observations not in the original IHW data set. The re-reduction has had two main advantages. Great care has been taken to refer all the observations to the same inertial reference system and the positions of the stars, which the observers used as reference, have been taken from modern star catalogues. The old star catalogues contained systematic errors and it has been demonstrated that the re-reduced observations are significantly less biased than the original ones. The random errors for the best observers in 1835–36 range from 2.0 arcsec for Bessel at Kaliningrad or 2.8 arcsec for Struve at Tartu, through to 5.5 arcsec for Nicolai at Mannheim. For the visual observations of 1909–11, 2 arcsec is a typical accuracy figure.

Many photographic plates from Comet Halley's last apparition are still available and in many cases are in remarkably good condition. Over one hundred have already been remeasured (here 'remeasured' is really a misnomer because many of the plates have been measured for the first time!). Among the sources of these plates are the Observatories at Heidelberg, Yerkes, Lowell and, most importantly, Córdoba. Using the European Southern Observatory (ESO) facilities at Garching, near Munich, Dr. Z. Pereyra of the Córdoba Observatorio Astronomico has painstakingly measured and reduced the comet's position on 93 plates to yield measurements of its coordinates to an accuracy of 1.5 arcsec or better.

By the time this article is published, the Comet Halley observations file will have been completely revised at ESOC, so that only re-reduced or remeasured observations from the 1835–36 and 1909–11 apparition will appear in the file.

New astrometric observations

In the period between its recovery on 16 October 1982 and the end of February 1985, 104 astrometric observations of Comet Halley have been reported from a total of 12 observatories around the world (Table 1).

Based upon the accuracy of contemporary observations of other comets and the claims of the observers themselves, it was expected that the observations of Comet Halley during its inactive or barely active period would be within about one second of arc for each of the two coordinates (right ascension and declination). Observations with residuals greater than 5 arcsec in either coordinate have been treated as erroneous and rejected. This does not necessarily imply that a mistake was made in the measuring and reduction process. The more likely cause would be poor image quality, making the reduction difficult.

If the residuals follow a normal distribution with a standard deviation of 1 arcsec, then only about 1% should be greater than 2.5 arcsec. If one takes as a simple criterion for a good observer or observatory that a reasonable number of observations should be obtained with almost all being of acceptable quality, then Table 1 shows that the observatories falling into this category so far are the European Southern Observatory (ESO), the Canada–France–Hawaii Telescope (CFHT), Kitt Peak and Calar Alto. The outstanding quality of the ESO observations is due in large part to a superb series of 25 astrometric observations obtained between the 27 and 30 January 1984. Of course, the relative shortness of this period limits the usefulness of the observations for orbit-determination purposes, as they help to fix the comet's state accurately over only a short time interval. Measurements of this quality, evenly spaced out up to the time of Giotto encounter, would certainly ease the problem of the spacecraft's navigation because more confidence could be placed in the comet's orbit determination.

Future astrometric observations

Until now, Comet Halley's faintness has meant that it could be observed by only a limited number of large telescopes with sophisticated instrumentation. After the solar conjunction in June 1985 the comet will be bright enough to be seen by quite modest telescopes, and thereafter will become progressively easier to observe until the solar conjunction of 6 February 1986 approaches.

By early December 1985 the comet is expected to become bright enough to be seen by an observer equipped with a pair of binoculars. By the end of the year, on a clear evening the amateur observer who chooses a location with the minimum of background light should be able to see the famous once-in-a-lifetime visitor with the naked eye. Comet Halley's path against the stellar background during the period around New Year is sketched in Figure 2.

A very large number of observations are expected during the latter half of 1985. However, the average quality of the observations is expected to deteriorate during this period for two reasons. First, a large proportion of the observers will not be experienced astrometrists. Secondly, the comet will become increasingly diffuse, making the nucleus progressively more difficult to pinpoint. There have already been indications that the comet started to become active towards the end of 1984 (Fig. 3).

Between its recovery and 4 March 1984, the comet's heliocentric distance decreased from 11.05 to 7.75 AU, at which distances it is certainly still an inactive object. Between 20 September 1984 and 19 February 1985, the distance decreased from 6.17 to 4.82 AU and several observers have now reported indications of some comet activity.

A comparison of the observation residuals during these two periods does show some evidence that the quality of the observations has already started to deteriorate, but whether this is due, at least in part, to the supposedly increasing activity of the comet or to the lesser skills of the observers now able to take measurements it is too early to say.

Table 1 – Summary of astrometric observations of Comet Halley during the present apparition

Observatory	Main observers	Observations Total	Rejected Residual >5 arcsec	Residual 2.5–5 arcsec
ESO, La Silla	West, Pedersen	29	0	0
Sanglok	Kiselyev	16	3	5
CFHT Hawaii	Sicardy, Racine, Le Fevre	15	0	1
Kitt Peak	Djorgovski, Spinrad, Belton, Wehinger, Wyckoff, Butcher	9	0	0
Geisei	Seki	7	1	2
Sofia	Shkodrov, Bonev, Ivanova	7	2	1
Zelenchukskaya	Karachentsev, Nazarchuk	6	1	3
Calar Alto	Graser, Neckel, Gruen, Schwehm	5	0	0
Mt. Palomar	Jewitt, Danielson	5	0	5
Lick	Miller	2	0	0
Oak Ridge	McCrosky	2	0	1
Yunnan	Zhang Bairong	1	0	0
		104	7	18

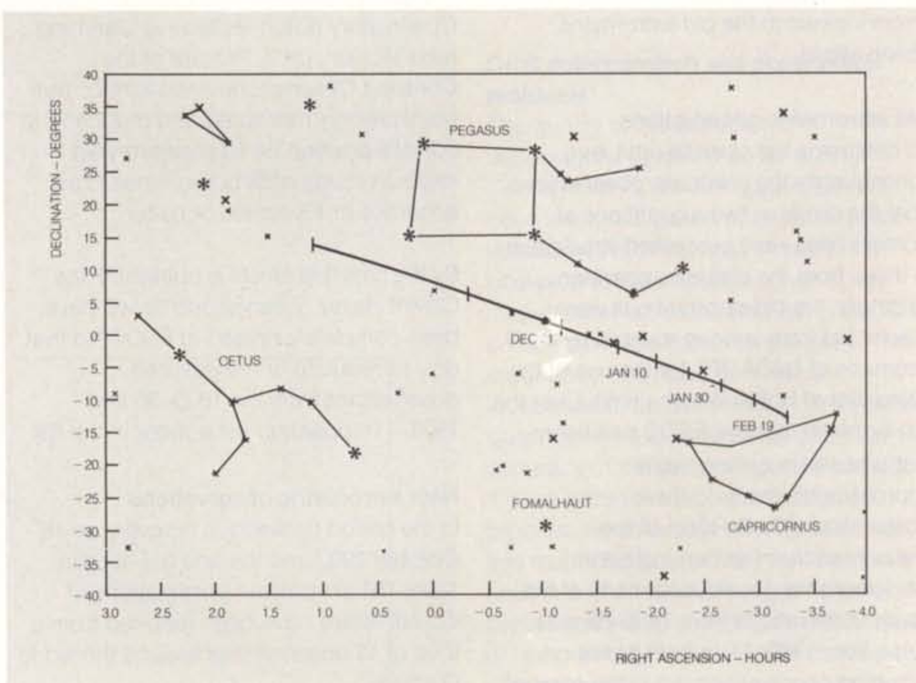


Figure 2 – Comet Halley's path between 1 December 1985 and 19 February 1986, in relation to the well-known constellations

Prediction accuracy at encounter
Even before the first observation of Comet Halley during the present apparition was received, studies were performed within ESA and elsewhere to estimate the targeting accuracy – the expected error in the Giotto flyby distance due to the uncertainty in the comet's position. These studies had to rely at that time on assumptions about the frequency and quality of the astrometric observations. These assumptions have been reviewed in the light of the knowledge now gained about the observations.

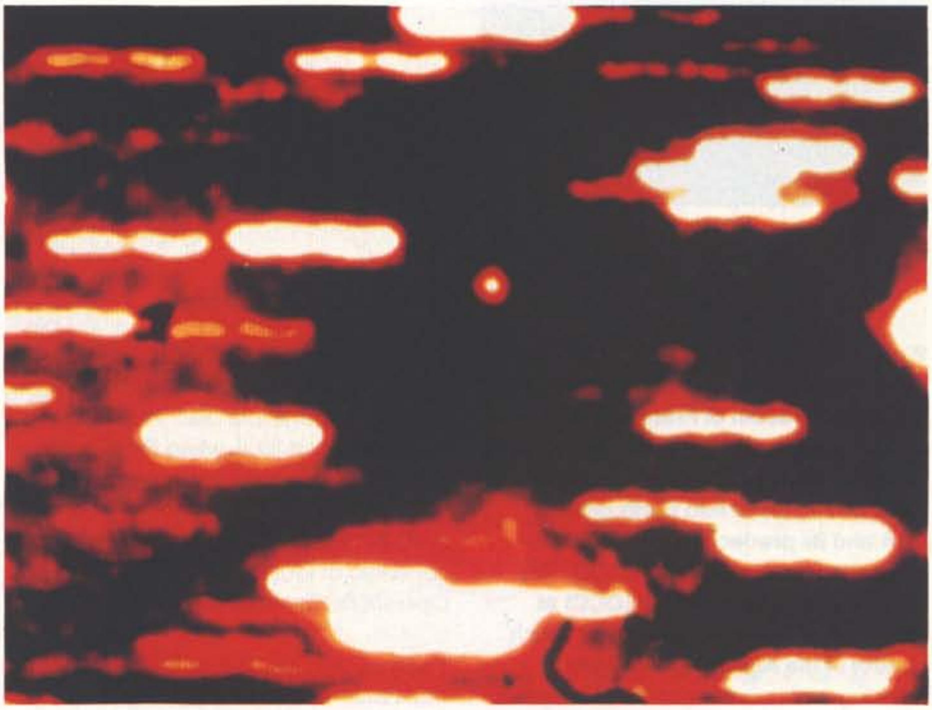
In terms of the accuracy of the observations, the baseline assumptions in the analyses were of the order of 2 arcsec random error on each coordinate plus a systematic error of 0.5 arcsec on the positions. This is definitely worse than has so far been experienced and, we hope, will prove pessimistic for the better of the forthcoming observations.

In terms of the frequency of observations, the assumptions were pessimistic regarding the number obtained before 1985, optimistic for those during the first half of 1985, and appear realistic for the number expected during the latter half of 1985.

Perhaps most pessimistic of all was the assumption of no observations when the solar elongation was less than 40°. For 1986, this translates into a 'blind' period from 10 January until 4 March. Strenuous efforts are being undertaken to try to ensure that some observations at least can be taken during this period. It is hoped to be able to halve the duration of the 'blind' interval.

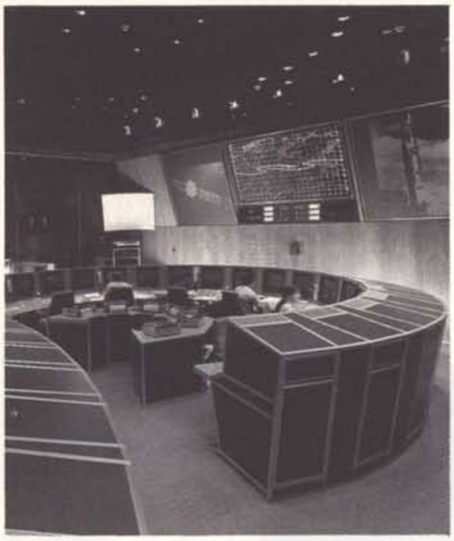
A revised estimate for the targeting uncertainty has been made. In the target plane (normal to Giotto's velocity relative to the comet), it should be possible to predict the comet's position to lie within an ellipse with a semi-major axis of 300 km and semi-minor axis of 100 km with 68% probability (i.e. at the 1 σ uncertainty level). For the flyby on the sunlit side of the cometary nucleus, with a nominal distance at closest approach of 500 km, these accuracy figures are certainly not acceptable. However, the additional use of Vega 'pathfinder' data can potentially improve the comet's position uncertainty by an order of magnitude. Nevertheless, there are several reasons for determining the best cometary ephemeris using only ground-based data. Until the final orbit correction, the Giotto navigation must rely on cometary positions derived solely from ground-based data. Furthermore, we have to be prepared for the contingency that the Vega data is not received, or that it is inconsistent with the other astrometric data.

Figure 3 – Halley's Comet on 17 December 1984 (centre of photo) observed through the 2.2 m telescope at Calar Alto, Spain, by U. Graser and E. Grün (MPI-Heidelberg). The artificial colours represent light intensity levels. The other objects are stars, blurred by telescope tracking



Conclusions

Of the twelve observatories and associated observers who have already obtained astrometric observations of Comet Halley, the best in terms of numbers of observations and accuracy are ESO at La Silla and Calar Alto in Spain. These observatories and their observing teams are being given every support and encouragement to continue their observing campaigns right through to March 1986. For the critical observing period in early 1986, the two observatories complement each other because they are located in the two North–South Hemispheres. For the Northern Hemisphere, both Kitt Peak and CFHT Hawaii have also proved themselves able to provide good-quality observations and should also be encouraged to obtain observations during early 1986. In the more critical Southern Hemisphere, no possible back-up to ESO has yet observed the comet. However, Dr. A. Gilmore of the Mt. John University Observatory in New Zealand and Dr. M. Candy of the Perth Observatory have already agreed to provide astrometric data. The UK Schmidt Telescope in Australia is another viable alternative. All of these observatories have the ability and intention to begin observing Comet Halley soon.



The European Space Operations Centre's New Control Centre

D. Wilkins, Spacecraft Operations Division, Operations Department, European Space Operations Centre (ESOC), Darmstadt, Germany

Since 1968, the European Space Operations Centre (ESOC) at Darmstadt, some 30 km south of Frankfurt, has conducted the operations for all of ESA's satellites in orbit. A total of 20 satellites have been placed into Earth orbit by ESA and its predecessor ESRO, and controlled successfully by ESOC. The Operations Control Centre (OCC) at ESOC is the 'nerve centre' from which control of the Agency's worldwide tracking and communications networks, the central computer complex and hence the orbiting satellites, is accomplished.

This article briefly describes the development of the Control Centre and the European Space Tracking Network (Estrack) since their inauguration in 1968, with emphasis on the newly-installed OCC and its computer complex, which has recently undergone extensive testing in preparation for the launch of ESA's Giotto mission to Halley's Comet.

To the author's knowledge, ESOC is the only control centre in the world from which scientific, communications and Earth-observation satellites are controlled simultaneously on a regular basis.

Evolution of the ESOC OCC and network

The ESOC OCC and the Estrack network have undergone four distinct stages of evolution since 1968, when ESRO's first scientific missions were supported.

In 1968/1969 the Estrack network consisted of four stations (Fig. 1) and an Operations Control Centre (OCC).

The stations were installed at locations that could observe the passage of polar-orbiting satellites, which were mainly in near-Earth orbit; hence the selection of such exotic locations as Fairbanks (Alaska), Spitzbergen (Norway) and Port Stanley in the Falkland Islands, plus the main control station at Redu in Belgium. Data transmission from these locations was accomplished by teletype, and telecommands were transmitted locally using telex schedules originated at the Control Centre. All telemetry, tracking and command interfacing with the orbiting spacecraft was done in the VHF band (136 MHz and 148 MHz).

By 1974/75, the network and the OCC had been modified to provide for real-time command and telemetry operations via Redu and Fairbanks, in order to support the Cos-B scientific mission, which was described in the last issue of the Bulletin.

During 1975/76 the network was again modified, with the following major changes taking place:

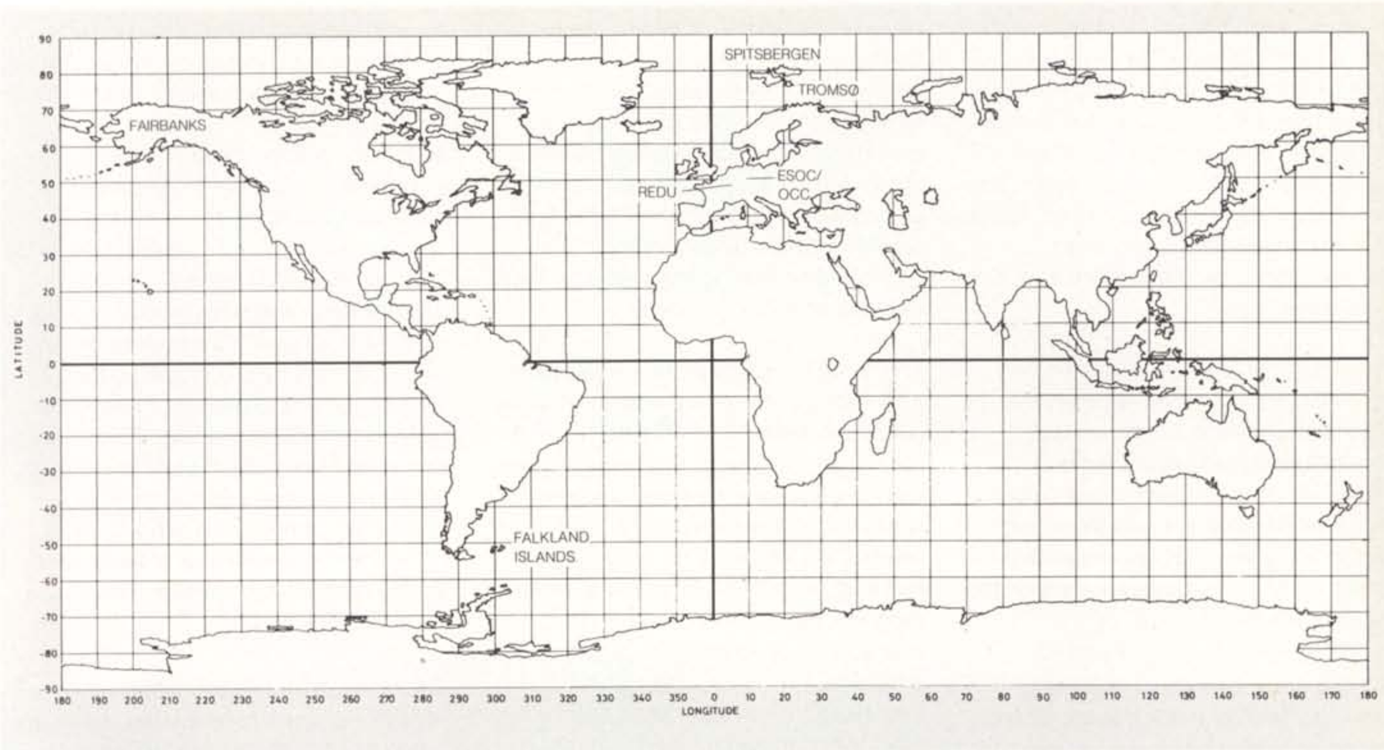
- The VHF network was radically changed to provide support in the equatorial regions, mainly for geostationary-transfer-orbit operations, with stations installed at Malindi in Kenya, Kourou in French Guiana, and Carnarvon, in Western Australia. These together with the Redu (Belgium) station formed the ESA launch and early-orbit-phase network.
- Stations were constructed at Fucino in Italy, the Odenwald in Germany, and Villafranca in Spain to support ESA's new scientific and applications missions (Geos, IUE, Meteosat and OTS). These stations operated in the C-, Ku-, S- and L-bands, as well as in the VHF (Table 1).
- The IBM-360 and 370 computer systems at the OCC were, in turn, replaced by a distributed network of Siemens-330 and CII-10070 machines, which could support not only the OTS, Geos and Meteosat missions, but also the new ECS and Marecs satellites scheduled for launch during the early 1980s. This system, designated the Multi-Satellite Support System (MSSS), is still in use at ESOC and is currently being replaced by a more modern version, as described below.

Between 1977 and 1980, two further Control Centres were built, at Villafranca in Spain and at Redu in Belgium, to provide for:

- the IUE mission (Villafranca), and
- the ECS satellites (Redu).

Early in 1983 a replacement for the MSSS was studied and a Gould/SEL-32/6750 mainframe machine was selected. The new MSSS system would use one large

Figure 1 – The Estrack network, 1968–1975



computer (with 100% redundancy on a back-up unit) to accomplish the spacecraft-control and flight-dynamics tasks that had previously been handled by eight computers. The decision was also made to modernise the OCC display and control facilities completely and to provide the Main Control Room with the ability to support a dual-launch on an Ariane vehicle from ESA's launch base at Kourou in French Guiana, i.e. to control two satellites launched into geostationary transfer orbit by a single launcher.

The new facility provides a modern Control Centre that should easily be capable of supporting current and future ESA missions well into the 1990s.

The '1990s' Control Centre – the new OCC

Plans to replace the ageing Siemens-330-based MSSS computer complex were completed during 1983 and, at the same time, advantage was taken of the opportunity to improve and modernise the control and display facilities of the OCC.

Table 1 – Missions currently being supported by the Estrack network

Station	Latitude/Longitude	Missions supported
Redu, Belgium*	50 00 01/05 08 38	• ECS-1, ECS-2 and ECS-3 (to be launched 3rd qtr 1985) • OTS-2, Geos-2 (uplink only) • Back-up support to geostationary satellites • VHF support to LEOP for geostationary satellites
Villafranca, Spain	40 26 36/356 02 48	• IUE • Marecs-A • Exosat
Odenwald, Germany	49 42 48/08 58 12	• Meteosat 1 & 2 • Geos-2 (reception only)
Ibaraki, Japan	36 16 23/140 12 47	• Marecs-B2
Carnarvon, Australia*	−24 54 14/113 43 12	• Primary station for Giotto mission control • VHF and S-band LEOP support
Malindi, Kenya*	−02 59 35/40 11 40	• VHF and S-band LEOP support
Kourou, French Guiana*	05 19 47/307 25 40	• VHF and S-band LEOP support

* Launch and Early-Orbit Phase (LEOP) network station

The consoles, originally installed in 1971 (and modified in 1975/76), were quite unsuitable for accommodating the large, colour display monitors selected for the new system. Also, because the old OCC display facilities relied to some extent on coloured lamps and strip-chart recorders, devices that were troublesome to maintain and to program, it was decided to replace them.

The decision was made to use 19-inch high-definition colour monitors as the basic display device, combined with standard keyboards equipped with function keys as the basic input/output device. Since the strip-chart recorders were to be phased out, it was decided to display continuous analogue data on the colour monitors.

As 'hard-copy' devices, able to make immediate copies of any display, ink-jet printers providing black and white copies were chosen. At a later date, when colour printers are more economically priced, these black and white printers will be replaced. The system design foresees this requirement and the replacement will be a relatively simple task.

For the console units, an extruded-aluminium-frame structure was selected which can accommodate a wide range of internal adjustments.

Once the design of the new OCC had been completed, a carefully planned integration and re-configuration schedule was established. Immediately after the launch of ECS-2 in August 1984, the OCC Main Control Room (MCR) was dismantled and the consoles reintegrated in an adjacent room to provide support to ongoing missions and to prepare for the launch of Marecs-B2 in November 1984. In the four-month period from September to December 1984, the ceilings and floors were removed, new power-distribution, earthing and signal cables were installed and a new false floor and false ceiling with controlled lighting (dimmers) fitted. The installation of all consoles also took place in this period, as did the integration of all displays, keyboards, microprocessors and intercoms. By the second week of January 1985, the new control centre together with the newly installed MSSS computer system could be tested as a system, to validate the Giotto flight-control software during tests with the Giotto flight-model spacecraft, which was installed at Matra, Toulouse.

The design, implementation, integration and testing of the new Control Centre was accomplished by an 'in-house' team of ESOC staff. This team, supplemented by service-contractor staff and a special service-contractor integration team, was established as a working group which met frequently to establish plans, review progress, carry out action items and manage the programme as a task additional to normal duties. This interdepartmental team proved to be a most effective management approach and also a most cost-effective method of implementing a complex system within a tight budget and an inflexible schedule.

The 'work-station' concept

The control and monitoring of a spacecraft requires that telemetry data be displayed in engineering units, that telecommand tasks be displayed, and that analogue data be graphically displayed. Experience at ESOC had revealed the need for display of all three functions simultaneously. This grouping of the displays and voice-communications terminals into a single unit led to the concept of individual 'work stations' for each operator. This in turn led to a new computer concept for the control and display of information (Fig. 2).

By grouping three displays with one keyboard, the number of transactions between each work station and the central computer system (MSSS) could be greatly reduced by using a microprocessor at each work station for communicating with the mainframe machine. Also, by programming the microprocessor to perform the repetitive tasks of formatting displays, the true data-processing tasks could be concentrated on the central computer. This led to a distributed computer system with a 512 kbyte microprocessor at each work station linked to the mainframe machine via a data link (Fig. 3).

The function of the work-station microcomputer is to relieve the mainframe computer (MSSS) of the application-independent tasks, such as data conversions in form filling, various general validity checks, graphics scrolling, etc. Generally speaking, all the application processing is performed on the MSSS after a request/input from the work station and the results are subsequently transferred back to the work station via the link.

The ink-jet printer/plotter is driven by the microprocessor software, and is used to produce a hardcopy of any screen (alphanumeric or graphic). Optionally, the graphics display can be switched to a closed-circuit video system for display to other users.

Table 2 — General characteristics of the MSSS

- 32-bit CPU with high-speed TTL logic, operating at 150 nanoseconds machine cycle-time
- 32 kbyte, dual-cache memory, which combined with main memory provides data to the CPU at approximately 150 nanoseconds access time
- Main memory presently 6 Mbyte, but being expanded to 8 Mbyte
- Main memory uses a hierarchical structure with hardware memory interleaving
- Main memory protection system is fail-safe in the case of power failure
- Peripheral (disk) memory of 2304 Mbyte (9 × 256 Mbyte disk units accessible by both machines)
- High-speed synchronous internal bus (Sel bus) which has a transfer rate of 26.67 Mbit/s
- The CPU, main memory and the input/output system reside on the Sel bus

Figure 2 – The 'standard work station' for the Main Control Room (MCR). From left to right, the alphanumeric display, alphanumeric display and keyboard, and the colour-graphic display

Figure 3 – The components of the Multi-Satellite Support System (MSSS) work-station console system

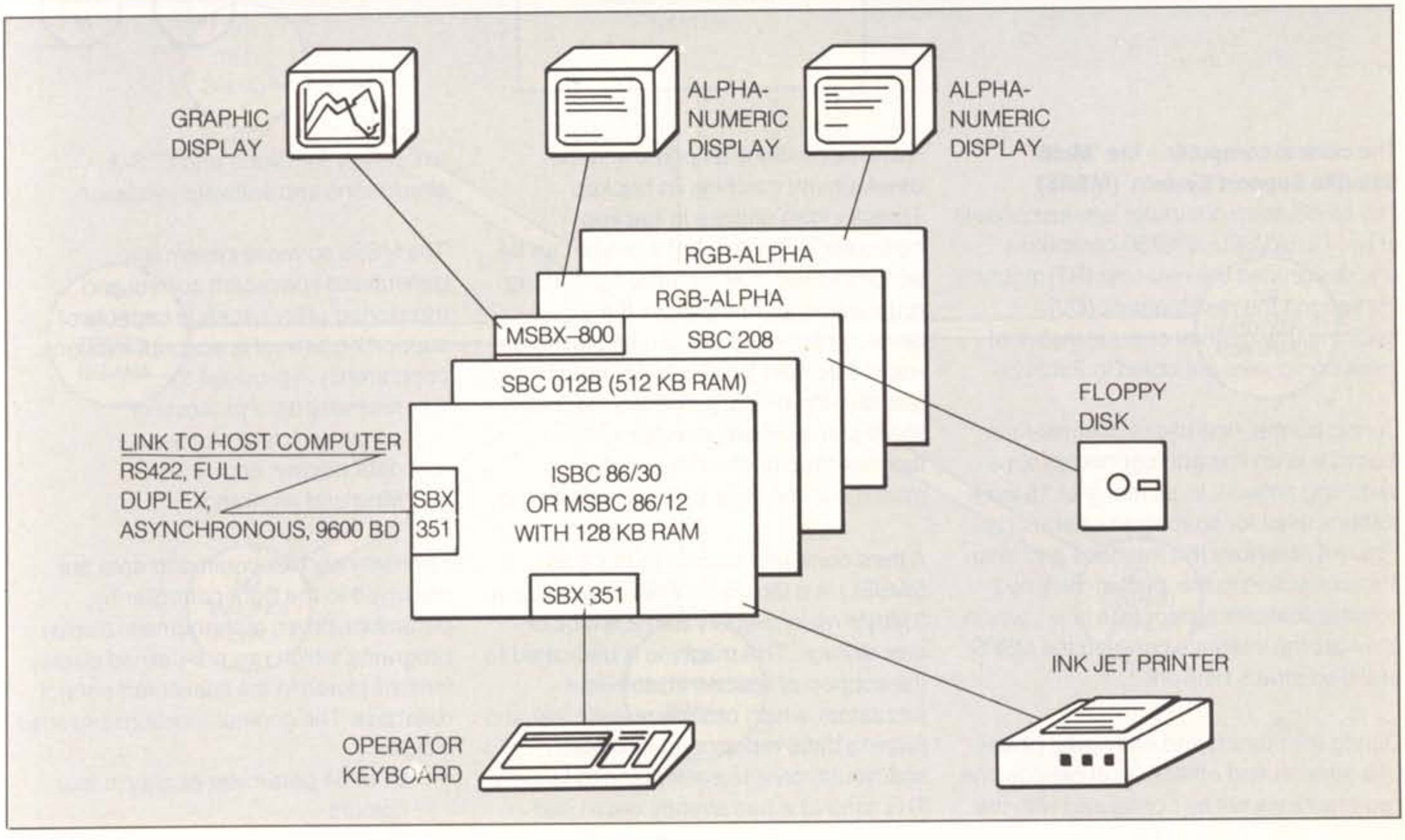
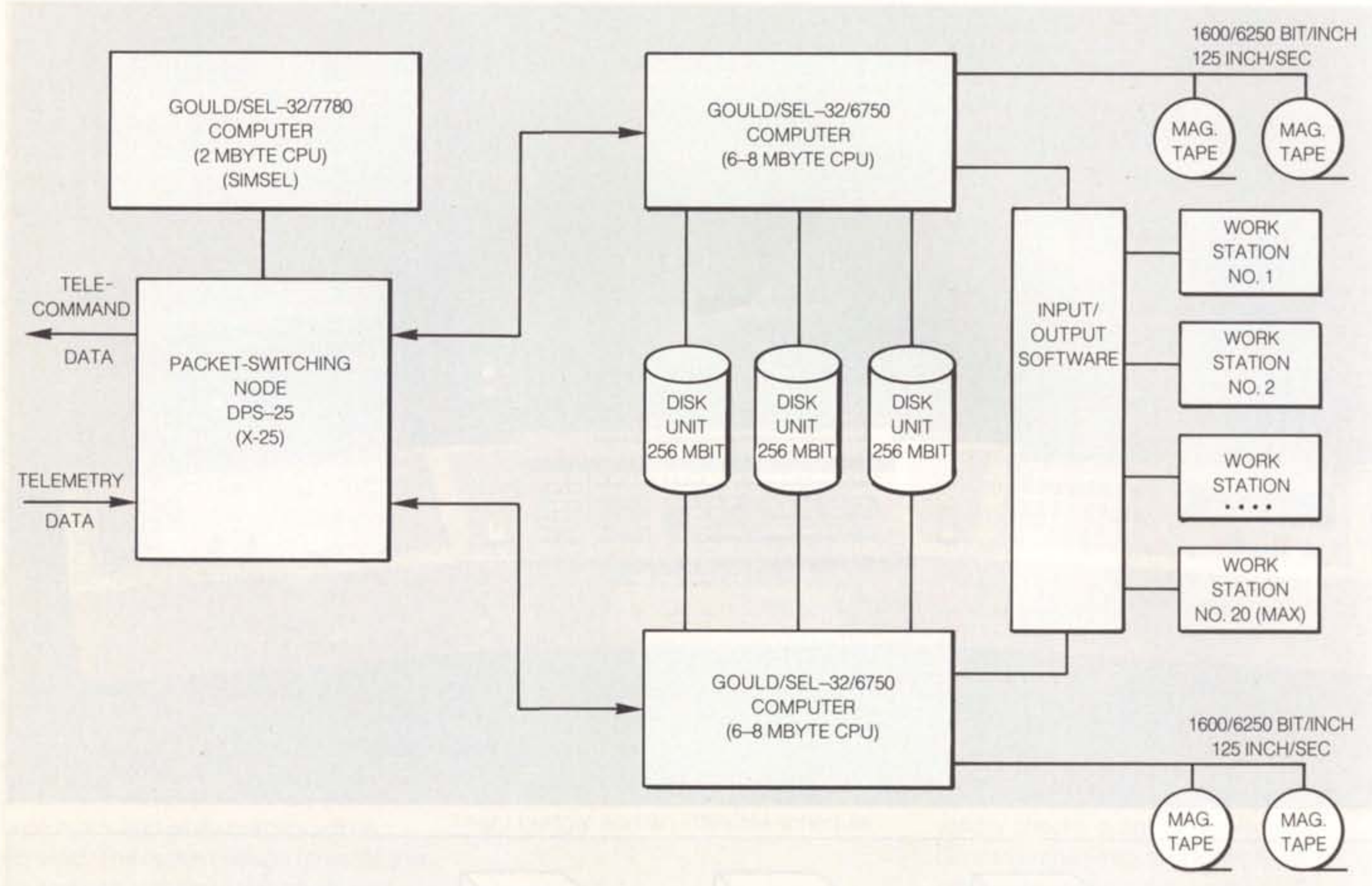


Figure 4 – System architecture for the work-station and mainframe links within the MSSS



The central computer – the 'Multi-Satellite Support System' (MSSS)
The MSSS main computer system consists of two Gould/SEL-32/6750 computers, one designated the real-time (RT) machine, the second the development (DV) machine (the general characteristics of these computers are noted in Table 2).

During normal operations, the real-time machine is on line and connected via a switching network to as many as 16 work stations used for spacecraft operations. Figure 4 illustrates this interface and also the connection to the 'packet-switched' communications system (see later), which provides the interface between the MSSS and the Estrack network.

During the launch and early-orbit phase of a mission and other critical periods, the two machines will be configured with the real-time machine as prime and the development machine as backup. Transfer from primary to backup computer in the event of a failure can be accomplished in less than 2 min. During routine operational phases the development machine can be placed on-line in less than 5 min in the event of a failure in the primary. The two machines share common disk storage, which facilitates rapid reloading of either machine in the case of the other's failure.

A third computer (shown in Fig. 4 as SIMSEL) is a Gould-32/7780 device with a 2 Mbyte main memory and 256 Mbit of disk storage. This machine is dedicated to the support of spacecraft software simulators, which provide realistic test and training data, representative of each spacecraft, prior to each planned launch. This simulator has already been used extensively for Giotto and ECS-3 simulations and software validation.

The MSSS software system is a generalised spacecraft control and monitoring utility package capable of supporting several spacecraft missions concurrently. It provides for:
– telemetry data processing
– command data processing
– data display, and
– filing and archiving.

Telemetry and telecommand data are displayed to the flight controller by parameter-driven alphanumeric display programs, which use pre-defined display formats stored in the spacecraft-control database. The general functions provided include:
– 32 or 64 parameter display in four colours

- graphical displays which plot parameter versus time, or parameter versus parameter, in up to eight colours
- updating of displayed data once per master frame (dependant on telemetry bit rate)
- retrieval and display of telemetry data from history files, with presentation in same format as real time
- display of command history and out-of-limits telemetry status
- hardcopy of any display format currently being displayed.

All telemetry data, command history and ranging transactions are stored on time-keyed circular history files, which can hold up to one week of data for most spacecraft missions. These so-called 'Short History Files' are periodically dumped to archive tape for permanent storage.

The communications network

The new communications network, which entered full operation in April 1985, is a 'packet-switched network' which uses leased public lines (Fig. 5). Designated the DPS-25 system, it will eventually replace the existing 'message-switched' network used to support all current spacecraft in orbit. The primary task of the 'packet-switched' network is to ensure that telemetry and ranging data from the Estrack network and telecommand data being transmitted to the Estrack stations are routed correctly and error-free.

Four main nodes are identified ($N_1 - N_4$), at Darmstadt (Germany), Villafranca (Spain), Carnarvon (W. Australia) and Kourou (French Guiana). All data is transferred between these points as packets of data with packet assembly (rather than individual messages) and disassembly being carried out within each node. Telemetry, telecommand, ranging, station monitoring and control, and telex data are all accommodated.

Malindi (Kenya) and Ibaraki (Japan), identified as M_1 and M_2 in Figure 5, make use of a slightly different arrangement, with multiplexing systems and line modems.

One important feature of the communications system is that it allows Control Centre staff at the Darmstadt OCC to reconfigure any of the remote stations from one central console, should this be necessary in order to correct for ground-station failures. The packet-switching capability of the network enables OCC controllers to select redundant units in the case of failure, since all station subsystems are connected as 'subscribers' to each node and hence to the Control Centre.

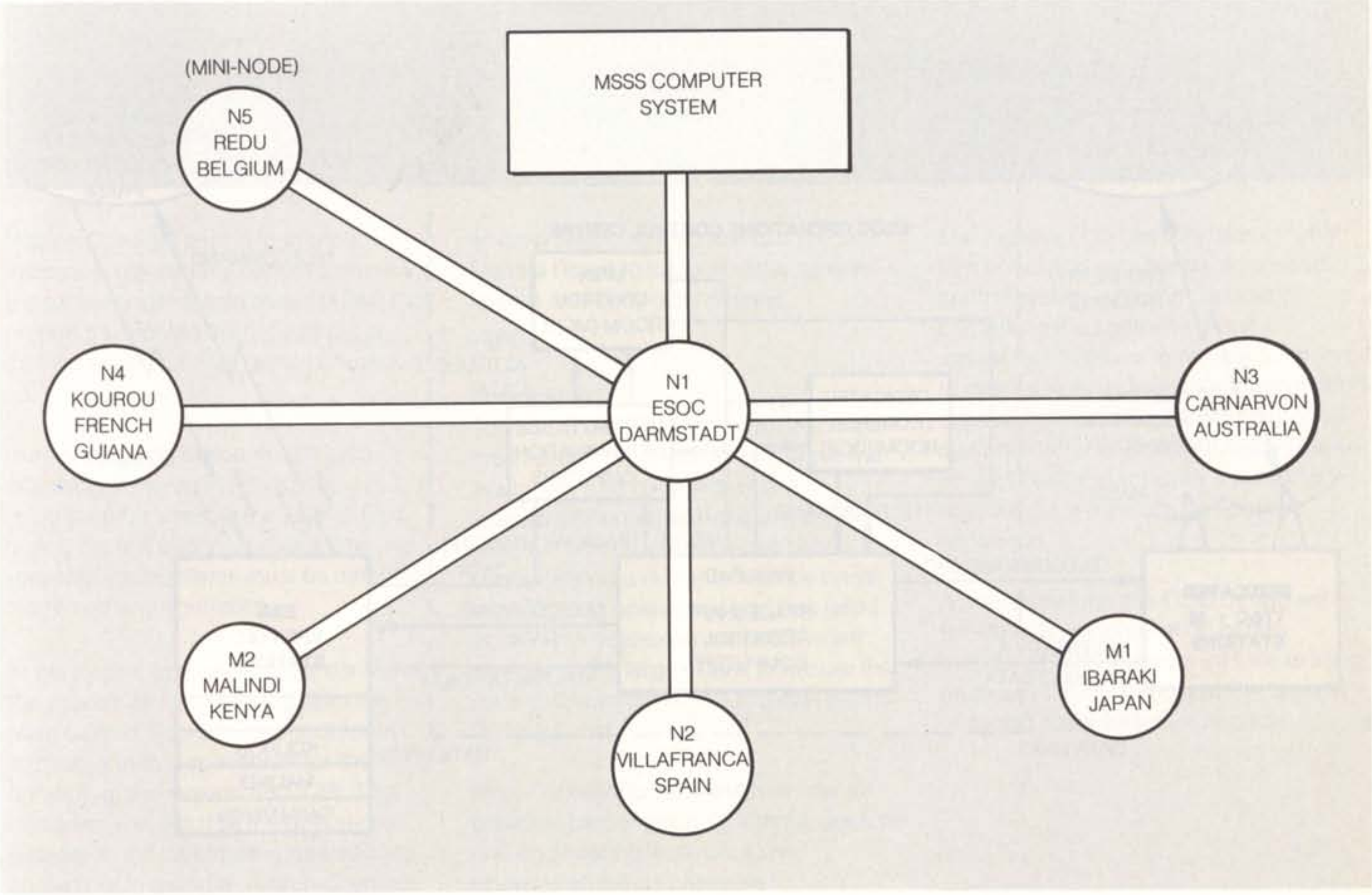


Figure 5 — ESOC's packet-switched communications network (per April 1985)

Figure 6 — Schematic flow chart for spacecraft-control data

The node at Redu (N_5) is actually a so-called 'mini-node' which acts as a packet-switching exchange but has fewer 'subscriber' interfaces within the Redu tracking station. This is because the Redu station support to the OCC is limited to VHF back-up support for ESA satellites.

The spacecraft control system
In order to carry out its spacecraft control responsibilities effectively, ESOC operates a dedicated ground system (Fig. 6), including the control and computing facilities, the telemetry, tracking and command stations of the Estrack network and the communications links.

The OCC is subdivided into Control Rooms. The Main Control Room (MCR) is used for all launch and early-orbit-phase operations for each mission, plus routine day-to-day control of the Estrack network stations, the communications network and the MSSS computer system.

For each satellite mission, a Dedicated Control Room (DCR) is provided in order to ensure noninterruption of ongoing missions while preparations for subsequent missions are carried out in the MCR. ESOC presently has DCRs in operation for the Exosat, Marecs, OTS, Giotto and Meteosat missions.

The primary objective of the launch and early-orbit-phase operations is, quite simply, to place the satellite into the requisite orbit and to perform in-flight commissioning and testing prior to putting it into service. This is therefore a very critical phase of any mission, technically and procedurally.

The launch and early-orbit phase starts with the final countdown and lasts until the payload has been fully switched on (typically, from a few days to almost a month after lift-off, depending on the type of mission). During this period the spacecraft is operated for the first time in the space environment in which it has been designed to function. In addition, the ground system is used in an operational role for the first time. Hence, if any problems are going to occur, they are more likely to occur here than in any other mission phase.

The intense level of operational activity and the number of staff involved at the OCC and supporting telemetry, tracking and command (TT&C) stations could lead to additional problems if operational plans and procedures were not carefully followed. It therefore follows that all of the operations must be conducted in strict accordance with the Flight Operations Plan, and the newly launched spacecraft is accorded first priority in the utilisation of the OCC and Estrack facilities.

In the case of geostationary-satellite early-orbit operations, the major task of the

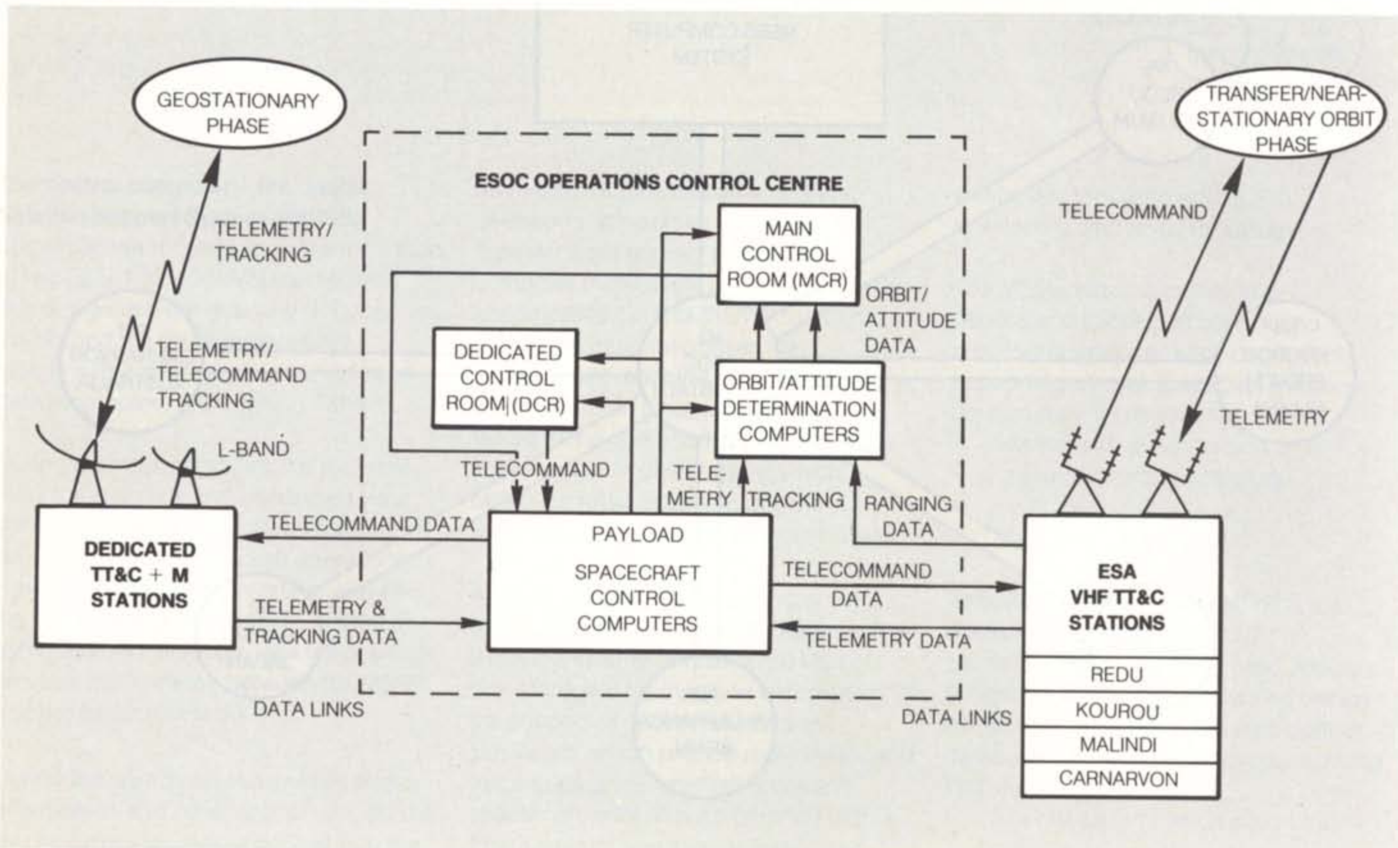


Figure 7 – General view of the Main Control Room (MCR) of the Operations Control Centre (OCC) at ESOC

Mission Control Team is to manoeuvre the spacecraft into the correct attitude for firing the Apogee Boost Motor (ABM) that propels the satellite from the elliptical transfer orbit to its final geosynchronous orbit.

During the same period, which lasts anywhere between 6 h and 38 h, depending on whether the ABM is fired during the first elliptical orbit or later, the spacecraft subsystems must be carefully monitored and controlled.

At the routine operation stage, control of the spacecraft is transferred from the Main Control Room to a control room dedicated to that spacecraft for the duration of the mission (its DCR). This handover ensures that the operations peculiar to the individual spacecraft are carried out in a single-mission-oriented environment, and also releases the Main Control Room to support other satellite launch and early-orbit phases.

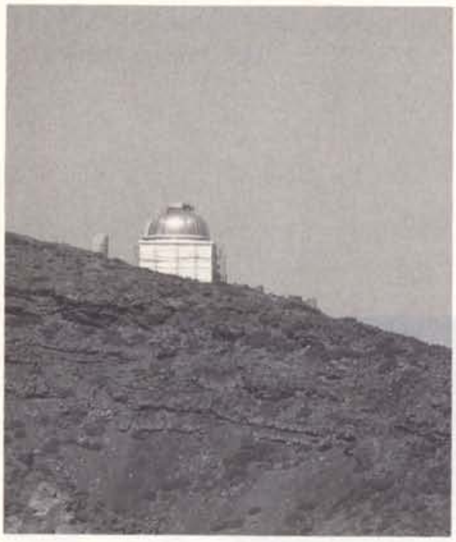
Conclusion

The ESOC OCC has undergone a major modification programme to improve the availability and capability of the spacecraft-control and ground-control systems. This programme has been conducted on a non-interference basis with ongoing operations and has relied on the technical expertise of ESA staff members, to a large extent, to ensure the successful completion of this task and to minimise cost.

Reuse of existing infrastructure was an essential part of this programme, since no civil-engineering work could be undertaken for cost reasons.

The Agency now has a modern, highly functional and very flexible spacecraft control system, which is capable of controlling the complete range of spacecraft missions from near-Earth orbit to deep space. By integrating the mission-control, spacecraft-control and ground-station-control tasks into a multi-satellite control facility, manpower needed for a wide range of missions has been minimised.

At the same time, the OCC design will facilitate the incorporation of new mission-control software into the existing multi-satellite control capability, thereby reducing costs for future projects.



Use of Meteosat Data to Assess the Suitability of Sites for Astronomical Observations

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M. Fea, Meteosat Exploitation Project, European Space Operations Centre (ESOC), Darmstadt, Germany

Three years' worth of Meteosat images have been analysed to investigate the suitability of six sites for astronomical observations. The six sites are: the Canaries (with particular attention to La Palma), the Sierras near Almeria (Spain), the Gennargentu (Sardinia), the northern coastal region of Sicily, the northern coastal region of Somalia, and finally that of Asiago Observatory (Italy) to provide a comparison with ground data. The analysis conducted has highlighted both the great value of this novel application of Meteosat data and also the limitations.

Italian astronomers have decided to build a 3.5 m diameter telescope, to be called after Galileo, to be sited in the Northern Hemisphere. Prime prerequisites in choosing the site are a high percentage of clear nights uniformly distributed throughout the year, an elevation of 2000 m or more, and good atmospheric stability.

Several locations had already been examined by other European astronomers over a number of years, and the efforts of these investigators had led to the identification of a few good sites; notably the Canary Islands, and the Sierra de los Filabres, in Spain. The Galileo Project Team therefore decided to perform a quick survey to compare these sites with candidates on national territory on the basis of cloud coverage. The latter dictates the number of effective observing hours, and hence the efficiency of the observatory. The images in the Meteosat archive at ESOC, with their uniform quality and ready availability, offer good material for such purposes. A preliminary discussion based on existing ground-based data showed that two Italian regions merited analysis on the Meteosat images, namely Sardinia and Sicily. To satisfy the needs of another, geological project, the northern part of Somalia was also included in the study.

Eventually, attention was focused on the six sites listed in Table 1: the Canaries, and in particular Roque de Los Muchachos on La Palma island, site of the observatory belonging to the international consortium of Spain, the United Kingdom, Sweden, Northern Ireland and Denmark; Montana de Calar Alto, in the Sierra de los Filabres in Almeria Province, chosen for the German observatory; Gennargentu Mountain in Sardinia; the northern coastal region of Sicily; and the northern coastal region of Somalia. Finally, the area housing Asiago Observatory was also included as a means of providing a comparison with ground-gathered data.

The data set and the method of analysis
A series of images obtained by the European geostationary meteorological satellite Meteosat-1 between 1 February 1978 and 18 November 1979 and by Meteosat-2 in 1983, and available from the Meteosat archive in the form of 20 cm × 20 cm negative film, have been analysed to study the meteorological

Table 1 – The locations and heights above sea level of the six sites chosen for study

	Latitude	Longitude	Height, m
La Palma	28°45′ N	17°53′ W	2423
Calar Alto	37°13′ N	2°34′ W	2165
N. Sicily	38° N	14° E	1800
Gennargentu	39°55′ N	9°10′ E	1830
Asiago	45°50′ N	11°34′ E	1350
N. Somalia	10° N	48° E	2000

Figure 1a – Meteosat visible (VIS) image taken at 11.55 GMT on 15 July 1984 (full Earth disc, as archived at ESOC)

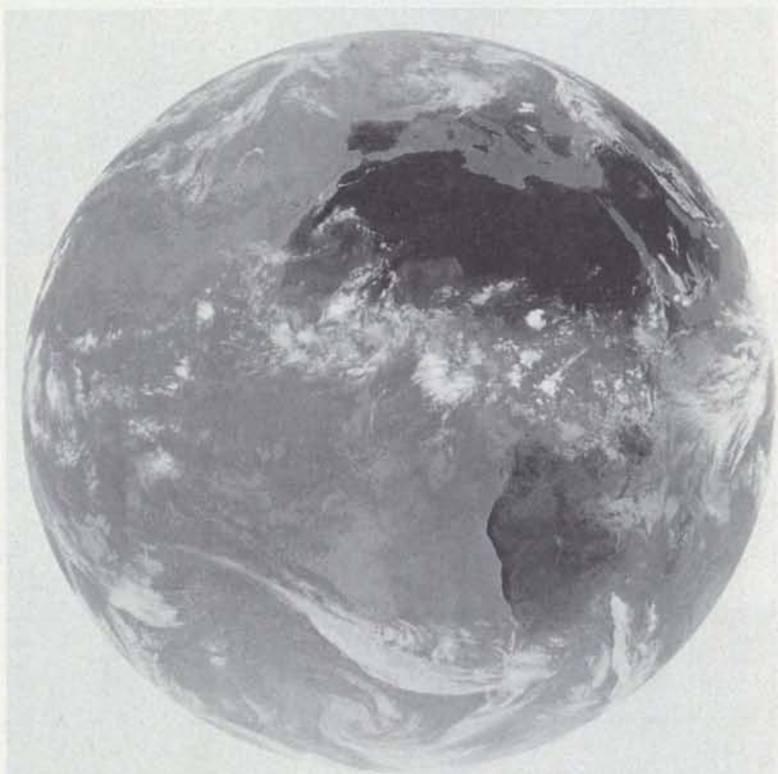
Figure 1b – Meteosat infrared (IR) image taken at 11.55 GMT on 15 July 1984

characteristics of the six sites. The purpose of the analysis was to derive a homogeneous set of cloud-coverage data extending over a period of a few years, during day and night. Meteosat images taken in both the visible (0.4–1.1 μm, hereafter referred to as VIS) and thermal-infrared (10.5–12.5 μm, hereafter referred to as IR) spectral bands were analysed.

As Meteosat provides multichannel Earth imaging every half an hour, images at about 12 UT in the VIS and IR channels, and at about 00 UT in the IR channel were selected (Fig. 1). The IR images taken at midday and midnight will be denoted here by IR(d) and IR(n), respectively.

Each site was inspected visually on the film and its cloudiness classified as: S = clear sky, no clouds within 100 km, QS = almost clear, few scattered clouds, N = extensive cloud layers, or C = overcast. [Codes derived from the Italian: Sereno (S), Quasi Sereno (QS), Nuvoloso (N), and Coperto (C)]. Table 2 shows the number of observations in each spectral band.

a.



b.

Results and discussion

Figure 2 shows the four cloudiness classifications for each of the six sites based on all VIS images available from 1978, 1979 and 1983.

Calar Alto (Almeria) shows the highest percentage of cloud-free days (S), followed by the Canaries, Sardinia, Sicily and Asiago. [The information for Somalia pertains only to 1983, as only IR(n) data were collected in 1978 and 1979].

The Canary Island site shows the highest percentage of 'mixed' days: i.e. the highest number of cloudy days (N), but also the lowest number of overcast days (C).

Figure 3 shows the same classification for the six sites using the IR(d) and IR(n) images.

Table 2 – Number of Meteosat observations

	1978	1979	1983	Total
VIS	329	320	364	1013
IR(d) (12 UT)	315	315	358	988
IR(n) (00 UT)	295	311	359	965

Note: (d) = day; (n) = night

Figure 2 – Classification of all Meteosat VIS images from 1978, 1979 and 1983 for all six sites, based on four classes of cloudiness:
S = clear; QS = almost clear;
N = cloudy; C = overcast

Figure 3 – Classification of all Meteosat IR images from 1978, 1979 and 1983 for all six sites, based on the same cloudiness classes as Figure 2

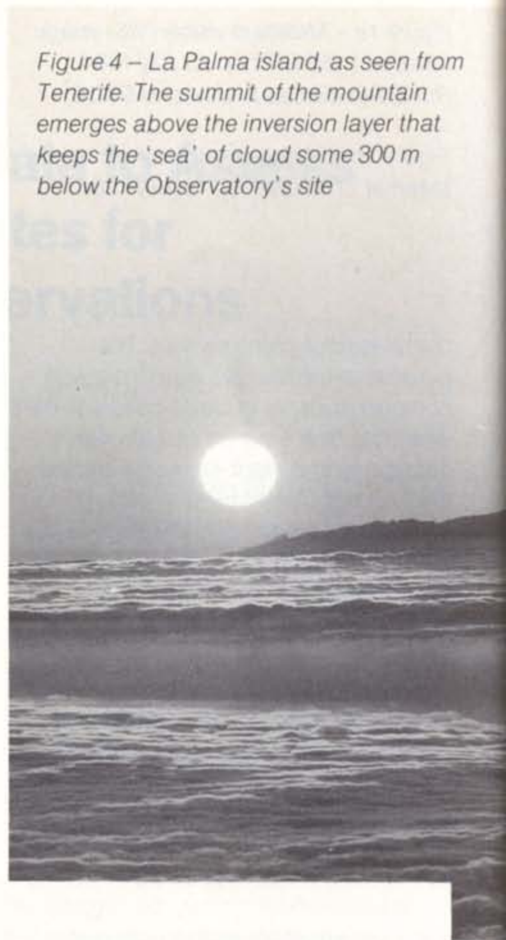
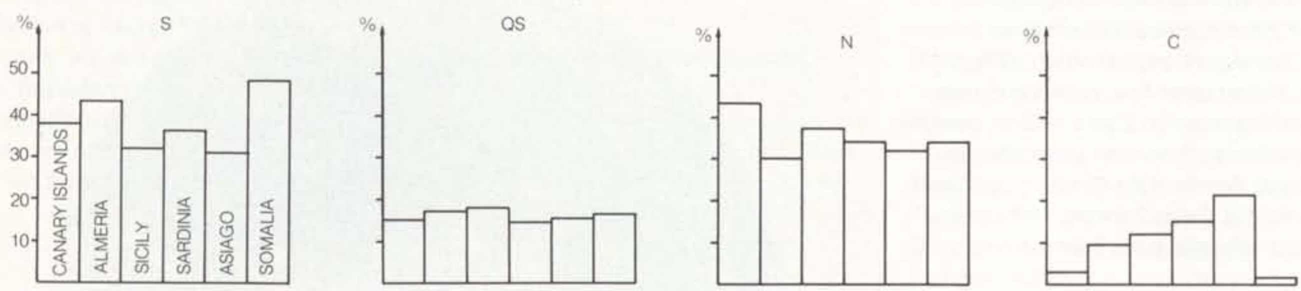


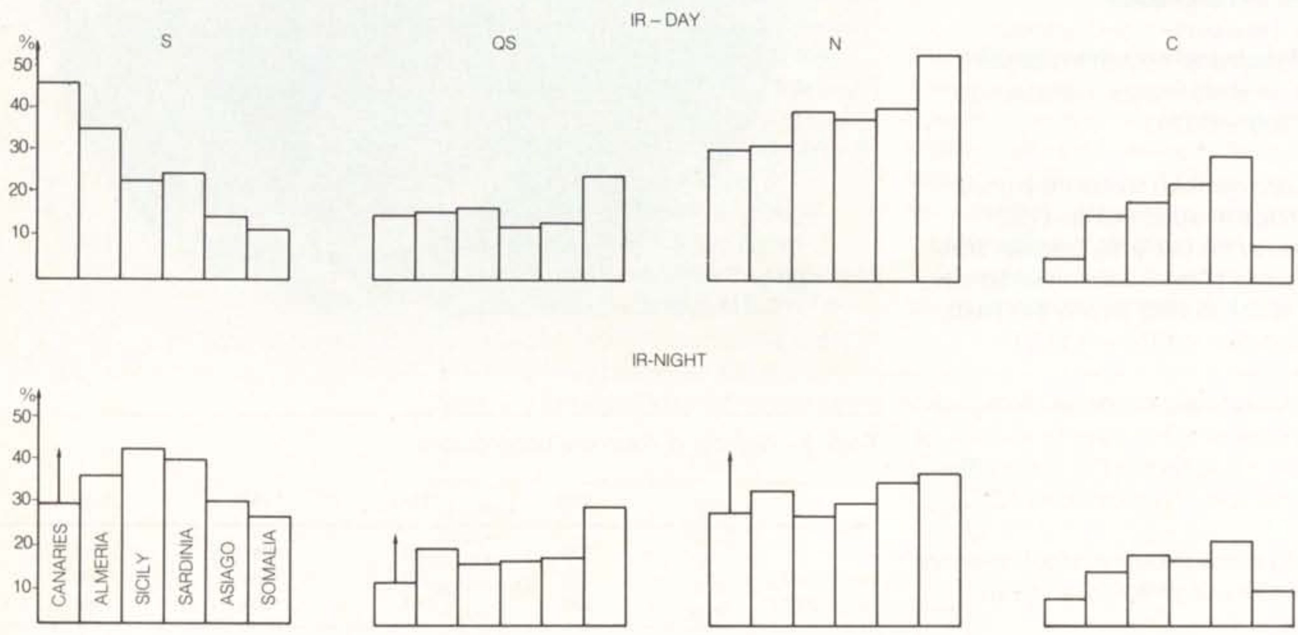
Figure 4 – La Palma island, as seen from Tenerife. The summit of the mountain emerges above the inversion layer that keeps the 'sea' of cloud some 300 m below the Observatory's site

On several IR(n) images, for several reasons the little island of La Palma was indistinguishable from the surrounding sea, making it was impossible to judge the prevailing cloudiness. Firstly, at the latitude of the Canary Islands, the spatial resolution of Meteosat's IR channel is some 6 km. Secondly, the thermal contrast between the sea and the island is very low at night. The situation is even worse when atmospheric conditions favour thermal inversion, which often occurs close to the top of the La Palma mountain (Fig. 4), making the temperature difference between the top of the cloud layer and the mountain peak rather small.

Moreover, the original 256 radiometric levels of the IR images are represented in the archived full Earth disc negatives by only 32 grey levels. This reduces the original 0.5°C resolution in temperature to about 4°C, i.e. top-height differences of less than 700 m cannot be resolved.

This problem is well-illustrated in Figures 5a,b: the island is clearly visible under cloud-free conditions due to the hot soil surface, whereas it cannot easily be identified when surrounded by low cloud. The S, QS and N values for La Palma therefore have to be taken as lower limits.





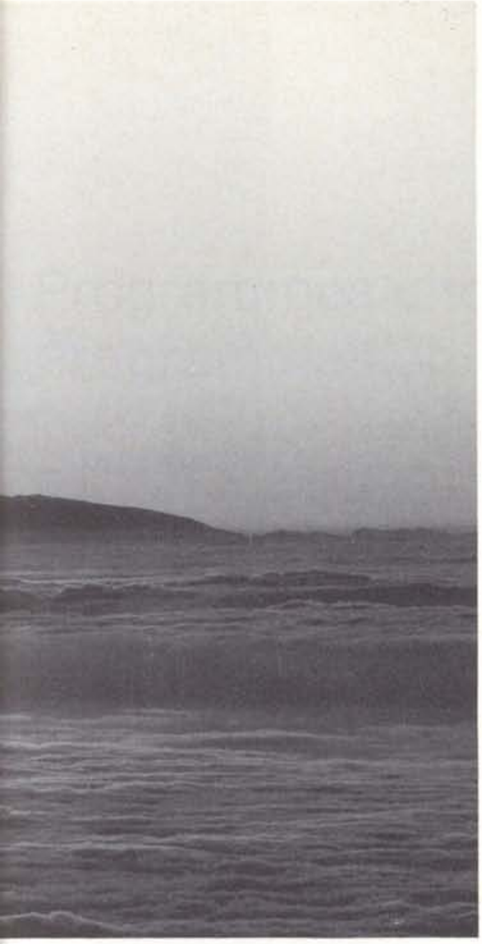


Figure 5a – Meteosat IR image taken at 12.55 GMT on 1 October 1978. The island of La Palma is clearly visible

Figure 5b – Meteosat IR image taken at 08.25 GMT on 19 August 1979. The low thermal contrast makes La Palma hard to distinguish from the surrounding low clouds

a.

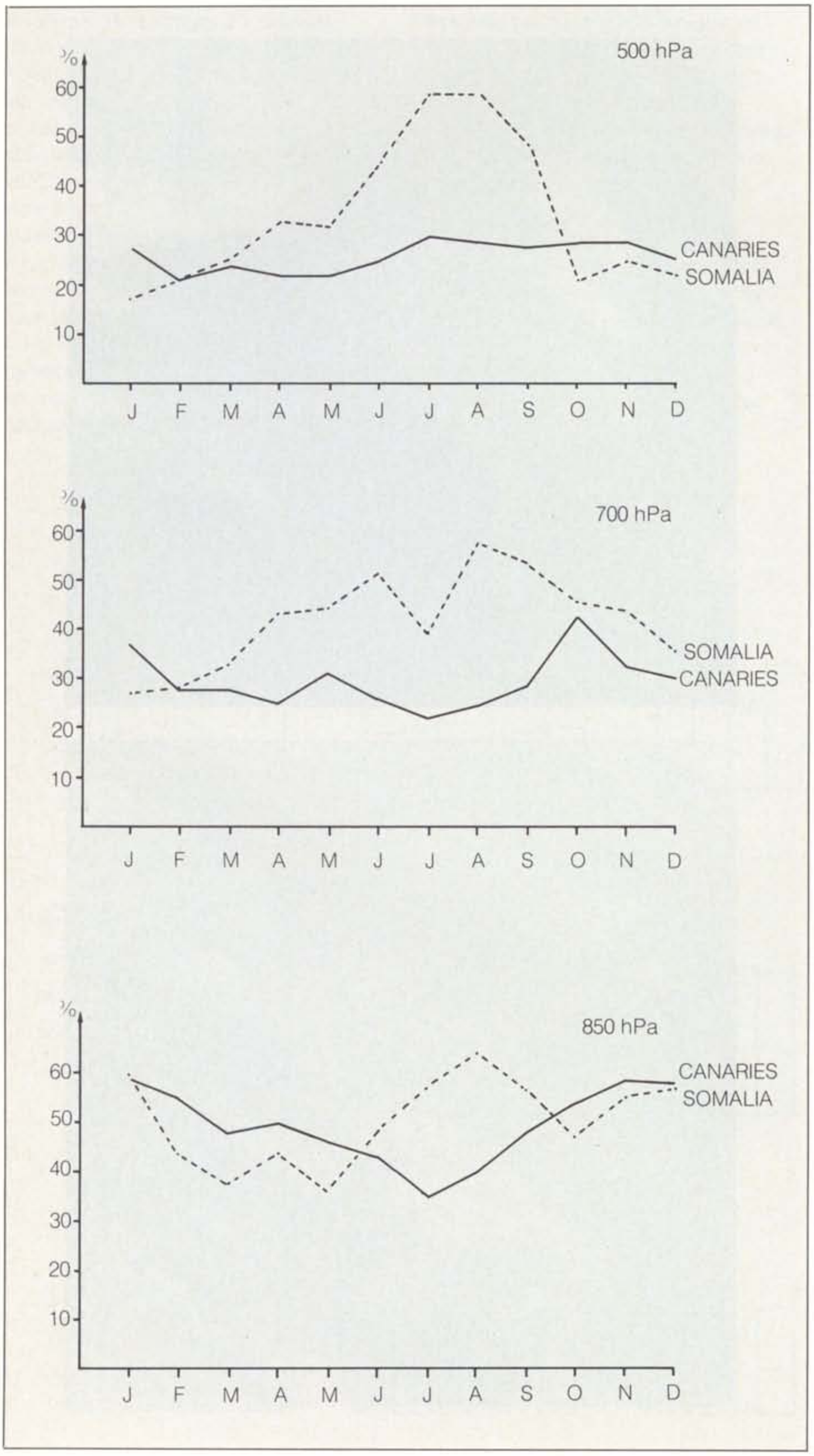
b.

The high percentage of QS nights in the IR(n) images for Somalia is due to filametary shadows which were frequently observed over the Horn of Africa and northern coastal regions on the Meteosat images, with the presence of a very humid atmosphere at the edge of the Intertropical Convergence Zone. The effect is emphasised by the geometric distortion of that area, so close to the horizon in the Meteosat pictures, and by the fact that the 'midnight' images actually show local early-morning conditions over Somalia. This hypothesis has been verified by comparing the mean relative humidity values (%), month by month, during 1980 for one region around the Canaries, and another in the area of interest in Somalia (Fig. 6).

It can be observed that the relative humidities over the Somalia region are much higher than over the Canaries in the hottest months of the year.

It was also checked whether the IR(d) and VIS images provide the same classification of cloudiness. In general, there was found to be excellent correlation. The greatest discrepancy was again noted for La Palma, where in 27.3%

Figure 6 – Mean-relative-humidity values at three different altitudes over Somalia and the Canaries. The atmosphere above Somali regions contains larger amounts of water vapour due to the influence of both the Intertropical Convergence Zone and a warmer sea surface beneath (Courtesy of U. Liepelt and R. Paulish, ESA SP-1027, 1980)



of cases a cloudy situation (N) as judged on the VIS images was classified cloud-free (S) on the IR negatives. The reason is likely to be the same as that mentioned earlier, namely that whenever there is extensive low cloud around the island, the sea and the low-level clouds cannot be easily distinguished in the 20 cm × 20 cm full-disc negative film.

Finally, a comparison was made of the classifications from Meteosat data and those from ground observations using the night data and the log-book for astronomical observations made from Asiago Observatory. The overall agreement is very good: in approximately 80% of cases the classification is the same, with large discrepancies in less than 5% of cases [e.g. cloud-free situations (S) observed from ground and overcast conditions (C) inferred from Meteosat images].

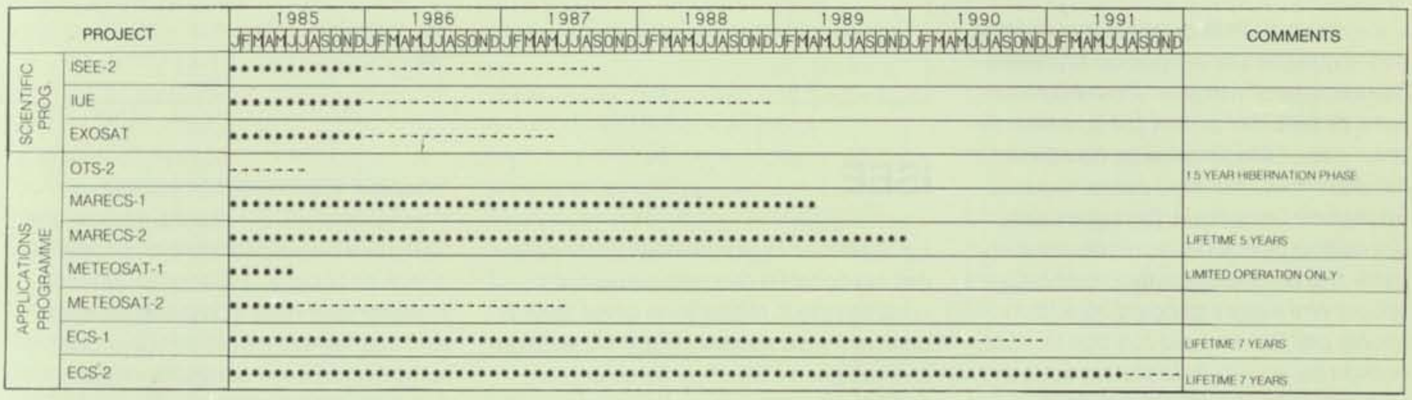
Conclusion

Despite the limitations of the method, the results obtained with Meteosat are very encouraging*. The one month of effort with Meteosat imagery has produced a considerable amount of information which will be certainly useful in choosing the location for the Galileo and other future telescopes. The resolution of the archived IR pictures sometimes represented a severe limitation, as in the case of the little island of La Palma. However, the availability of such a complete archive of continuous coverage over such a very large area, year in and year out, more than compensates for this limitation, providing a powerful tool for 'non-traditional' Meteosat-based activities of this type.

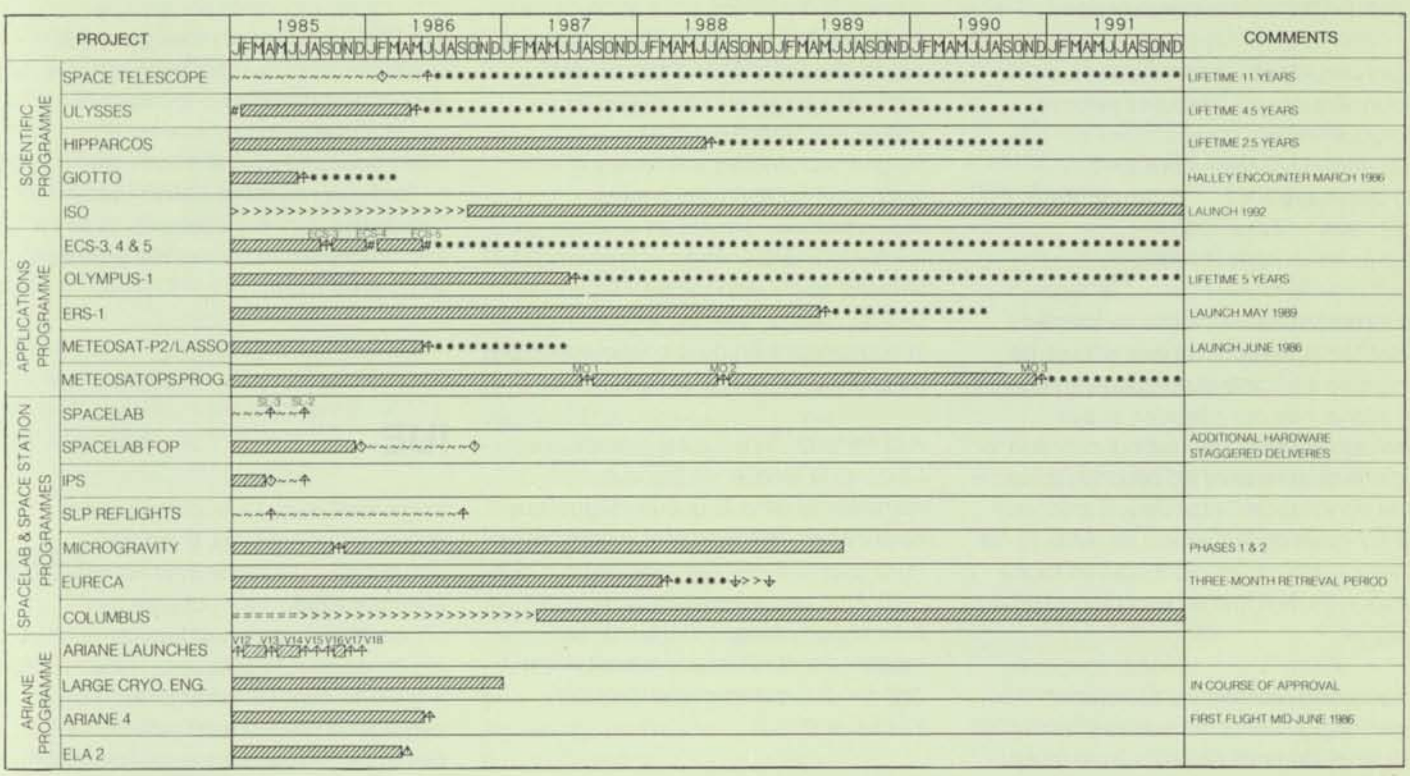
* For economy of space, the detailed tables and results for each site are not published here. However both series of data are available from the authors on request.

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
> PREPARATORY PHASE
▨ MAIN DEVELOPMENT PHASE
■ STORAGE
◇ HARDWARE DELIVERIES
~ INTEGRATION
↑ LAUNCH/READY FOR LAUNCH
• OPERATIONS
- ADDITIONAL LIFE POSSIBLE
↓ RETRIEVAL

Geos

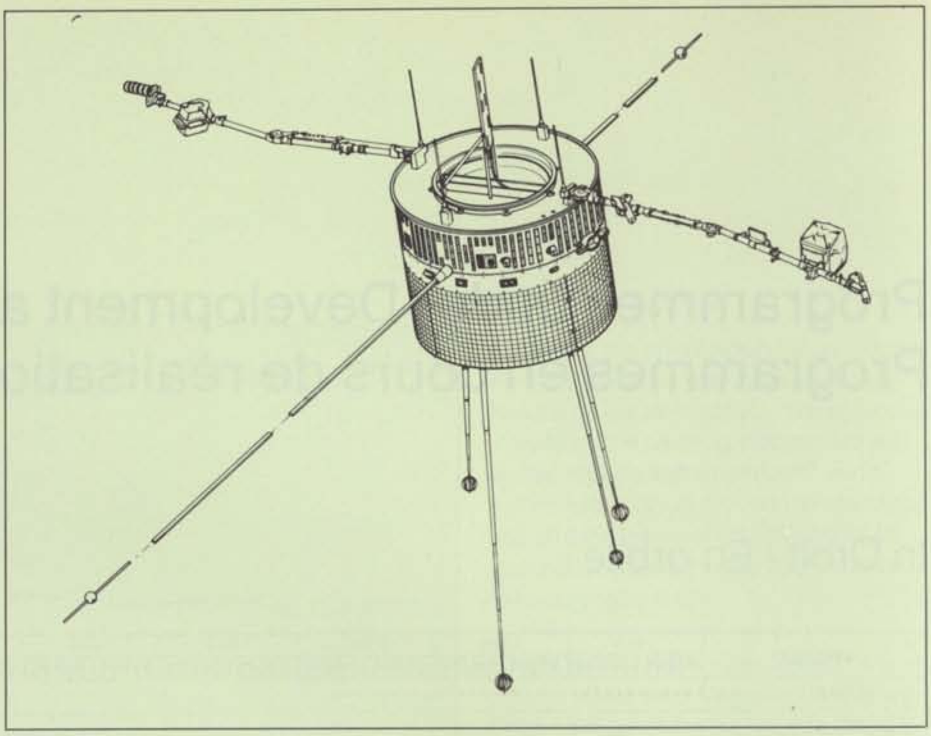
La saisie des données de Geos-2 s'est poursuivie dans le cadre d'un programme spécial financé par l'Allemagne et la Suisse. L'orbite n'est plus géosynchrone; l'altitude est de 300 km au-dessus de l'altitude synchrone et l'inclinaison s'élève à 4,5°. La période orbitale est légèrement supérieure à 24 heures, si bien que le satellite dérive vers l'ouest, en longitude, de 3,1° par jour, devenant visible pour la station sol de l'ESOC pendant 40 jours tous les 116 jours.

L'insuffisance de la quantité d'hydrazine embarquée ne permet pas de nouvelles manoeuvres d'inversion. Pour éviter aux mâts de faire de l'ombre sur le réseau de photopiles, l'axe de rotation du satellite est désormais maintenu perpendiculaire au plan de l'écliptique. Bien que cette orientation ne soit pas optimale pour la saisie des données, ces dernières peuvent encore être reçues pendant 10 à 15 heures par jour chaque fois que le satellite est en vue de la station sol. Les plans de financement actuels ne permettent la mise en oeuvre que de deux expériences, le spectromètre d'électrons et d'ions énergétiques (S-321) et le spectromètre de masse pour ions (S-303).

Les périodes suivantes de saisie de données ont été financées selon le programme en vigueur:
20 août – 20 septembre 1984
6 décembre 1984 – 15 janvier 1985
29 mars – 7 mai 1985
22 juillet – 30 août 1985.

Les émissions chimiques du satellite AMPTE (émissions de vent solaire, de comète artificielle et de queue) tombent à l'intérieur de ces périodes, et des tentatives ont été faites pour coordonner ces émissions avec les périodes de saisie de données de Geos. Depuis le 20 avril 1977 (date de lancement de Geos-1), les deux satellites Geos ont couvert tour à tour près de 8 ans et demi du cycle solaire actuel.

La station réceptrice d'Odenwald ne sera pas disponible après le mois d'août 1985 et les opérations de Geos-2 devront par conséquent être terminées avant cette date.



ISEE

La mission d'exploration internationale des relations Terre-Soleil, entreprise conjointe de la NASA et de l'ESA faisant intervenir trois satellites (ISEE 1, 2 et 3) qui a commencé à fonctionner en octobre 1977, a été très réussie aussi bien quant aux résultats scientifiques que quant à la coopération entre les deux Agences. Il a été possible en de nombreuses occasions de faire la distinction entre les variations temporelles et les variations spatiales des paramètres étudiés et d'obtenir des mesures fiables de l'étendue et de la vitesse des caractéristiques magnétosphériques aux limites. Il semblerait qu'enfin des preuves expérimentales directes de la fusion entre le champ interplanétaire et le champ terrestre soient disponibles. Ce processus de fusion est un élément fondamental de la compréhension de la configuration des magnétosphères planétaires.

A la mi-1982, ISEE-3 a été redirigé, avec l'aide de la lunaire, de façon à manoeuvrer dans la queue magnétique de la Terre à des distances d'environ 200 rayons terrestres (1 rayon terrestre = 6,5 $\times 10^3$ km). Les données provenant de cette région presque inexplorée sont maintenant étudiées activement et ont déjà produit quelques résultats très intéressants.

En décembre 1983, de nouveau avec l'aide de la pesanteur lunaire, ISEE-3 – rebaptisé 'Explorateur Cométaire International' (ICE) – a été placé sur une trajectoire qui lui permettra de couper la queue de la comète Giacobini-Zinner le 11 septembre 1985. Des plans détaillés sont maintenant établis en vue d'une récupération optimale des données pendant la rencontre.

Il n'est pas surprenant qu'il y ait eu quelques défaillances de pièces des instruments emportés par les trois satellites. Cependant, celles qui restent constituent des charges utiles qui sont encore parfaitement adéquates pour le travail à effectuer. Les milieux scientifiques, de part et d'autre de l'Atlantique, restent très actifs dans l'étude des données obtenues, et en fait les publications associées ont atteint un sommet en 1984.

IUE

Largement dans sa huitième année d'opérations orbitales, le satellite 'Explorateur Ultraviolet International' continue à prendre en charge des observations astrophysiques dans le région du spectre ultraviolet (1150 – 3200 Å), avec seulement une dégradation mineure du satellite. La demande des milieux scientifiques pour l'utilisation de l'observatoire constitué par IUE reste à un niveau élevé (les demandes

Geos

Geos-2 data acquisition has continued in the framework of a special programme financed by Germany and Switzerland. The orbit is no longer geostationary; altitude is 300 km above synchronous altitude and the inclination has increased to 4.5°. The orbital period is slightly more than 24 h, so that the spacecraft drifts westwards in longitude at a rate of 3.1° per day, becoming visible to the ESOC ground station for 40 d in every 116 d.

The shortage of on-board hydrazine does not permit any further inversion manoeuvres. To avoid the booms shadowing the solar array, the satellite's spin axis is now kept perpendicular to the ecliptic plane. Although this attitude is not optimal for data acquisition, data can still be received for 10–15 h per day whenever the satellite is in view of the ground station. The current funding arrangements only permit two experiments to be operated, the energetic electron and ion spectrometer (S-321) and the ion mass-spectrometer (S-303).

The following acquisition periods have been funded under the current programme:
20 August – 20 September 1984
6 December 1984 – 15 January 1985
29 March – 7 May 1985
22 July – 30 August 1985.

The chemical releases from the AMPTE spacecraft (Solar Wind, Artificial Comet and Tail releases) fall within these periods and attempts have been made to coordinate these releases with Geos data-acquisition periods. Since 20 April 1977 (the launch date of Geos-1), the two Geos spacecraft have sequentially covered almost 8.5 years of the current solar cycle.

The Odenwald receiving station will not be available after August 1985 and Geos-2 operations will therefore have to be terminated.

ISEE

The International Sun-Earth Explorer (ISEE) Mission, the joint NASA/ESA venture involving three spacecraft (ISEE-1, 2 & 3) which began operating in October 1977, has been very successful both in terms of scientific achievement and of inter-Agency cooperation. It has been possible in many cases to discriminate between temporal and spatial variations in parameters studied and to obtain reliable measurements of the extent and velocity of magnetospheric boundary features. It would seem that at last direct experimental evidence is available for the merging between the interplanetary field and the Earth's field. This merging process is a basic element in understanding the configuration of planetary magnetospheres.

In mid-1982 ISEE-3 was redirected with the help of lunar gravity to manoeuvre in the Earth's magnetotail at distances around 200 Earth radii (1 Earth radius $= 6.5 \times 10^3$ km). The data arriving from this almost unexplored region is now being actively studied and has already produced some very interesting results.

In December 1983, again with the help of lunar gravity, ISEE-3 was set on a trajectory that will allow it to intersect the tail of the comet Giacobini-Zinner on 11 September 1985. At that time ISEE-3 was renamed the International Cometary Explorer (ICE) spacecraft. Detailed plans are now being made for optimum data recovery during the encounter.

Not surprisingly there have been some failures of parts of the instruments carried by the three spacecraft. However, those remaining constitute payloads that are still entirely adequate for the job in hand. The scientific community on both sides of the Atlantic remains very active in studying the data obtained and in fact the associated publications reached a peak in 1984.

IUE

Well into its eighth year of orbital operations, the International Ultraviolet Explorer satellite continues to support astrophysical observations in the ultraviolet spectral region (1150–3200 Å), with only minor spacecraft degradation. The demand of the scientific community for use of the IUE spacecraft observatory stays high (oversubscribed by a factor of 3) and the scientific productivity, measured by the publication rate in refereed journals, is at a level unparalleled by any astronomical telescope, and is still increasing. By the end of 1984 904 such papers based on IUE observations had been published (present rate 200 per year).

A multi-Agency (ESA/NASA/SERC*) Committee, the IUE Long-Range Planning Committee (IUE-LRPC), has been formed to evaluate the rundown of the IUE project and to give advice on its longer term aspects, such as archiving.

The main constraining factor on current spacecraft operations is the gradual decrease in solar-array power output of about 6% per year. Present power projections indicate a lifetime extension into 1990, without serious impact on the scientific operations. A first power-saving reconfiguration has recently been implemented.

Of the original six gyros, three are still fully operational. The only operational short-wavelength camera shows only marginal degradation in sensitivity. The long-wavelength camera now being used was put into operation in 1983. It still provides redundancy for the long-wavelength spectrograph at 69% sensitivity.

It therefore seems reasonable to conclude that, in the absence of an unforeseen catastrophic failure, IUE will still be returning valid scientific data beyond 1990.

The flexibility of the IUE scheduling and operations continues to provide unique opportunities through the Target of Opportunity Team observations. A total of eight shifts have been used recently for observations of novae, supernovae and comets.

IUE data are used in a wide range of scientific studies, a few highlights in 1984/85 being:

1. The detection of a considerable number of Lyman-limit systems in the low-resolution spectra of QSOs and their subsequent detailed study in high-resolution spectra.

2. The finding that individual active galactic nuclei behave similarly to quasars in their light variations.

3. The first bolometric light curve for a Type-I supernova.

4. The discovery of a new physical binary star combination of a late-type giant star with an AM Her cataclysmic variable companion.

* UK Science and Engineering Research Council

d'abonnement sont trois fois supérieures à l'offre) et la productivité scientifique, mesurée par le taux de publication dans les journaux de référence, est à un niveau sans commune mesure avec celle de n'importe quel autre télescope astronomique, et elle augmente encore. A la fin de 1984, 904 articles basés sur des observations d'IUE avaient été publiés (le taux actuel est de 200 par an).

Un comité multi-agence (ESA-NASA-SERC), le Comité de Planification à long terme de l'IUE (IUE-LRPC), a été formé pour évaluer les retombées du projet IUE et pour donner son avis sur ses aspects à plus long terme, tels que l'archivage.*

Le facteur le plus contraignant pour les opérations actuelles du satellite est la diminution progressive de la puissance débitée par les réseaux de photopiles, qui est de 6 % environ par an. Les projections de puissance actuelles indiquent une prolongation de la durée de vie jusqu'à 1990, sans incidence sérieuse sur les opérations scientifiques. Une première reconfiguration d'économie d'énergie a récemment été mise en oeuvre.

Des six gyroscopes d'origine, trois sont encore totalement opérationnels. La seule caméra à ondes courtes opérationnelle ne montre qu'une dégradation marginale de sensibilité. La caméra à grandes ondes qui est maintenant utilisée a été mise en service en 1983. Cette caméra assure encore la redondance pour le spectrographe à grandes ondes avec une sensibilité de 69 %.

Il semble par conséquent raisonnable de conclure que, sauf défaillance catastrophique imprévue, IUE continuera à renvoyer des données scientifiques valables au-delà de 1990.

La souplesse de la programmation et des opérations d'IUE continuent à offrir des occasions uniques par l'intermédiare des observations de l'équipe chargée des cibles d'opportunité. Un total de huit décalages ont été utilisés récemment pour l'observation de novae, de supernovae et de comètes.

Les données d'IUE sont utilisées dans une large gamme d'études scientifiques, avec les points saillants en 1984–85:

1. *La détection d'un nombre considérable de systèmes limites de Lyman dans les spectres à faible résolution de QSO (objets quasi-stellaires ou quasars) et leur étude détaillée ultérieure dans des spectres à haute résolution.*
2. *La découverte du fait que des noyaux galactiques actifs individuels se comportent comme des quasars dans leurs variations de lumière.*
3. *La première courbe de lumière bolométrique pour une supernova de type I.*
4. *La découverte d'une nouvelle combinaison physique d'étoiles binaires entre une étoile géante du type tardif et une étoile variable cataclysmique AM Her.*

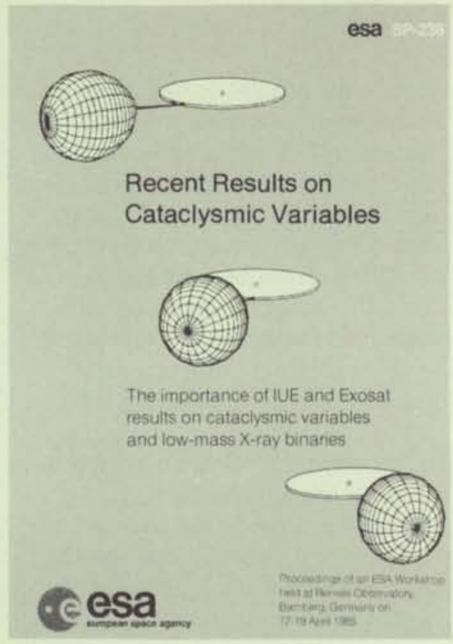
Une réunion de travail parrainée par l'ESA, à laquelle assistaient plus de 90 scientifiques de 16 pays, s'est tenue à Bamberg, en Allemagne, pour discuter de l'incidence des observations effectuées avec IUE et avec Exosat sur la compréhension que nous avons des variables cataclysmiques. Les comptes rendus de cette réunion ont été publiés sous la référence ESA SP-236, par le Service des Publications Scientifiques et Techniques de l'ESA.

Les opérations d'IUE sont actuellement financées jusqu'à la fin de 1985. Lors de sa 37ème réunion, le Comité des Programmes Scientifiques de l'Agence a convenu, à titre d'hypothèse de planification, que les opérations se poursuivraient jusqu'à 1987 pour permettre un chevauchement avec les opérations du Télescope spatial.

Exosat

Exosat, lancé à la fin de mai 1983, est opérationnel depuis maintenant deux ans. A ce jour, l'observatoire a effectué plus de 1500 observations de sources de rayons X, allant des amas de galaxies aux étoiles normales. La demande d'utilisation de cet observatoire par les milieux scientifiques reste à un niveau très élevé, dépassant de beaucoup le temps d'observation réel qui est disponible.

Trois offres de participation au programme d'observation d'Exosat ont



été lancées, plus de 1500 propositions ont été reçues, et environ 600 ont été acceptées en totalité ou en partie. Les propositions acceptées suite à la troisième annonce complètent actuellement le programme d'observation jusqu'à mars 1986. Une quatrième offre sera lancée en août 1985, et le programme dérivé durera environ un an jusqu'à la fin de la mission.

Une fraction significative des résultats d'Exosat a été obtenue pendant que cet observatoire était coordonné avec IUE ou avec des installations basées au sol. En fait, un succès majeur a été la souplesse permanente dont a fait preuve l'observatoire pour effectuer des observations coordonnées. Exosat continue à effectuer régulièrement des observations simultanées avec la plupart des types d'installations basés au sol, et des observations coordonnées avec le satellite IUE sont courantes. Les résultats actuellement publiés dans la littérature et présentés à des conférences indiquent clairement l'intérêt de telles observations.

L'équipe de l'observatoire à l'ESOC a continué à élever le niveau des programmes d'application embarqués, d'une part, et du logiciel d'analyse scientifique basé au sol, d'autre part. Un système d'analyse interactive a également été mis au point et a été mis à la disposition des utilisateurs d'Exosat depuis le début de 1985. Celui-ci a été spécifiquement conçu comme un service supplémentaire pour les observateurs, en particulier ceux qui ne disposent pas

* *Conseil de la Recherche Scientifique et de la Technologie du Royaume Uni.*

An ESA-sponsored Workshop, attended by more than 90 scientists from 16 countries, was held in Bamberg in Germany to discuss the impact of observations with IUE and Exosat on our understanding of cataclysmic variables. The Proceedings of this meeting have been published as ESA SP-236, by ESA Scientific & Technical Publications Branch.

IUE operations are currently funded to the end of 1985. At its 37th meeting, the Agency's Science Programme Committee agreed, as a planning assumption, that operations would continue until 1987 to allow overlap with Space-Telescope operations.

Exosat

Exosat, launched at the end of May 1983, has now been operational for two years. To date the observatory has performed over 1500 observations of X-ray sources, ranging from clusters of galaxies to normal stars. The demand to use the observatory from the scientific community continues to be very high, far exceeding the actual observing time available.

Three Announcements of Opportunity to participate in the Exosat observing programme have been issued, with over 1500 proposals received and around 600 accepted fully or in part. The accepted proposals from the Third Announcement currently make up the observing programme up to March 1986. A fourth Announcement of Opportunity to participate in the programme will be issued in August 1985 and the derived programme will run for approximately one year up to the end of the mission.

A significant fraction of Exosat's results have been obtained whilst the observatory was coordinated with IUE or ground-based facilities. In fact, a major success has been the continuing flexibility displayed by the observatory in performing coordinated observations. Exosat continues to perform simultaneous observations regularly with most types of ground-based facilities, and coordinated observations with the IUE satellite are commonplace. The results being published in the literature and presented at conferences clearly indicate the worth of such observations.

The Observatory Team at ESOC has continued to upgrade both the on-board application programmes and the ground-based scientific analysis software. An interactive analysis system has also been developed and made available to Exosat users from the beginning of 1985. This has been specifically designed as an additional service to observers, particularly those without major software facilities for Exosat analysis at their home institutes. Data tapes are issued to observers less than 25 days after the observation, while the automatic scientific analysis of the observation tapes is now issued to observers, for all experiments, within a further three weeks. The few remaining instrument-calibration refinements will be implemented on the data tapes in the next few months.

Exosat data from the first year of operations have been made available to the general scientific community. It is anticipated that the demand to utilise this data will be extremely high. An observing log will be issued to assist observers in making archive requests.

Exosat's natural lifetime will terminate during April 1986, unless the active on-board orbit control system is used to increase the perigee height. A 'delta-V' capability of 170 m/s can provide a maximum mission extension of about 12 months with, however, a penalty in the use of attitude control gas (up to 1 kg) which is required to maintain stability during the orbit manoeuvre to compensate for misalignment between the thruster and the spacecraft centre of mass. Clearly the amount of attitude-control gas (propane) remaining, its normal usage and any contingency allowance are the critical factors that will determine the strategy for lifetime extension. A 'propane gauging' exercise was undertaken in April 1985 and the results are currently being analysed. In the meantime, procedures have been implemented to reduce the propane consumption throughout the remainder of the mission.

Full Exosat orbital operations are funded to the end of 1985. It is hoped that Exosat operations can be funded through 1986, and extended into 1987 for as long as it will be technically possible to assure a valid scientific output.

ECS

The ECS system continues to give full satisfaction to its users. ECS-1 (launched 16 June 1983) and ECS-2 (launched 4 August 1984) are fully operational and their capacity (9 transponders per satellite) is totally allocated to customers. At the request of Eutelsat, because of the

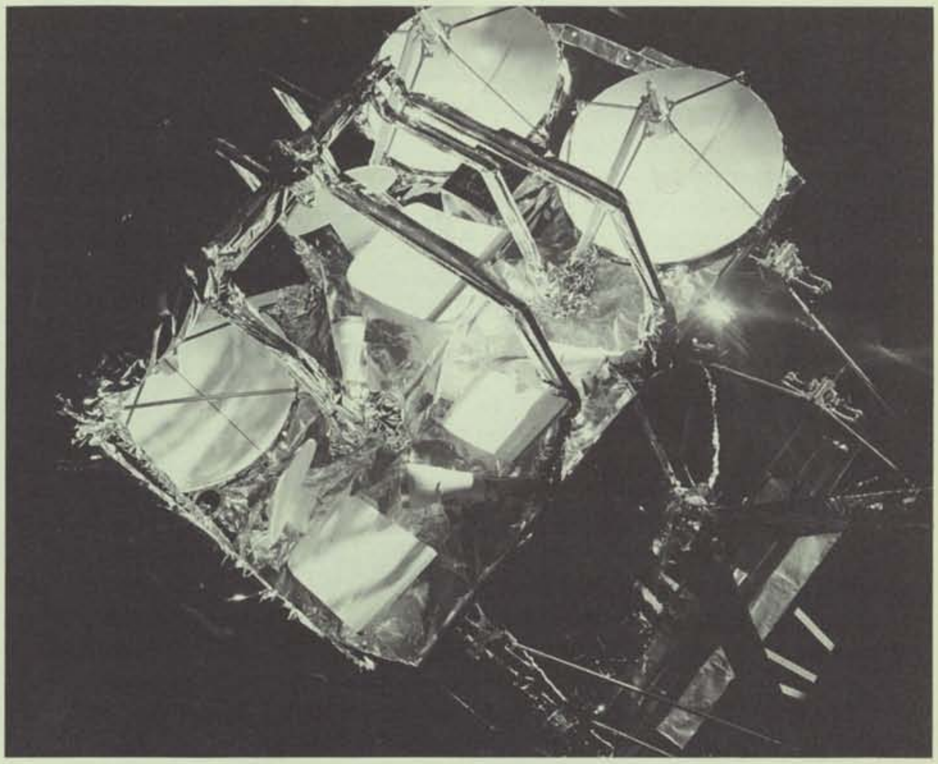


Plate-forme d'antennes d'ECS au cours des essais de simulation solaire chez Matra, Toulouse

ECS antenna platform during solar-simulation testing at Matra, Toulouse *d'installations majeures de logiciel pour l'analyse d'Exosat dans leurs instituts locaux. Des bandes de données enregistrées sont mises à la disposition des observateurs moins de 25 jours après l'observation, tandis que l'analyse scientifique automatique des bandes d'observation est maintenant mise à la disposition des observateurs, pour toutes les expériences, dans un délai supplémentaire de trois semaines. Les quelques rafinements restants d'étalonnage des instruments seront mis en oeuvre sur les bandes de données dans les tout prochains mois.*

Les données d'Exosat de la première année d'opérations sont désormais accessibles à la communauté scientifique. Il est prévu que la demande d'utilisation de ces données sera extrêmement importante. Un journal de bord des observations sera publié pour aider les observateurs dans leur recherche.

La durée de vie naturelle d'Exosat prendra fin au cours du mois d'avril 1986, à moins que le système actif de commande d'orbite embarqué soit utilisé pour augmenter l'altitude du périgée. Une capacité 'delta-V' de 170 m/s peut assurer une prolongation maximale de la mission de 12 mois environ, mais au prix d'une augmentation de la consommation du gaz de commande d'orientation (jusqu'à 1 kg) qui est nécessaire pour maintenir la stabilité pendant la manoeuvre orbitale pour compenser le défaut d'alignement entre le propulseur et le centre d'inertie du satellite. Il est évident que la quantité restante de gaz (propane), sa consommation normale, et une réserve éventuelle pour faire face aux événements imprévus, sont les facteurs critiques qui détermineront la stratégie permettant de prolonger la durée de vie. Un exercice de 'jaugeage du propane' a été entrepris en avril 1985, et les résultats obtenus sont en cours d'analyse. Dans l'intervalle, des procédures ont été mises en oeuvre pour réduire la consommation de propane jusqu'à la fin de la mission.

Les opérations orbitales complètes d'Exosat sont financées jusqu'à la fin de 1985. On espère qu'elles pourront être financées jusqu'à la fin de 1986, et prolongées jusqu'en 1987 dans la mesure où il sera techniquement possible d'assurer une production scientifique valable.

ECS

Le système ECS continue à donner toute satisfaction à ses utilisateurs. ECS-1 (lancé le 16 juin 1983) et ECS-2 (lancé le 4 août 1984) sont totalement opérationnels et leur capacité (9 répondeurs par satellite) est totalement réservée aux clients. A la demande d'Eutelsat, en raison de l'utilisation croissante des transpondeurs en orbite, les services d'un dixième canal seront offerts sur ECS-1 et ECS-2 dans un proche avenir. La décision a été prise d'offrir cette capacité supplémentaire après analyse des bonnes performances des satellites en orbite, et a été rendue possible par le surplus de puissance qui était disponible à bord pendant les premières années.

Pour faire face à l'augmentation des besoins en répondeurs en orbite, ECS-3 sera lancé sur Ariane V15 le 11 septembre 1985, et des négociations ont lieu avec Eutelsat en vue du lancement de la quatrième unité de vol, ECS-4, fin 1986 ou début 1987, pour servir de capacité de réserve.

Télescope spatial

Activités de la NASA

Les éléments majeurs du télescope spatial, de l'ensemble du télescope optique et du module de système de soutien ont été intégrés avec succès. Les quatre instruments axiaux ont également été intégrés mécaniquement à la structure du plan focal. Des problèmes incessants avec le logiciel d'essai au sol de la NASA et avec le système de gestion de données du télescope ont fait que les essais d'interface électrique du télescope intégré sont en retard de quelque deux mois sur le calendrier. Cela compromet la date de lancement prévue pour juin 1986, mais la NASA et les contractants travaillent 24 heures par jour et 7 jours par semaine pour essayer de rattraper le retard.

Générateur solaire

Les difficultés éprouvées pendant les essais de qualification sur des échantillons des couvertures de 4,4 kW utilisant des cellules à 'champ électrique de surface dorsale et réflecteur optique'

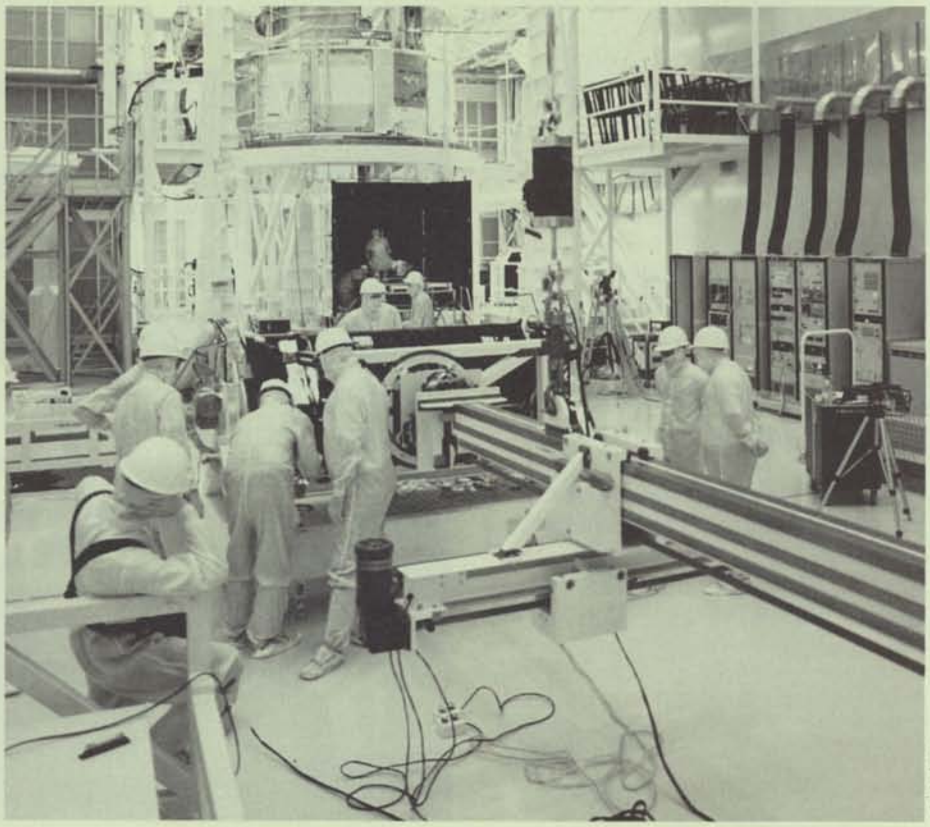


photo lmsc

Space Telescope's Faint Object Camera being mounted onto an integration jig at LMSC's California facility

La Chambre pour objets faibles du Télescope spatial en cours de montage dans les installations du LMSC increasing demand for in-orbit transponders, a tenth channel will be offered on ECS-1 and ECS-2 in the near future. The decision to offer this supplementary capacity was taken after analysis of the good in-orbit performance of the satellites, and is made possible by the excess power available on board during the first years in orbit.

In order to cope with the need for more transponders in orbit, ECS-3 will be launched on Ariane V15 on 11 September 1985, and negotiations are taking place with Eutelsat on the launch of the fourth flight unit, ECS-4, in late 1986 or early 1987 to serve as spare capacity.

Space Telescope

NASA activities

The major elements of the Space Telescope, the optical-telescope assembly and the Support System Module (SSM) have been successfully integrated. The four axial instruments have also been mechanically integrated to the focal-plane structure. Continuing problems with the NASA ground test software and the Space Telescope data management system have meant that electrical-interface testing of the integrated Space Telescope is some two months behind schedule. This is threatening the June 1986 launch date, but NASA and contractors are working 24 hours a day seven days a week to try to recover the schedule.

Solar Array

The difficulties experienced during the qualification tests on samples of the 4.4 kW blankets using Back Surface electrical Field and optical Reflector (BSFR) cells have not yet been resolved. Discussions have been held with NASA to investigate the feasibility of flying the 4 kW blankets using the available High-Efficiency Cells (HECs) for the initial launch. An agreement is expected shortly.

The flight-1 secondary deployment mechanism boom synchronisation failed during thermal vacuum test. The unit has been reworked and a repeat vacuum test is under way. The flight-2 secondary deployment mechanism passed its thermal vacuum test and is now in wing assembly.

Faint Object Camera

The Faint Object Camera was mechanically integrated into the Space Telescope on 19 May 1985. Because of minor mechanical problems all axial instruments will have to be removed later for reworking of the focal-plane structure. The schedule for functional testing of the FOC is uncertain. The first of the two spare detectors (the reworked original that was replaced after vacuum calibration) has been delivered to ESTEC.

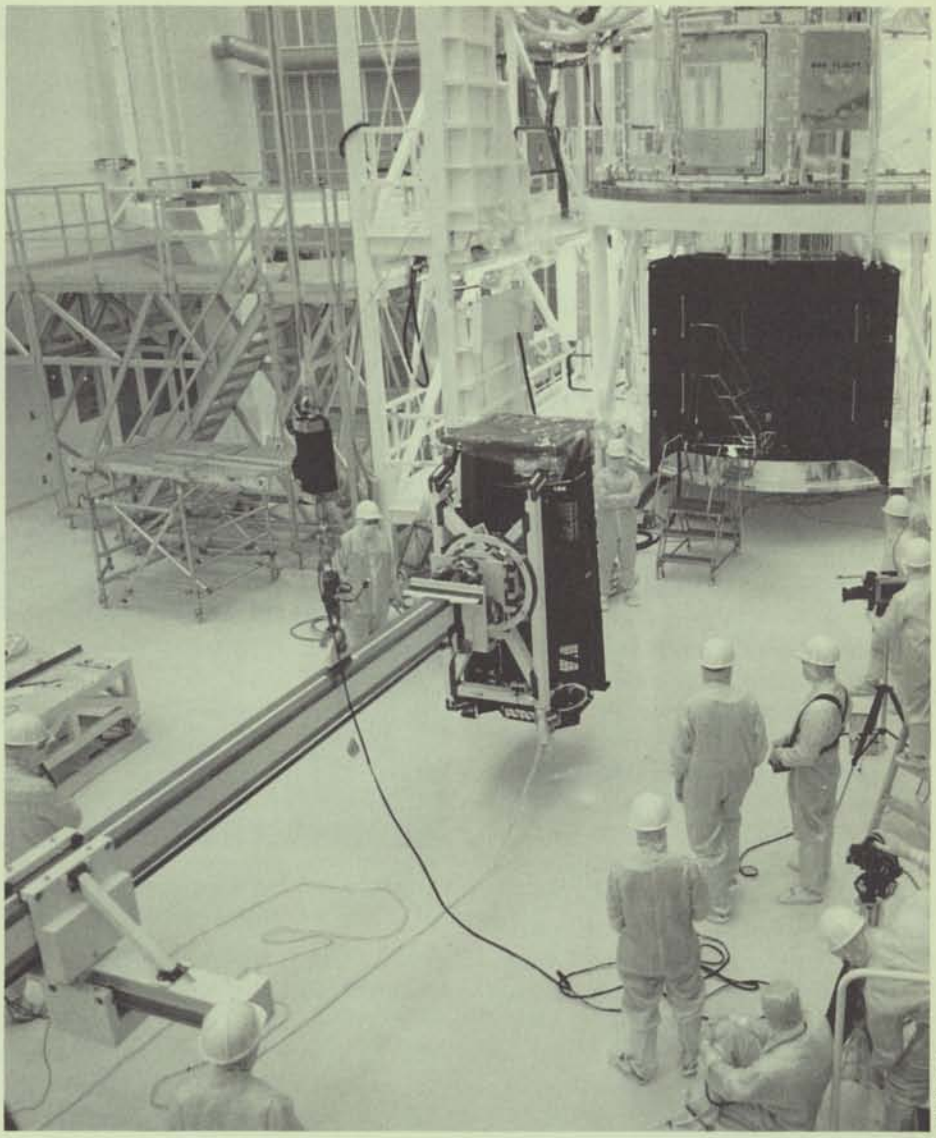


photo lmsc

La Chambre pour objets faibles, montée sur bâti d'intégration avant intégration au Télescope spatial

Space Telescope's Faint Object Camera in position on the integration jig at LMSC's premises, prior to installation into the ST's after shroud

Ulysses

The launch of Ulysses is now starting to look very near and the level of activity surrounding the launch and operations has therefore shown a very significant increase. There have been several meetings between the various NASA centres and the ESTEC and ESOC teams since the final date for freezing software requirements has now arrived. It has been decided to use a 110 nautical mile altitude Shuttle orbit rather than the 130 nm orbit previously planned. It is hoped that this decision, besides permitting the use of the 104% Shuttle engine, will enable some increase in the cargo weight which, if used for extra Centaur propellant loading, will lead to an improved scientific mission.

Another important milestone was reached at a recent meeting at Johnson Space Center (JSC) where the Payload Integration Plan Annexes (effectively the work agreements for JSC) were formally signed off.

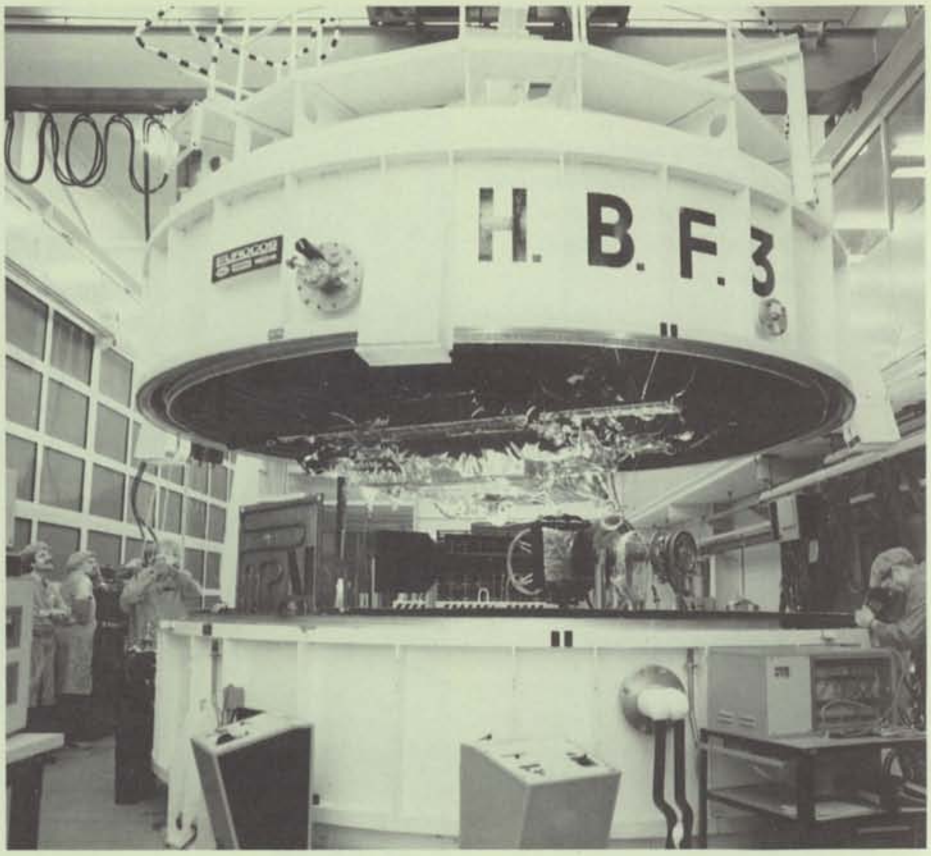
Within Europe the recertification of the spacecraft is progressing well and on

(BSFR) n'ont pas encore été résolues. Des discussions ont eu lieu avec la NASA pour explorer la possibilité d'envoyer dans l'espace les couvertures de 4 kW en utilisant pour le lancement initial les cellules à haut rendement qui sont disponibles. Un accord est attendu sous peu.

La synchronisation de la flèche du mécanisme de déploiement secondaire du vol No. 1 n'a pas fonctionné pendant l'essai de vide thermique. L'unité a été refaite et un nouvel essai de vide est en cours. Le mécanisme de déploiement secondaire du vol No. 2 a subi avec succès son essai de vide thermique et est maintenant en cours d'assemblage d'aile.

Chambre pour objets faibles

La chambre pour objets faibles (FOC) a été intégrée mécaniquement au télescope spatial le 19 mai. Du fait de problèmes mécaniques mineurs, tous les instruments axiaux devront être démontés ultérieurement pour réfection de la structure du plan focal. Le calendrier des essais fonctionnels de la FOC est incertain. Le premier des deux détecteurs de rechange (l'original refait a été remis en place après étalonnage sous vide) a été livré à l'ESTEC.



Ulysses (formerly ISPM) during final testing in the HBF-3 chamber at ESTEC, Noordwijk

Ulysse (ex-ISPM) au cours des essais finaux dans la Chambre HBF-3 à l'ESTEC

Ulysse

Le lancement d'Ulysse commence maintenant à sembler très proche, et le niveau d'activité entourant le lancement et les opérations a par conséquent montré une augmentation très nette. Il y a eu plusieurs réunions entre les divers centres de la NASA et les équipes de l'ESTEC et de l'ESOC puisque la date finale de fixation définitive des exigences de logiciel a maintenant été atteinte. Il a été décidé d'utiliser une orbite de Navette d'altitude 110 milles nautiques au lieu de l'orbite de 130 milles antérieurement prévue. On espère que cette décision, outre qu'elle permettra l'utilisation du moteur de la Navette à 104%, permettra une certaine augmentation du poids de la cargaison, qui, si elle est utilisée pour le chargement d'une quantité supplémentaire de propergol Centaure, aboutira à une mission scientifique améliorée.

Une étape importante a été atteinte lors d'une réunion récente au Centre Spatial Johnson (JSC), au cours de laquelle les annexes du plan d'intégration de la charge utile (en fait les accords de travail pour le JSC) ont été formellement signées.

En Europe même, la recertification du satellite se déroule bien et conformément au calendrier. L'essai du système intégré, étape majeure faisant suite à l'intégration du satellite, a récemment été mené à bien, et des préparatifs sont en cours pour l'essai de vide thermique, qui est programmé pour le mois de juillet. L'activité à l'ESOC, qui sera responsable de l'exploitation du satellite après le lancement, a maintenant atteint un niveau élevé, et une grande partie du logiciel opérationnel et de dynamique de vol est maintenant complète. L'ordinateur au sol qui doit être utilisé pour commander le satellite après le lancement est maintenant opérationnel et est utilisé dans des essais d'opérations de satellites qui sont exécutés par l'intermédiaire d'une liaison terrestre entre l'ESOC et l'ESTEC.

Hipparcos

Des revues de conception préliminaire (PDR) du matériel ont été effectuées pour de nombreux éléments et ont, en général, abouti à l'établissement d'un état de conception satisfaisant. L'autorisation de procéder à la fabrication du matériel du 'modèle d'identification' (EM) a en conséquence été accordée à l'industrie. La fabrication de nombreux éléments du matériel optique, structurel et thermique aussi bien pour la charge utile que pour le satellite est bien avancée, et pour la charge utile en particulier (dont le programme a un calendrier en avance sur celui du satellite), de nombreux éléments ont été livrés et sont en cours d'assemblage. Mais un secteur de préoccupation est représenté par la structure secondaire et les déflecteurs de la charge utile, pour lesquels des livraisons tardives ont nécessité la prise de mesures spéciales au niveau de la direction et l'introduction de solutions permettant de contourner la difficulté.

Un phénomène physique connu sous le nom d'effet Cerenkov, selon lequel l'interaction d'électrons avec les éléments optiques de transmission du téléscope produit des émissions de photons, a été identifié comme ayant un effet de dégradation des performances de la charge utile. Le problème a été étudié en schedule. The Integrated System Test, a major milestone following spacecraft integration, has recently been completed successfully and preparations are under way for the Thermal Vacuum Test, scheduled for July. Activity at ESOC, which will be responsible for operating the spacecraft after launch, is now at a high level and much of the operational and flight dynamics software is now complete. The ground computer to be used for controlling the spacecraft after launch is now operational and is being used in spacecraft operations tests performed via a ground link between ESOC and ESTEC.

Hipparcos

Equipment Preliminary Design Reviews (PDRs) have been conducted for numerous items and have, in general, resulted in the establishing of satisfactory design status. Authorisation for industry to proceed with the manufacturing of Engineering Model (EM) equipment has been granted accordingly. Manufacture of many items of optical/structural/thermal hardware for both payload and spacecraft is well advanced, and for the payload in particular (the programme for which is scheduled ahead of that of the spacecraft), many items have been delivered and are being assembled. An area of concern, however, is the payload secondary structure and baffles where late deliveries have necessitated special action at management level and the introduction of work-around solutions.

A physical phenomenon known as the Cerenkov effect, whereby electrons interacting with the transmitting optical elements of the telescope produce emissions of photons, was identified as a degrading effect for the payload performance. The problem has been investigated in detail and remedies involving shielding within the payload and possibly within the spacecraft have been proposed, necessitating some redesign work and a mass penalty.

Bonding of the two halves of the beam combiner mirror has caused difficulties. The technology employed was found, in practice, to degrade the mirror's performance. An alternative bonding technique that will give acceptable performances has therefore been evolved and will now be applied to the EM mirror.

The effects of the industrial problems of subcontractor bankruptcy and strikes have been investigated at length. The proposed solutions involve a transfer of work between contractors and major realignment of the schedule. Consequently the Satellite Acceptance Review, originally planned for 12 December 1987 has had to be rescheduled for 18 January 1988, while the launch date, originally 31 March 1988, is now set for 1 July 1988.

ISO

The major activity during the last few months has been the evaluation and optimisation of the four instruments proposed for ISO. A number of meetings have been held with the various groups and several modifications and simplifications have been made. The resulting payload has been approved and, although work will continue on further simplification, the shape of the payload, and its requirements in terms of satellite resources, is now known.

On the technical front, the various studies made necessary by the change from an Ariane-2 to an Ariane-4 launch vehicle are nearing completion, and these, together with the results of a study of potential contractors giving an acceptable geographical distribution are now being examined within the Agency.

Olympus

The system level Development Baseline Review (DBR) between the Prime Contractor and the Agency was held on 6 March 1985 as planned.

The modal survey series of tests on the structural model was completed during the course of March with satisfactory results. This development model was then transported to Canada, where it arrived on 8 April 1985, to be prepared for dynamic testing. The solar arrays have been integrated, deployment tests made, and a series of exploratory low level sine vibration tests performed. Integration of the remaining items will be completed ready for the main series of dynamic tests which is expected to start in August.

Preparations continue for the appendage release tests on the thermal-model spacecraft that will be conducted towards the end of the year.

Integration of the Electrical Integration Model (EIM) started in March with the fitting of the electrical harness, followed by installation of the telemetry and telecommand subsystem. Power subsystem equipment is now being integrated. Integration and test of the payloads on the respective communications-module panels has continued in parallel and two of the payloads are now ready for shipment to the main payload contractor for further integration activities.

The service module structure of the flight model is now in the final stages of thermal equipping before delivery to the prime contractor.

Evaluation of the responses to the series of Invitations to Tender (ITT) for ground station equipment continues.

ERS-1

The industrial consortium, led by Dornier System, has continued with detailed definition and design work, and with the preparation of the associated requirements documentation. The passive thermal design of the payload has been demonstrated to be viable. The electrical distribution system for the payload is now well defined, in accordance with modifications introduced in the spacecraft platform to increase the energy capability. Hi-rel parts procurement is well underway, with the bulk of the very long-lead items already ordered.

Major efforts have been devoted to continuing negotiations with the consortium, with the aim of finalising the prime contract later this year.

The C-band wind scatterometer campaign, carried out in March 1985 in Brittany, was very successful, confirming the capabilities of in-situ and airborne instruments for measurement of wind velocity and direction.

The Satellite Development Baseline Review is scheduled for October 1985. Prior to this starting in July a full series of subsystem reviews at co-contractor level will be conducted.

détail et des remèdes mettant en jeu un blindage à l'intérieur de la charge utile et éventuellement à l'intérieur du satellite ont été proposés, ce qui nécessite un certain travail de reconception et se traduit par une augmentation de masse défavorable.

Le collage des deux moitiés du miroir combinateur de faisceaux a suscité des difficultés. On a constaté que la technologie utilisée, en pratique, dégradait les performances du miroir. Une autre technique de collage qui devrait donner des performances acceptables a été adoptee pour être appliquée au miroir du modèle d'identification.

Les effets des problèmes sociaux posés par la faillite et les grèves des sous-traitants ont fait l'objet d'études prolongées. Les solutions proposées impliquent un transfert de travail entre contractants et une totale révision du calendrier. La 'revue de recette du satellite', qui était prévue à l'origine pour le 12 décembre 1987, a dû être reprogrammée pour le 18 janvier 1988, tandis que la date de lancement, prévue à l'origine pour le 31 mars 1988, est maintenant fixée au 1er juillet 1988.

ISO

L'activité majeure au cours des derniers mois a consisté à évaluer et optimaliser les quatre instruments proposés pour l'ISO. Un certain nombre de réunions ont eu lieu avec les différents groupes, et plusieurs modifications et simplifications ont été apportées aux instruments. La charge utile résultante a été approuvée et, si les travaux se poursuivent en vue de nouvelles simplifications, la forme de la charge utile, ainsi que ses exigences quant aux ressources du satellite, est maintenant connue.

Sur le plan technique, les diverses études rendues nécessaires par le passage du lanceur Ariane-2 à Ariane-4 sont près d'être terminées, et celles-ci, ainsi que les résultats d'une étude des contractants possibles assurant une répartition géographique acceptable, sont maintenant en cours d'examen à l'intérieur de l'Agence.

Olympus

La 'Revue de référence du développement' (DBR) au niveau du système a eu lieu entre le maître d'oeuvre et l'Agence le 6 mars 1985, comme prévu.

La série d'essais modaux sur le modèle de structure a été achevée au cours du mois de mars, avec des résultats satisfaisants. Ce modèle de mise au point a été ensuite expédié au Canada, où il est arrivé le 8 avril 1985, pour être préparé à des essais dynamiques. Les réseaux de photopiles ont été intégrés, des essais de déploiement ont été faits, et une série d'essais exploratoires de vibration sinusoïdale de faible niveau ont été exécutés. L'intégration des autres éléments sera prête pour la série principale d'essais dynamiques, qui devrait commencer en août.

Les préparatifs se sont poursuivis pour les essais de libération des organes annexes sur le modèle thermique de satellite, qui seront effectués vers la fin de cette année.

L'intégration du modèle d'intégration électrique a commencé en mars, avec le montage du faisceau de conducteurs électriques, suivi par l'installation du sous-système de télémesure et de télécommande. Le matériel du sous-système d'alimentation électrique est maintenant en cours d'intégration. L'intégration et l'essai des charges utiles sur les panneaux respectifs du module de communications se sont poursuivis en parallèle, et deux des charges utiles sont maintenant prêtes à être expédiées au contractant principal de la charge utile en vue de nouvelles activités d'intégration.

La structure du module de service du modèle de vol du satellite en est maintenant aux derniers stades de l'équipement thermique avant d'être livrée au maître d'oeuvre.

L'évaluation des réponses à la série d'appels d'offres pour le matériel des stations au sol continue.

ERS-1

Le consortium industriel, mené par Dornier System, a poursuivi ses travaux de définition détaillée et de conception, et a continué la préparation de la documentation d'exigences correspondante. La viabilité de la conception thermique passive de la charge utile a été démontrée. Le système de distribution électrique de la charge utile est maintenant bien défini, conformément à des modifications qui ont été apportées à la plate-forme du satellite pour accroître le rendement énergétique. L'approvisionnement en pièces à haute fiabilité se déroule bien, le gros des éléments à très long délai de livraison ayant déjà été commandé.

Des efforts majeurs ont été consacrés à la poursuite des négociations avec le consortium, avec pour objectif de mettre le contrat de maîtrise d'oeuvre sous sa forme définitive au cours de cette année.

La campagne 'diffusiomètre vents' en bande C, menée en mars 1985 en Bretagne, a été couronnée de succès, en confirmant les possibilités de divers instruments in situ et embarqués pour la mesure de la vitesse et de la direction des vents.

La 'Revue de référence du développement du satellite' est programmée pour octobre 1985. Auparavant, à partir de juillet 1985, toute une série de revues de sous-systèmes sera menée au niveau des co-contractants.

Météosat

Programme préopérationnel

Une année environ avant que commence la campagne de lancement de Météosat-P2, l'intégration se déroule normalement.

Un retard dans la livraison de la boîte de dérivation destinée au modèle d'identification du satellite opérationnel (MOP) a entraîné un décalage de deux semaines dans la préparation de P2. Des mesures ont été prises pour optimaliser les séquences d'essai et pour les rendre compatibles avec la date de lancement d'Ariane-4, qui est encore fixée au 15 juin 1986.

En ce qui concerne les défauts qui ont été constatés le long des bords des cellules des panneaux solaires, le résultat final des analyses qui ont été faites par l'ESTEC n'est pas encore connu. Mais d'après les conclusions auxquelles on a abouti jusqu'à présent, il y a lieu de penser qu'il

Campagne 'diffusiomètre vents' en bande C en Bretagne (mars 1985)

ERS-1 C-band wind scatterometer campaign in progress in Brittany (France) in March 1985

Meteosat

Pre-operational programme
With about a year to go before the start of the Meteosat-P2 launch campaign, integration is proceeding normally.

A delay in the delivery of the distribution box unit for the Engineering Model has meant a two-week slippage in the preparation of P2. Action is underway to optimise the test sequences and to render them compatible with the Ariane-4 launch, which is still set for 15 June 1986.

As regards the defects found along the cell edges of the solar panels, the final outcome of the analyses done by ESTEC is not yet known. From the conclusions reached so far, however, there is reason to think that it will be possible to use the solar generators as they are, provided that the power tests due to be carried out very shortly at SNIAS, Cannes, produce satisfactory results. This assumes that the P2 model will, as planned, have a shorter lifetime than Meteosat-1 and -2.

Lasso
All activities on the Laser Synchronisation from Synchronous Orbit (Lasso) experiment are continuing normally. However, tests at subsystem level of the Lasso box equipped with mechanical models representing the various parts of the experiment show very substantial amplification co-efficients. This means that there must be a dynamic analysis and an additional test before the design of the box can be validated. Action is underway to identify possible improvements, to verify the specifications and to define the conditions for a test at system level, hopefully without repercussions on the planning.

Operational programme
Space segment
The main event during the last reporting period was the System Design Review (SDR) held at SNIAS, Cannes, at the beginning of March. The aims of this review were:

- to evaluate the system and satellite design compliance status with respect to relevant requirements and specifications
- to review the results of subsystem and equipment design reviews and their possible impacts at system level
- to assess the proposed verification and qualification programme.

The Board concluded that the review can be considered successfully completed and that, subject to satisfactory close-out of actions and deeper analysis of the radiometer, the MOP Engineering Model can be released for integration and tests.

Following the Board's recommendations, a review of the radiometer took place at the beginning of May and the Panel concluded that it could also be released for tests. The radiometer tests were therefore performed towards the end of May at SNIAS' Cannes premises.

A Schedule Meeting was held in SNIAS, Cannes, at the beginning of May in order to review the MOP-1 and -2 situation, to identify critical paths and to define the MOP-2 launch period. Based on current status, in spite of problems in the delivery of some components, the launch period for MOP-1 remains unchanged (August/September 1987). The launch period for MOP-2 will be decided at the next Meteosat Programme Board at the beginning of June.

Ground segment
The ground-segment upgrading and refurbishment activities are still progressing according to plan. A major review of these activities will be conducted during July 1985.

The Meteosat-F1 satellite, which supported the data collection mission for over 8 years, has finally run out of station-keeping fuel and is now drifting slowly eastwards. An agreement has been reached with NOAA/NESDIS to re-position their GOES-IV satellite at 10°W and to transfer the European Data Collection Mission from Meteosat-F1 to that satellite during the July – August 1985 period. GOES-IV will then support this mission until Meteosat-P2 is launched and commissioned in the second half of 1986.

Meteosat-F2 continues to support the image acquisition and data dissemination missions efficiently.

Spacelab

The launch of Spacelab-3 (SL-3) aboard the STS-51B launch vehicle took place on 29 April 1985 from Kennedy Space Center (KSC), Florida. The SL-3 configuration consisted of a long module and a mission-peculiar experiment support structure. The mission included fifteen experiments covering five scientific disciplines.

The mission lasted seven days, with a landing at Edwards Air Force Base (EAFB) in California. The Spacelab systems generally performed satisfactorily and only three significant problems were encountered: the Scientific Airlock (SAL) was inoperative after preliminary use; the Experiment Computer (EC) failed but was *sera possible d'utiliser les générateurs solaires tels quels, à condition que les essais de puissance qui doivent être effectués très prochainement à l'Aérospatiale-Cannes, donnent des résultats satisfaisants. Cela suppose que le modèle P2 aura, comme prévu, une durée de vie plus courte que Météosat-1 et 2.*

Lasso

Toutes les activités relatives à l'expérience de 'synchronisation laser à partir d'orbite synchrone' (Lasso) se poursuivent normalement. Cependant, des essais au niveau des sous-systèmes de la boîte Lasso équipée de modèles mécaniques représentant les différentes parties de l'expérience font apparaître des coefficients d'amplification très importants. Cela signifie qu'il faut procéder à une analyse dynamique et à des essais supplémentaires avant que la conception de la boîte puisse être validée. Des mesures ont été prises pour identifier des améliorations possibles, pour vérifier les spécifications et pour définir les conditions d'un essai au niveau du système, en espérant qu'elles n'auront pas de répercussions sur le planning.

Programme opérationnel

Secteur spatial

L'événement principal qui a eu lieu pendant la période écoulée depuis le dernier rapport a été la 'Revue de conception de système' (SDR) qui a eu lieu à l'Aérospatiale-Cannes, début mars. Les objectifs de cette revue étaient:

- *d'évaluer l'état de conformité de conception du système et du satellite en ce qui concerne les exigences et les spécifications correspondantes;*
- *de passer en revue les résultats des revues de conception des sous-systèmes et des matériels, ainsi que leurs conséquences possibles au niveau du système;*
- *d'évaluer le programme proposé de vérification et de qualification.*

Le Conseil a conclu que la revue pouvait être considérée comme terminée avec succès et que, sous réserve d'un bouclage satisfaisant des actions et d'une analyse plus approfondie du radiomètre, le feu vert pouvait être donné pour l'intégration et les essais du modèle d'identification du MOP.

Suite aux recommandations du Conseil directeur, une revue complémentaire du radiomètre a eu lieu début mai. Le jury a conclu que le feu vert pouvait également être donné pour les essais du modèle d'identification du radiomètre, qui ont été effectués fin mai à Cannes.

Une réunion de planification s'est tenue à l'Aérospatiale, au début du mois de mai, afin de passer en revue la situation de MOP-1 et 2, d'identifier les chemins critiques et de définir la période de lancement de MOP-2.

Etant donné l'état d'avancement actuel, et en dépit de problèmes dans la livraison de certains composants, la période de lancement de MOP-1 reste inchangée (août-septembre 1987). La période de lancement de MOP-2 sera décidée lors de la prochaine réunion du Conseil directeur du programme Météosat au début du mois de juin.

Secteur terrien

Les activités d'amélioration et de modernisation du segment sol progressent encore selon les prévisions. Une importante revue de ces activités aura lieu au cours du mois de juillet 1985.

Le satellite Météosat F1, qui a pris en charge la mission de collecte de données pendant plus de 8 ans, s'est finalement retrouvé à court de combustible pour le maintien à poste et dérive maintenant lentement vers l'est. Un accord a été conclu avec NOAA/NESDIS pour repositionner leur satellite GOES-IV à 10°W et pour faire passer la mission européenne de collecte de données de Météosat-F1 à ce satellite pendant la période de juillet-août 1985. GOES-IV prendra en charge cette mission jusqu'à ce que Météosat-P2 soit lancé et mis en service dans la seconde moitié de 1986.

Quant au satellite Météosat-F2, il continue à assurer efficacement les missions d'acquisition d'images et de diffusion de données.

Spacelab

Le lancement de Spacelab-3 (SL-3) à bord de la Navette STS-51B a eu lieu le 29 avril 1985 du Centre Spatial Kennedy, en Floride. La configuration du SL-3 se composait d'un long module et d'une structure de support d'expériences particulière à la mission. La mission comportait quinze expériences couvrant cinq disciplines scientifiques.

La mission a duré sept jours avec un atterrissage à la base de l'Armée de l'Air d'Edwards en Californie. Les systèmes de Spacelab se sont généralement comportés de manière satisfaisante, et il ne s'est posé que trois problèmes importants: le 'sas scientifique' (SAL) a cessé de fonctionner après utilisation préliminaire; l''ordinateur d'expériences' (EC) est tombé en panne mais a été remplacé par la machine de secours; et un moyen de commande d''unité d'acquisition à distance' (RAU) d'expériences a été perdu, mais a été transféré par l'équipage sur une autre RAU.

C'est la défaillance du SAL qui a eu le plus de conséquences sur la mission, en ce sens que l'expérience de 'caméras à champ très large' n'a pas pu être mise en oeuvre. Un examen, postérieur au vol, du levier de commande et des loquets de sécurité du SAL permettra de déterminer s'il s'agissait d'une défaillance du matériel ou d'une fausse manoeuvre de l'équipage.

Les préparatifs du vol SL-2 se poursuivent. La première partie de la 'Revue d'aptitude au vol' (FRR) s'est terminée le 24 mai, et le feu vert a été donné pour installer la charge utile dans l''Orbiter', à partir du 6 juin. Une fois que la charge utile, composée de 13 expériences couvrant six disciplines, aura été installée en toute sécurité, les essais finaux d'interface Orbiter-Spacelab auront lieu. Le lancement de SL-2 est programmé pour le 12 juillet avec atterrissage le 19 juillet.

IPS

La revue d'aptitude au vol du système de pointage d'instruments (IPS) a été terminée par la NASA, et l'installation dans l'Orbiter en vue du lancement du 12 juillet progresse.

Production ultérieure (FOP)

La NASA a demandé des offres de prix pour d'autres matériels de Spacelab, et l'industrie prépare ces offres. Un certain nombre de tâches de reconstruction du matériel de Spacelab ont été exécutées dans le cadre du contrat FOP de la NASA.

La livraison de l'IPS (FOP) a encore été retardée et est maintenant prévue pour le 8 juillet. Ces retards ont été causés par des problèmes de matériau relatifs aux ressorts à lames du mécanisme de replaced by the back-up machine; an Experiment Remote Acquisition Unit (RAU) command capability was lost, but was repatched by the crew to another RAU.

The SAL failure had the most impact on the mission in that the Very-Wide-Field Camera experiment could not be operated. A post-flight examination of the SAL operating handle and safety latches will determine whether it was an equipment failure or a crew operational error.

Preparations for the SL-2 flight are continuing. The Flight-Readiness Review (FRR) Part 1 was completed on 24 May 1985 and the go-ahead was given to install the payload in the Orbiter, commencing on 6 June. Once the payload, consisting of 13 experiments covering six disciplines, is safely installed, the final Orbiter/Spacelab interface tests will take place. The launch of SL-2 is scheduled for 29 July with a landing on 5 August.

IPS

The Flight Readiness Review by NASA, of the Instrument Pointing System (IPS) has been completed and installation into the Orbiter for the 29 July launch is in progress.

Follow-on Production (FOP)

NASA has requested quotations for more Spacelab hardware, and industry is preparing bids. A number of refurbishment tasks for Spacelab hardware have been performed under the NASA FOP Contract.

The FOP IPS has been further delayed and delivery is now scheduled for 8 July. These delays have been caused by material problems associated with the leaf springs of the payload-gimbal-separation mechanism (PGSM).

The FOP IPS acceptance activities started on 30 May 1985 at Dornier System, attended by NASA.

Microgravity

Biorack

The pre-shipment review of the D1 payload was held on 14–15 March at ERNO and shipment of the D1 Spacelab train took place in early May.

A review of the Experiment Sequence test results with the Principal Investigators was held at CNES, Toulouse on 25–26 April. Some recommendations for minor modifications to the Biorack hardware and the flight procedures were made by the crew and the experimenters, and are currently being implemented. The retesting of experiments 52/NL and 58/F is planned for the last week of June.

An introductory visit of the Biorack Principal Investigators (PIs) to the Life Science Support Facility (Hangar-L) of the Kennedy Space Center was organised from 21 to 23 May. Hangar-L is where preparation of the biological material for D1 will take place and the ground control experiments will be performed.

The reflight of the Biorack facility as a payload element of the NASA International Microgravity Laboratory (IML) Mission, as part of Phase II of ESA's Microgravity Programme, was approved by the Spacelab Programme Board on 12–13 February 1985 and accepted by NASA. The launch of IML-1 is planned for mid-1987.

A technical coordination and interface meeting with the engineers of NASA Marshall Space Flight Center who are responsible for the IML-1 payload was conducted at ESTEC on 15–16 April. The Call for Experiments for the Biorack reflight resulted in 28 European proposals, which are presently under evaluation by a peer group. A meeting on ESA/NASA Scientific Coordination for the joint final evaluation of European and American experiments took place on 29–30 April.

The industrial activities for this new project, in particular the procurement of long lead items, have been initiated.

Fluid Physics Module (FPM)

The FPM has been integrated with the Spacelab hardware and the D1-mission simulations have been performed successfully at MBB/ERNO. The hardware has been shipped to Kennedy Space Center (KSC) to be prepared for launch in October 1985.

Vestibular Sled

The crew has been trained extensively on the Sled and the flight procedures have been prepared. Like the FPM, the Sled has passed the mission simulations successfully and has been shipped to KSC.

Sounding rockets

The Texus-11 and -12 sounding-rocket payloads with a total of 17 experiments investigating the influence of free-fall conditions on processes such as solidification, crystal growth, critical point phenomena and cell fusion, were successfully launched from Esrange's Kiruna launch site, on 29 April and 6 May 1985, respectively.

ESA-sponsored experiments from France, Germany, Spain, United Kingdom and Sweden were carried out, in the areas of:
- Phase Decomposition of Critical Binary Fluids
- Self- and Interdiffusion in Alkalisilicate Melts
- Maximum Injection Rate into a Floating Zone
- Ionic Solutions near the Critical Point
- Floating Zone Crystallisation of Germanium
- Preparation of Single Crystals of Rare-Earth Magnesium Compounds
- Gradient Solidification of Bi-Zn-Alloys
- Retention of Fine Precipitate Dispersion.

All systems performed nominally and the samples, films and photographs taken during flight, as well as the data recorded, have been forwarded to the experimenters for analysis.

The success of these two launches brings the total number of sounding-rocket experiments in material and fluid sciences conducted under the auspices of the Agency to 35.

In response to the 'Announcement of Opportunity' for Sounding-Rocket Experiments issued on 13 March 1985, a total of 19 experiment proposals were received. After review of the proposals by peer groups, experiments in the following areas have been recommended for flight in April/May 1986 on Texus-13 and -14:
- Thermal Marangoni Convection in a Floating Zone
- Phase Decomposition of Fluid Mixtures near the Critical Point
- Surface Forces in Contacting Solids
- Materials (alloy and semiconducting) Solidification.

Phase-2

Phase-2 of the Microgravity Programme started in mid-February 1985.

The procurement proposals for time-critical elements were approved by the *séparation à la cardan de la charge utile (PGSM).*

Les activités de recette de l'IPS (FOP) ont commencé le 30 mai chez Dornier System, et sont suivies par la NASA.

Microgravité

Biorack

La revue de pré-expédition de la charge utile D1 a eu lieu les 14 et 15 mars chez ERNO et l'expédition du train Spacelab D1 a eu lieu début mai. Une revue des résultats des essais de séquence des expériences a eu lieu avec les 'chercheurs principaux' au CNES, à Toulouse, les 25 et 26 avril. Quelques recommandations pour des modifications mineures à apporter au matériel de Biorack et aux procédures de vol ont été formulées par l'équipage et par les expérimentateurs, et sont actuellement en cours d'application. Les nouveaux essais des expériences 52/NL et 58/F sont prévus pour la dernière semaine de juin.

Une visite d'introduction des chercheurs principaux de Biorack à l''installation de soutien des sciences de la vie' (Hangar L) du Centre Spatial Kennedy a été organisée du 21 au 23 mai. C'est dans le Hangar L qu'aura lieu la préparation de la matière biologique pour D1, et que seront effectuées les expériences de commande au sol.

Le renvoi dans l'espace de l'installation Biorack, en tant qu'élément de charge utile de la mission 'Laboratoire international de microgravité' (IML) de la NASA, dans le cadre de la phase II du programme de microgravité de l'ESA, a été approuvé par le Conseil directeur du Programme Spacelab les 12 et 13 février et a été accepté par la NASA. Le lancement d'IML-1 est prévu pour la mi-1987.

Une réunion de coordination technique et d'interface avec les ingénieurs du Centre des Vols Spatiaux Marshall de la NASA, responsable de la charge utile d'IML-1, a eu lieu à l'ESTEC les 15 et 16 avril. L'appel aux expériences pour le nouveaux vol de Biorack a suscité 28 propositions européennes, qui sont en cours d'évaluation par un 'groupe de pairs'. Une réunion sur la coordination scientifique ESA-NASA pour l'évaluation finale conjointe des expériences européennes et américaines a eu lieu les 29 et 30 avril.

Les activités industrielles relatives à ce nouveau projet ont été mises en route, en particulier l'approvisionnement en éléments à long délai de livraison.

Module de physique des fluides (FPM)

Le FPM a été intégré au matériel de Spacelab et les simulations de la mission D1 ont été effectuées avec succès chez MBB et ERNO. Le matériel a été expédié au Centre Spatial Kennedy et sera préparé en vue du lancement en octobre.

Sled vestibulaire

L'équipage a subi un entraînement extensif sur le Sled, et les procédures de vol ont été préparées. Le Sled, comme le FPM, a subi avec succès les simulations de mission et a été expédié au KSC.

Fusées-sondes

Les charges utiles des fusées-sondes Texus-11 et Texus-12 avec un total de 17 expériences d'étude de l'influence des conditions d'impesanteur sur des processus tels que la solidification, la croissance des cristaux, les phénomènes de point critique et la fusion des cellules, ont été lancées avec succès de la base de lancement d'Esrange à Kiruna, la première le 29 avril, la seconde le 6 mai.

Des expériences parrainées par l'ESA en provenance de France, d'Allemagne, d'Espagne, du Royaume-Uni et de Suède ont été effectuées, dans les secteurs suivants:

- *Décomposition de phase de fluides binaires critiques*
- *Auto- et interdiffusion dans les bains fondus de silicates alcalins*
- *Vitesse d'injection maximale dans une zone flottante*
- *Solutions ioniques à proximité du point critique*
- *Cristallisation du germanium en zone flottante*
- *Préparation de monocristaux de composés du magnésium et de terres rares*
- *Solidification à gradient d'alliages Bi-Zn*
- *Rétention de dispersion de Précipités fins.*

Tous les systèmes ont donné des performances normales et les échantillons, les films et les photographies qui ont été pris en cours de vol, ainsi que les données qui ont été enregistrées, ont été transmis aux expérimentateurs pour analyse.

Le succès de ces deux lancements porte à 35 le nombre total des expériences sur fusées-sondes dans les sciences des matériaux et des fluides qui ont été conduites sous les auspices de l'Agence.

En réponse à l'Offre de participation aux expériences sur fusée-sonde qui a été lancée le 13 mars, un total de 19 propositions d'expériences ont été reçues. Après revue de ces propositions par des groupes de 'pairs', des expériences dans les secteurs suivants ont été recommandées pour le vol d'avril-mai 1986 sur Texus-13 et Texus-14:

- *Convection de Marangoni thermique dans une zone flottante*
- *Décomposition de phase de mélanges de fluides près de leur point critique*
- *Forces superficielles dans les solides en contact*
- *Solidification des matériaux (alliages et semi-conducteurs).*

Phase-2

La Phase-2 du programme de microgravité a commencé à la mi-février.

Les propositions d'approvisionnement pour les éléments à durée critique ont été approuvées par l'IPC à la fin de février. La première réunion de négociation avec Kayser-Threde et l'Aérospatiale pour l'Anthrorack a eu lieu après un appel d'offres concurrentielles. Les opérations d'approvisionnement en vue de la livraison de deux supports d'expériences de Spacelab sont en cours.

Eureca

La date de signature du contrat étant fixée au 13 juin, tous les documents contractuels ont été mis dans leur forme définitive (voir dernière information page 88). Le dernier point ouvert, la question de la garantie de conception, a été résolu de manière satisfaisante.

Des évaluations critiques du 'Système de traitement de données' (DHS), du 'Matériel mécanique de soutien au sol' (MGSE) et du 'Système de contrôle d'attitude et d'orbite' (AOCS) d'Eureca, ainsi que du réseau de photopiles, sont en cours et seront achevées en juin.

En ce qui concerne la charge utile de la

Agency's Industrial Policy Committee (IPC) at the end of February 1985. The first negotiation meeting with Kayser-Threde/Aerospatiale for Anthrorack has been held after a competitive tender action. The procurement action for delivery of two Spacelab racks is under way.

Eureca

With the date for contract signature set for 13 June 1985, all contractual documents have been finalised (see page 88 for latest information). The last open point, the design guarantee issue, has been satisfactorily resolved.

Critical assessments of the Eureca Data Handling System (DHS), Mechanical Ground Support Equipment (MGSE) and Attitude and Orbit Control System (AOCS), and the solar array are in progress and will be completed in June.

As regards the first Eureca mission payload, the Instrument Interface Agreement Documents have been distributed to the instrument developing institutions for final review. The majority of the interface agreements are expected to be concluded during an ESA/ERNO/ instrument developers' working meeting in Bremen on 18–20 June 1985.

Based on payload models provided by the user communities in the fields of solar physics and astrophysics, two payload accommodation studies for potential Eureca missions are about to commence, to be completed by November 1985. In parallel, calls for conceptual payload ideas in the fields of space sciences and earth observation have been issued by the respective ESA directorates. The Agency expects to have completed evaluation of these proposals by mid-September 1985.

In addition, possibilities for joint utilisation of Eureca are being discussed with NASA and US industry.

Ariane

Ariane-4 development

Ground qualification of the structure and of the propulsion systems is progressing on schedule for a first launch in mid-1986.

Phase-2 test firing of the solid boosters took place on 10 May at BPD in Colleferro (Italy), and two short-duration test firings (20 seconds each) were successfully performed on the liquid boosters at DFVLR in Lampoldshausen (Germany). Two development test firings for the nominal thrust time of 132 seconds are due to take place in June.

The first qualification test of the solid booster is planned for the end of June, and that of the liquid booster is scheduled for the end of September.

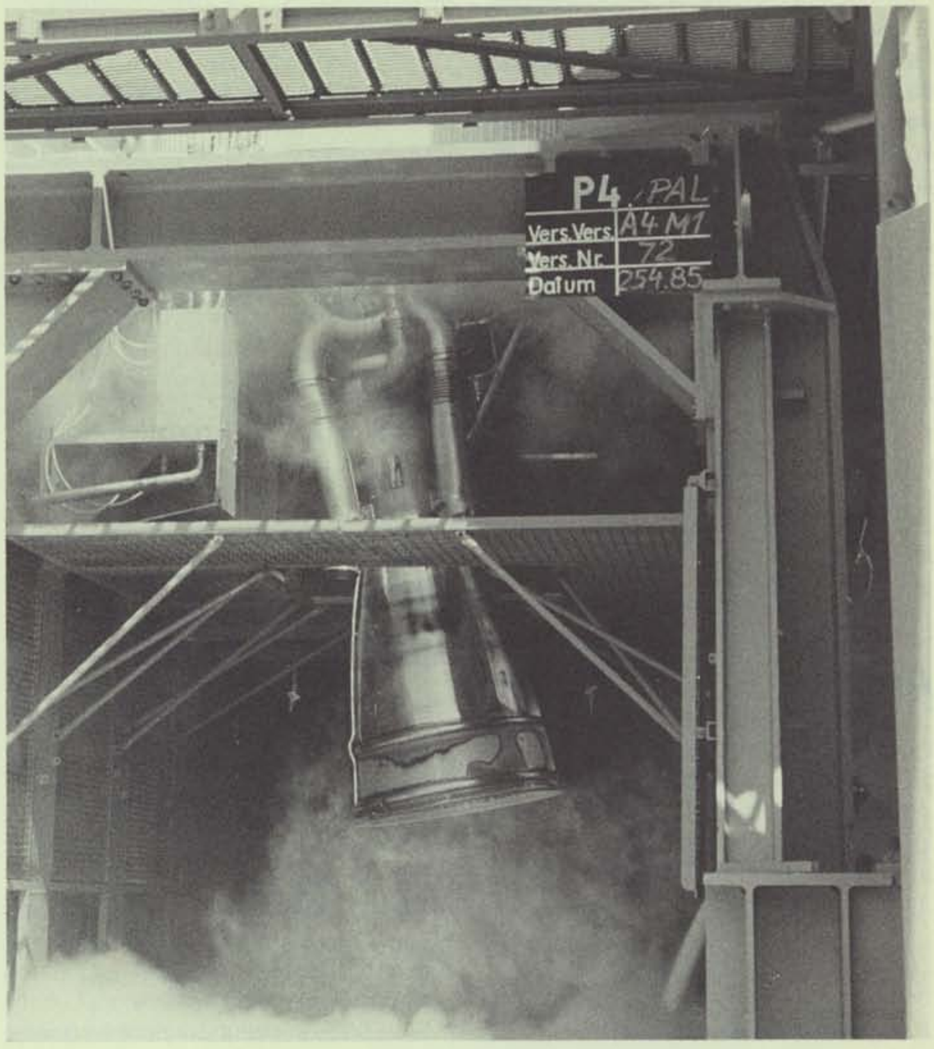
The two qualification tests on the fairing (soft release system and rainproofing) have been successfully completed.

Dynamic testing of the upper part of the SPELDA system (load-carrying structure) is proceeding normally.

Space Station/ Columbus

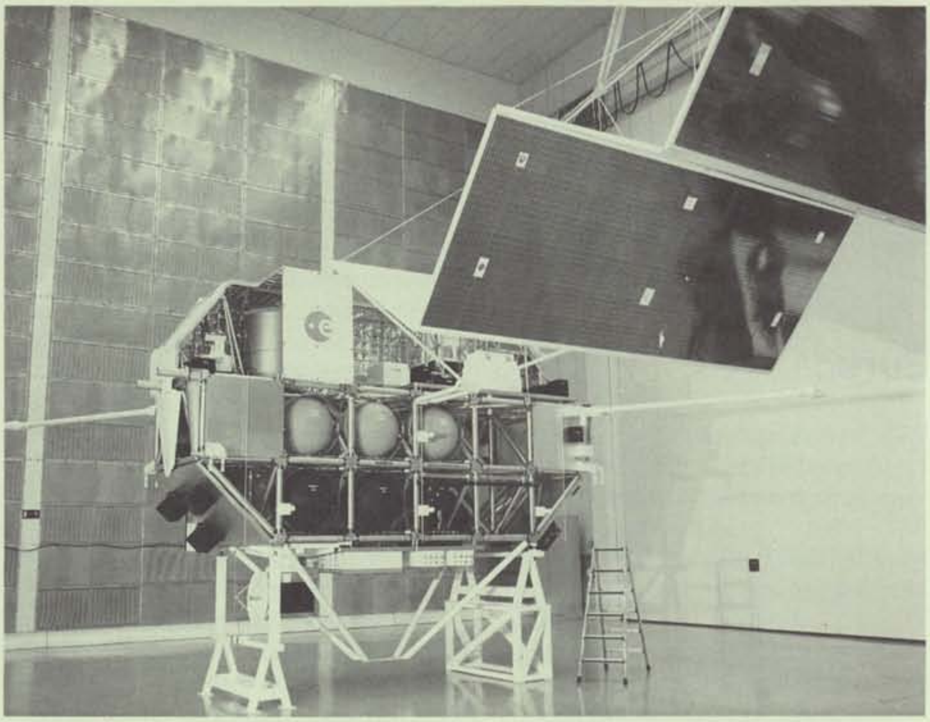
Five industrial proposals for the five major work packages of the Columbus Phase-B1 study have been received and evaluated, and the results presented to the Tender Evaluation Board (TEB) on 3 May and subsequently to the Agency's Industrial Policy Committee (IPC) on 24 May. Kick-off meetings could therefore be held on 28 May for the System Architecture (MBB/ERNO) and in early June for the four element contracts: Laboratory Module (Aeritalia), Platforms (British Aerospace), Service Vehicle (Aerospatiale) and Resource Module (Dornier System).

Austria has joined the Columbus Preparatory Programme with a 0.5% contribution and Denmark has increased its contribution from 0.5 to 1.0%.



Propulseur d'Appoint à Liquides (PAL) lors de ses essais à feu au DFVLR

Ariane liquid booster during test firing at DFVLR



Hard mock-up of the Eureca retrievable carrier

Maquette en grandeur nature de la plate-forme récupérable Eureca

première mission Eureca, les documents d'accord d'interface des instruments ont été distribués aux institutions de mise au point des instruments pour revue finale. Il est prévu que la majorité des accords d'interface seront conclus au cours d'une réunion de travail entre l'ESA, ERNO et ceux qui sont chargés de mettre au point les instruments, qui se tiendra à Brême du 18 au 20 juin.

Sur la base de modèles de charge utile fournis par les milieux utilisateurs dans les domaines de la physique solaire et de l'astrophysique, deux études de réception de charge utile pour des missions Eureca possibles sont sur le point de commencer, et devraient être terminées d'ici le mois de novembre. En parallèle, des appels aux idées conceptuelles de charge utile dans les domaines des sciences de l'espace et des observations de la terre ont été lancés par les directions respectives de l'ESA. L'Agence pense qu'elle aura terminé l'évaluation de ces propositions d'ici à la mi-septembre.

De plus, des possibilités d'utilisation conjointe d'Eureca sont en cours de discussion avec la NASA et l'industrie américaine.

Ariane

Développement Ariane 4

La qualification au sol des structures et ensembles propulsifs se poursuit selon le calendrier établi pour permettre un lancement du premier exemplaire à la mi-86.

Le deuxième tir de développement des propulseurs d'appoint à poudre (PAP) a eu lieu le 10 mai chez BPD à Colleferro en Italie, et deux tirs courts (20 s) ont été réalisés avec succès sur les propulseurs d'appoint à liquide (PAL) au DFVLR à Lampoldshausen en Allemagne. Deux tirs de développement de durée nominale (132 s) sont prévus en juin.

Le premier essai de qualification du propulseur d'appoint à poudre est prévu fin juillet, celui du propulseur d'appoint à liquide en septembre.

Les deux essais de qualification sur la coiffe (désanglage doux et étanchéité à la pluie) se sont terminés de façon satisfaisante.

Les essais dynamiques sur la partie haute du SPELDA (structure porteuse) sont en cours et se déroulent normalement.

Station spatiale/Columbus

Cinq propositions industrielles pour les cinq lots de travail majeurs de l'étude de Phase-B1 de Columbus ont été reçues et évaluées, et les résultats ont été présentés à la 'Commission d'évaluation des offres' (TEB) le 3 mai, puis au 'Comité de politique industrielle' (IPC) de l'Agence le 28 mai. Des réunions de démarrage d'étude ont donc pu avoir lieu le 28 mai pour l'architecture du système (MBB/ERNO) et début juin pour les quatre contrats élémentaires: module de laboratoire (Aeritalia), plates-formes (British Aerospace), véhicule de service (Aérospatiale) et module de ressources (Dornier System).

L'Autriche s'est jointe au programme préparatoire Columbus avec une contribution de 0,5%, et le Danemark a porté sa contribution de 0,5 à 1.0%.

The Electronic Transmission of ESA Invitations to Tender – The EMITS System

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The Agency issues a large number of competitive Invitations to Tender which, under its rules, have to be widely distributed to potential bidders throughout the ESA Member States. To reduce unproductive effort, costs and mailing delays, a system for making these texts available by electronic means is being introduced.

Introduction

ESA has some 1500 firms and organisations on its list of potential suppliers, about 200 of whom carry out regular business with the Agency and about twice as many are occasionally involved in ESA procurements. The Agency issues between 100 and 120 open competitive Invitations to Tender (ITTs) each year, and receives in the order of 3000 to 4000 responses. The List of Intended ITTs is sent twice a year to all firms on the bidders list, at an approximate cost for reproduction, paper and postage of 16 000 French francs per issue.

The ITTs themselves vary considerably in scope, but an approximate average cost for printing and dispatch is perhaps 33 000 French francs. These figures exclude the not inconsiderable costs of secretarial effort for labelling and assembling the packets. ITTs and offers must be sent by registered mail and experience shows that the mailing time within Europe varies considerably between the various Member States, with the corresponding disadvantaging of some firms.

This bare recitation of facts indicates the motivation that led the Agency to begin to consider, in 1982, the feasibility of using modern electronic means of communication to reduce the costs and in-built inefficiencies of the existing system. Any such approach would have to meet a number of constraints, procedural, technical and economic, be strictly functional and effective in operation, and be readily acceptable to users with little familiarity with electronic data retrieval. There was no room for an advanced system with wide application and potential, but riddled with the teething problems that seem endemic in many large, ambitious, computer-based management and information systems.

The design of a possible system was entrusted to a small working group with diverse but complementary skills. To avoid the danger of an apparently attractive but ultimately impractical system, a secretarial assistant with experience of modern electronic office equipment and methods was associated with the group from the outset.

It was recognised that what could be achieved was savings in the mechanical production and dispatch of documents, and perhaps in terms of efficiency and speed. It was not to be expected that 'intellectual' efforts could be reduced. The electronic tendering system might well give other benefits, of essentially two types:

- the possibility of archiving data electronically, thus eliminating bulky physical archives, often duplicated in different establishments
- the ability to have data on past ESA procurement actions in a searchable form.

These potential benefits should not play, at least in the initial phases, a dominant role or affect negatively the simple useability of the basic system. The drafting of good specifications and contractual texts remains the prime task.

* Recently retired

The result so far is a system that, in terms of information technology, is simple but, it is believed, effective and user friendly. Whether this is really so remains to be verified by operational experience. The process of setting up the system has itself been instructive, and in the hope that the lessons might be of benefit to others concerned with similar projects, the system as it now stands is first described, and then some of the major contraints and the responses thereto are discussed.

The EMITS system

The EMITS system as presently conceived and operated consists of a database on the IBM-compatible mainframes of ESA's Information Retrieval Service (IRS) in Frascati. The data are accessible to anyone with a password, which is freely obtainable on request. When the user links up with EMITS, the first information given is an index of the overall contents:

(i) List of intended Invitations to Tender
(ii) Currently issued competitive ITTs
(iii) Standard contractual texts
(iv) Certain technical standards from the ESA Procedures, Standards and Specifications (PSS) document series
(v) An explanation of the EMITS file.

Each file is operated via a simple menu and no special language, codes or instructions are needed. A summary of the various information levels and how the different menus are interlinked is given in Figure 1. The system ensures rapid access to the desired information.

The list of forthcoming actions is the part of the file that is likely to be used the most widely and frequently. It contains all the information that is in the List of Intended Invitations to Tender, published quarterly by the Agency. The user can search the list according to issuing Establishment, or in the case of ESTEC, the issuing Department, by the annual quarter of intended issue, or by subject, against a list of keywords.

The end product of any search in this part of the file is a summary description of the particular action, which gives various administrative and programme references, whether a procurement proposal to the Industrial Policy Committee is needed, the type of tender action (open competitive, restricted or direct negotiation), the quarter of issue, the price range foreseen, the title, and usually a brief description of the nature of the work.

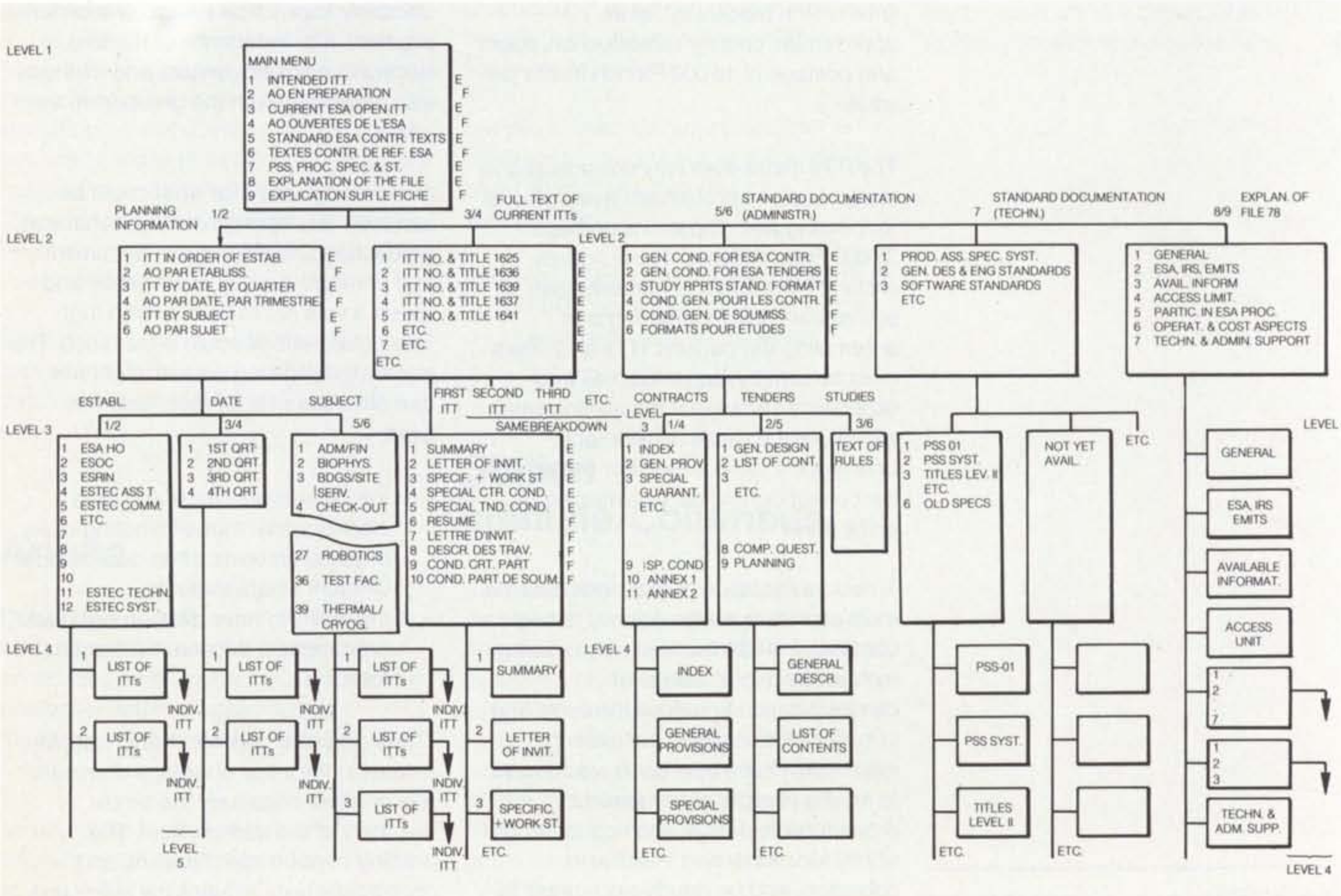


Figure 1 – The menu structure and internal levels of the EMITS system (per April 1985)

This part of the file, which is now fully operational, is therefore identical in content to the printed List of Intended ITTs, with the added advantages that it can be updated at more frequent intervals, and is searchable.

The second major element of the file contains the current *open competitive* ITTs. It would not be proper to publish the full texts of noncompetitive or restricted ITTs and for practical reasons ITTs for major satellite projects or similar, which have texts of enormous length of interest primarily to a relatively small number of potential prime contractors, are not included. The complete text of the ITT, consisting of the summary description, cover letter, technical requirements, draft contract conditions and special conditions of tender, is filed. These can be looked at separately, if so desired, by persons with a specialist interest.

The preparation of texts in a format that lends itself to easy and, above all, accurate transmission from the issuing establishment to the ESRIN facilities has involved a degree of 'education' of those who produce the documents on a wide range of personal computers or mainframe facilities. For this reason, it has taken longer to make this part of the file fully operational.

The third part of the file contains a number of standard contractual documents, these being at present the General Clauses and Conditions for ESA Contracts, the General Conditions of Tender and the Specification for the Production of Study Reports. This list will be added to from time to time with appropriate documents.

In a similar way, some technical standards of general application have been put on file in the fourth section. This part will also be expanded in the future.

Some of these standard documents remain stable over a long period, others are subject to updating from time to time. The costs and effort involved in making small changes to a document and issuing it widely often discourage the introduction of a useful and necessary change, and EMITS should allow this reluctance to be overcome. The concomitant danger of a continuous and uncontrolled updating of standards is recognised, and strict discipline has to be exercised.

The last part of the EMITS file contains an explanation of the system, in the form of a series of questions that experience has shown are likely to be put by potential or new users, and the answers thereto. This section will be updated from time to time to match the latest status, and to cover any issues that may arise in the future through operational experience.

By mid-1985, several ITTs have already been entered into the system; for others, there is a statement that the ITT is issued and available by mail. For the time being, it is considered necessary to maintain the existing system of issuing ITTs by registered mail in parallel with EMITS. As users become familiar with the system, and appreciate the advantages of immediate availability of texts, it is hoped that EMITS will become the standard, and texts will only be mailed on specific request, especially as the firms so requesting would have less time to prepare bids.

The requirements and constraints

The system users

As the whole process of tendering is one of dialogue between various parties, the number of different types of users is large, and their needs are not necessarily identical.

ESA's internal users

The production and issue of the list of forthcoming tender actions and of an Agency ITT falls under the formal responsibility of the Contracts Department, but in terms of effort is clearly a joint activity by Contracts and the initiating Division/Department. Any system that decreased the efforts in Contracts Department at the expense of greater effort on the technical side was seen as not realistic. In general, the initiator presents the technical requirements (usually in both English and French) to Contracts, who then produce the contractual documents (cover letter, conditions of tender and draft contract conditions) to complete the ITT package.

The system as envisaged therefore requires a certain discipline in the typing and presentation of technical requirements, in the machine used, in the layout, and in the restricted use of symbols and diagrams, but involves no major changes to existing working procedures. While it must remain the sole authority of Contracts to put information into the database, all ESA staff will have read access to the data.

Industrial users

There has been no detailed study of who in industry makes most use of ESA ITT documents. For the larger firms, both the list of forthcoming ITTs and the ITTs themselves are sent, at the firm's request, to someone with a marketing function, which may or may not be linked to the contracts function. It has been suspected that sometimes a firm fails to bid because the engineers who would be perhaps best placed to decide whether the work falls within the firm's potential either never see the papers, or receive them too late. There is, however, no hard evidence for this. In smaller firms, the functions tend to be less sharply divided, and internal communication lines are shorter.

In setting up the system, it has been assumed that the first-line user in industry would typically be a marketing manager, probably not overfamiliar with use of a terminal, and unwilling to involve himself with a system that complicated matters or failed to give immediate and simple results. On the other hand such a person would be very appreciative of faster access to information and more frequent updates of the ITT list. The technical staff would most appreciate the opportunity to

Figure 2 – Typical example of a terminal that can be used to access EMITS

make an independent scan of what was currently requested, including the full technical documentation, and maybe identify potential work overlooked by his colleagues.

Other possible users
Copies of all but the lowest-value ITTs have to be sent to the ESA Delegations. It was recognised that Ministries have different constraints from those of industrial firms; in particular the early availability of information and its full referencing according to various criteria are of vital importance to Delegates. Many Delegations see the EMITS system as a valuable aid in helping them in their tasks of disseminating information and increasing awareness of possible Agency contract work for firms within their own Member States.

Availability of facilities

One of the first objections raised when the EMITS scheme was mooted was that it was unrealistic to assume that industry would have the necessary hardware, and that one could not expect firms to make substantial investments. In particular it was feared that small firms would be excluded. The system as designed, using ESA's IRS, means that all that is required to access the EMITS database is a simple terminal with a synchronous modem or acoustic coupler(Fig. 2). This includes any word processor, micro- or personal computer equipped with a serial interface.

In addition, to use the system for anything other than browsing, a reasonably fast printer is needed. A survey of firms confirmed that in the majority of cases this was not a problem. Smaller specialist firms in particular found the use of this equipment perfectly normal. In larger firms the equipment is always to be found, but not always with the prime EMITS user, so that some degree of education, rather than capital investment, might be needed.

In the few cases where a firm does not possess the standard equipment (assuming such a firm is seriously interested in space business), it could equip itself for some 2000 AU.

The basic facility without which the whole project could not even have been considered is ESA/IRS, with its proven network and a large number of established users. To access EMITS, the user has only to call the nearest access point of his national public network and specify the IRS network address, in order to be connected to the IRS system. He can be assisted through the IRS national centres in case of difficulties.

The implementation of EMITS has not required any hardware investment and a limited software effort. The existing terminals, word-processors, personal computers and IBM-compatible mainframes have been used. The recent installation of Local-Area Networks (LANs) in two ESA Establishments has improved communication facilities, covering also the EMITS requirements. The EMITS software is mainly a special ESA-QUEST application written using the Information Processing Utilities (IPUs) already available on the IRS system. Some batch programs have been developed to prepare the EMITS data and to print the booklet of the Intended Invitations to Tender on the laser printer for mail distribution.

Procedural considerations

The ESA Contract Regulations [ESA/C(82)111], approved at Council level, lay down certain rules governing the issue of ITTs. No possible amendment to these rules in order to implement an EMITS system was contemplated. Changes to internal rules, procedures and working methods were regarded as acceptable provided that they did not entail more work or create a counterproductive level of confusion or unfamiliarity.

The main relevant rules of the Contract Regulations are:

- *Article 11*, which states that competitive ITTs are normally to be issued in both English and French. Any system would therefore have to be able to cope with both languages on an equal footing, and without confusion.
- *Article 12*, which states, in essence, that open competitive ITTs shall be issued to all potential tenderers (i.e. firms on the ESA bidding list) in the

Member States participating in the programme. Under certain restricted circumstances, they may be sent to firms outside the participating States. There is no rule that the text must be kept secret from firms not entitled to bid, but it would clearly be improper to give such a firm access to the text without a warning to this effect. Article 12 also stipulates that ITTs shall be issued simultaneously and free of charge to all potential tenderers.
- *Article 13*, which stipulates that any clarification or modification to the ITT shall be issued simultaneously to all potential bidders.

On a first examination, only three elements in the above were seen as needing special consideration.

While simply making a text available from a database does constitute simultaneous release (the ESRIN facility has ample capacity for multi-access), a firm that previously registered its interest in a particular action and then received a text by mail would be in the same position as a firm that notices the ITT by chance during a scan. To be fair to firms which positively show interest, and also to encourage information that would assist the Agency in its planning, it was decided that firms would still be asked to announce their interest in forthcoming actions from time to time. Such firms would then be notified by telex that a particular text was being made public on EMITS. The chance of their missing useful bids would thereby also be reduced.

Clarifications and modifications to the ITT posed a more difficult problem, as these may be of great importance and a firm missing them might be seriously disadvantaged. The risk of just putting such modifications and clarifications on the database would be too great. It was therefore agreed that firms should continue to be asked to return the usual 'acknowledgement of receipt' form which contains the statement that they intend (or do not intend) to bid. Firms responding positively would be sent amending texts by telex. The possibility of using EMITS both for the expression of intent to bid and for transmitting the new texts will be tackled at a later phase.

Figure 3 – Just a few of the Invitations to Tender that will now be accessible electronically with the help of EMITS

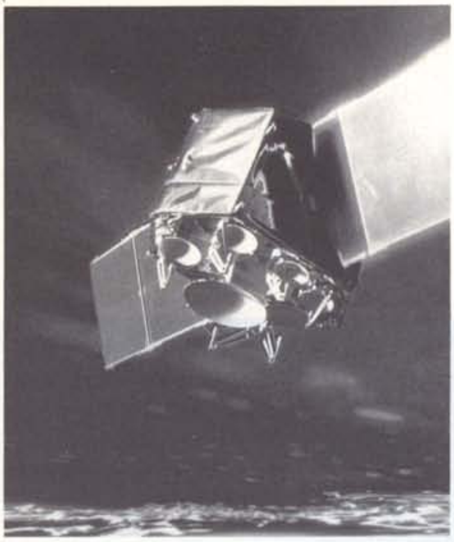
The third problem was the interpretation of the term 'issued free of charge'. If ESA absorbs the IRS utilisation costs (10 AU per hour), the only costs to an EMITS user are the telecommunications charges that accrue directly and vary from country to country. Typically the costs of printing an average ITT text are similar to the costs of posting a registered package. Firms can still request hard copies of ITTs (though hopefully not too many will do this), so that the costs of using EMITS can be seen as a small price to pay for receiving the text more rapidly than under the classical scheme. In practice, many firms currently send a messenger by air to hand-carry an ITT in which they are interested, in order to avoid delay.

Conclusions

The overall result of the dialogue with the various users has been that the usefulness, feasibility and perhaps need for EMITS have been demonstrated and that the scheme, as initially designed, while adapted and ameliorated in the light of many comments, has remained remarkably unchanged in basic outline. Already a number of additional functions and developments for EMITS have been identified for future investigation, the principal ones being:

a. the possibility for firms to express their interest in forthcoming or current tender actions via a terminal, thus obviating the need for a large amount of form-filling and mailing;
b. the possibility of sending information, such as modifications or clarifications to ITTs, through the system to potential bidders;
c. the integration of EMITS with existing and future ESA contract and financial-management systems.

Users will have to become familiar with the system before a final judgement can be made, but there is confidence that the improvement in efficiency in issuing ITTs will justify the need to modify existing working habits.



The Agency's Orbital Test Satellite (OTS) – Results and Benefits from Seven Years in Orbit

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On 12 May 1985 seven years had elapsed since OTS-2 was successfully put into orbit from Eastern Test Range in Florida. The technology feedback from the satellite has been invaluable in defining the design and operations for ECS, Marecs and other OTS-derived European communications satellites.

The launch of OTS ushered in the pre-operational phase of the European Communications Satellite (ECS) programme. In addition, OTS has served as a test bed for the Orbital Test Programme (OTP), designed to prepare the way for ECS, by:

- verifying the performance of the satellite in orbit
- carrying out transmission tests for the PTTs directly relevant to the implementation of the ECS system
- determining atmospheric attenuation and polarisation disturbances
- carrying out communications experiments for new applications.

The objectives foreseen for the OTP were fully met and have had a positive impact on the definition and implementation of the operational ECS system. The payload of OTS was operated until the end of 1983 – well beyond its original three-year requirement – to overlap with the first satellite of the ECS series. Beyond that date, OTS is continuing to operate, but now with a non-transparent payload for carrying out some technological End-of-Service (EOS) tests and to collect further lifetime data relevant to the missions of operational satellites derived from OTS.

This 'hibernation mode' as it is called, is still being maintained and delivers extremely useful data, while minimising the operational effort required from the ground station. Inclination control has had to be terminated, due to near depletion of fuel, but east–west station-keeping continues, and sufficient fuel will be maintained onboard to put OTS into a higher 'graveyard' orbit when this becomes necessary.

The conceptual design of OTS and ECS

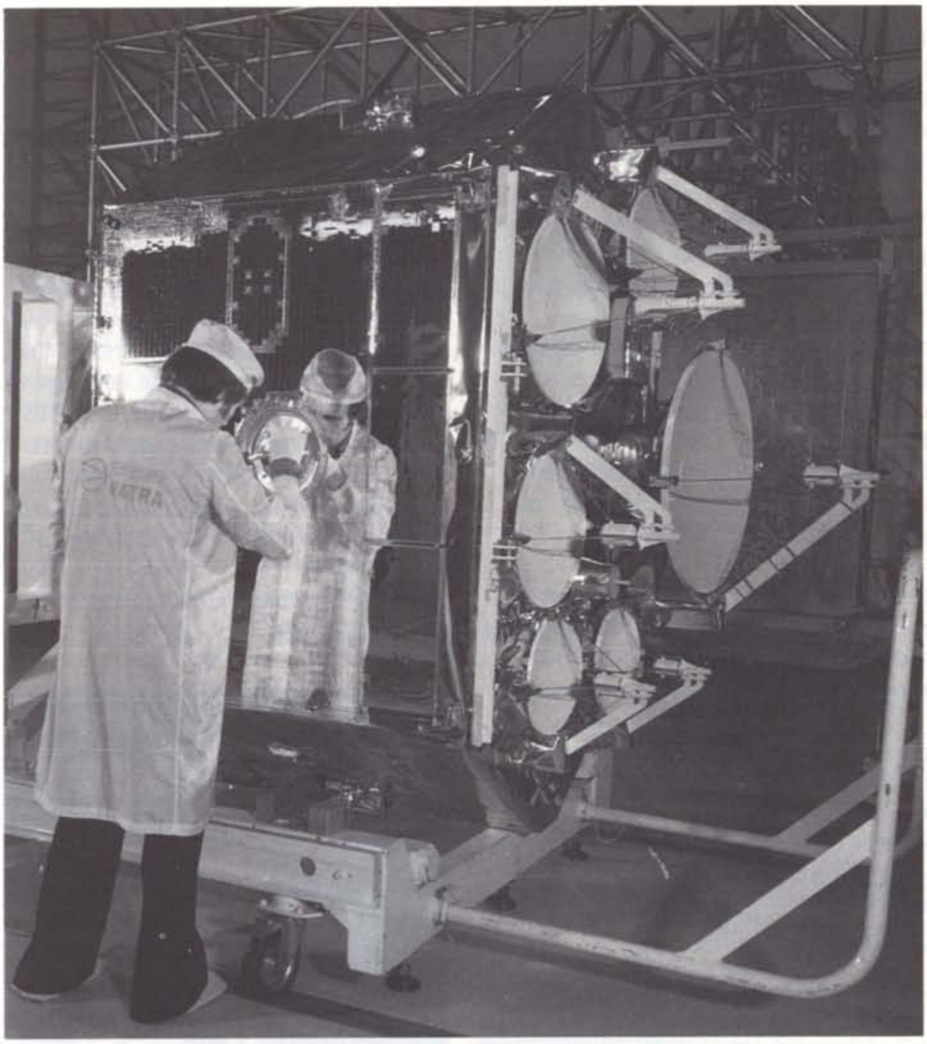
OTS was designed to be the forerunner of the operational ECS system (Fig. 1). A pre-operational test satellite was required because, during the configuration definition for a European communication system via satellites, there was only a rather vague picture of its utilisation. The OTP was therefore designed to include experiments defined by the Conference of European Postal and Telecommunications Administrations (CEPT). New communications applications were foreseen to capitalise on the benefits of communication via space.

Among the new payload technologies to be verified by OTS for utilisation on ECS were:

- higher frequencies not interfering with terrestrial networks: 11 GHz for the downlink, 14 GHz for the uplink
- digital transmission techniques
- multiple access by Earth stations on a time-division basis
- reuse of the radio-frequency spectrum by dual-polarisation, while keeping atmospheric effects within acceptable limits.

The payload and spacecraft design was further influenced by the need to keep the cost for the large number (about 30) of earth stations low. Another ground-station requirement defined in the interest of achieving cost savings for smaller earth stations and which affected the design of OTS and finally also that of ECS, was the

Figure 1 – The ESA Orbital Test Satellite (OTS)



absence of satellite autotracking by the ground antennas. North–South Station-Keeping (NSSK) had therefore to be carried out by the satellite.

The size of the payload and the satellite was determined by both the pre-operational needs of OTS, related to the final ECS system, and the availability of launch vehicles at that time. The final result was the provision of six payload channels on OTS, two of which could be kept operational during eclipses. The initial design of OTS was based on use of the Thor-Delta 2914 launch vehicle. When the more powerful 3914 version finally became available, the extra mass capability was used mainly to increase the redundancy in the payload and to provide more fuel for NSSK.

Provision of sufficient redundancy was one of the major design criteria. This, together with the use in some cases of alternative technology for redundant equipment, gave additional insurance against the unknowns of designs that had not yet been flight-qualified.

A second major design criterion that contributed to the success of OTS was the built-in operational flexibility and capability for in-orbit adjustment of drive parameters. Automatic corrections for failures that might otherwise lead to loss of the mission were also implemented. All onboard automatic functions could, however, be overriden by telecommand from the ground.

A third feature in the approach to OTS was the thorough qualification and functional test programme implemented to rule out as many weaknesses as possible prior to launch.

Finally, a fourth major design feature of OTS was its conceptual growth capability. This led, for example, to the selection of a three-axis-stabilised platform with deployed Sun-tracking solar arrays.

In order for OTS to pave the way for the ECS system, most of its key technology had to be developed in Europe. A Supporting Technology Programme (STP) in the early 1970s was hence a major step for pioneering the necessary communications-satellite technology, and for strengthening European space industry's position in the international market.

It was based on the technological development and in-orbit demonstration of OTS that the more powerful and commercially operated ECS could be realised. Its platform also served, in turn, to implement Marecs successfully.

In-orbit experience with OTS

All basic objectives of the OTP originally scheduled could be accomplished within a three-year period after launch, thereby confirming the ongoing design for ECS. It was subsequently decided to extend the payload operations well beyond this period in order to continue the pre-operational service via OTS for Interim Eutelsat until the first satellite of the ECS series became available at the end of 1983.

Beyond this date of payload utilisation, further technology experience could be gathered in an End-of-Service (EOS) Test Programme carried out early in 1984. These EOS tests had not been carried out during the operational phase of OTS

Figure 2 — A typical earth station used in the appraisal of OTS's performance. The antenna was mounted on the roof of a building at the Royal Aircraft Establishment at Farnborough (UK). The right-hand photograph shows the supporting electronics cabinet

because they might either have caused a service outage, or presented a major risk in terms of loss of the spacecraft.

During the subsequent hibernation phase, additional lifetime data are being collected to study the continuation of performance trends. The satellite is also kept available for other technology investigations, in particular for the attitude-control subsystem.

OTS has delivered a wealth of information and provided a considerable service to the users, which has been assessed continuously and reported regularly in yearly performance reports. So far six 'In-Orbit Reports' have been published, and a seventh is in preparation. What follows is a short summary of the major results gathered during the seven years of OTS's in-orbit operation and the lessons learnt that have benefitted subsequent related missions, and ECS/Marecs in particular.

Usage

When OTS reached geostationary orbit, a series of tests were conducted from the ground to measure the payload's performance in detail. These tests provided comprehensive information concerning the short- and medium-term radio-frequency performance of the satellite.

The measured performance of the payload was well in excess of specification in nearly all respects, both in the short term and throughout the satellite's lifetime. The measurements were conducted using earth stations constructed by the Agency at Fucino in Italy (in cooperation with Telespazio), ESTEC (The Netherlands), Stockholm (Sweden), Dublin (Ireland), Villafranca (Spain) and Milo (Sicily) (Fig. 2).

One of the principal utilisation-oriented roles of OTS was to provide the means for the scientific community to study the propagation of radio waves in the 14 and 11 GHz frequency bands. This was particularly important at the time of the satellite's inception as these frequency bands had not previously been used for satellite communications either in Europe or elsewhere. The results could be applied later to assist in the system design of ECS and other European satellite systems.

Many technical institutes and universities throughout Europe participated in the propagation measurements, using small earth stations to measure beacon signals emitted from the satellite itself and those passed through the satellite transponders from ground transmissions. The satellite provided the possibility to compile statistical data on fading in both the 14 and 11 GHz frequency bands. Also, due to the high cross-polar isolation of the OTS dual-polarised antennas, experimenters have been able to compile and analyse information on the cross-polar isolation of the atmosphere over a period of years.

Wide-band propagation experiments to

Figure 3 – Coverage footprints of OTS's Eurobeam and Spot-beam antennas

investigate the bandwidth-related dispersion of the atmosphere were also conducted by some of the larger earth stations, principally Fucino and Goonhilly.

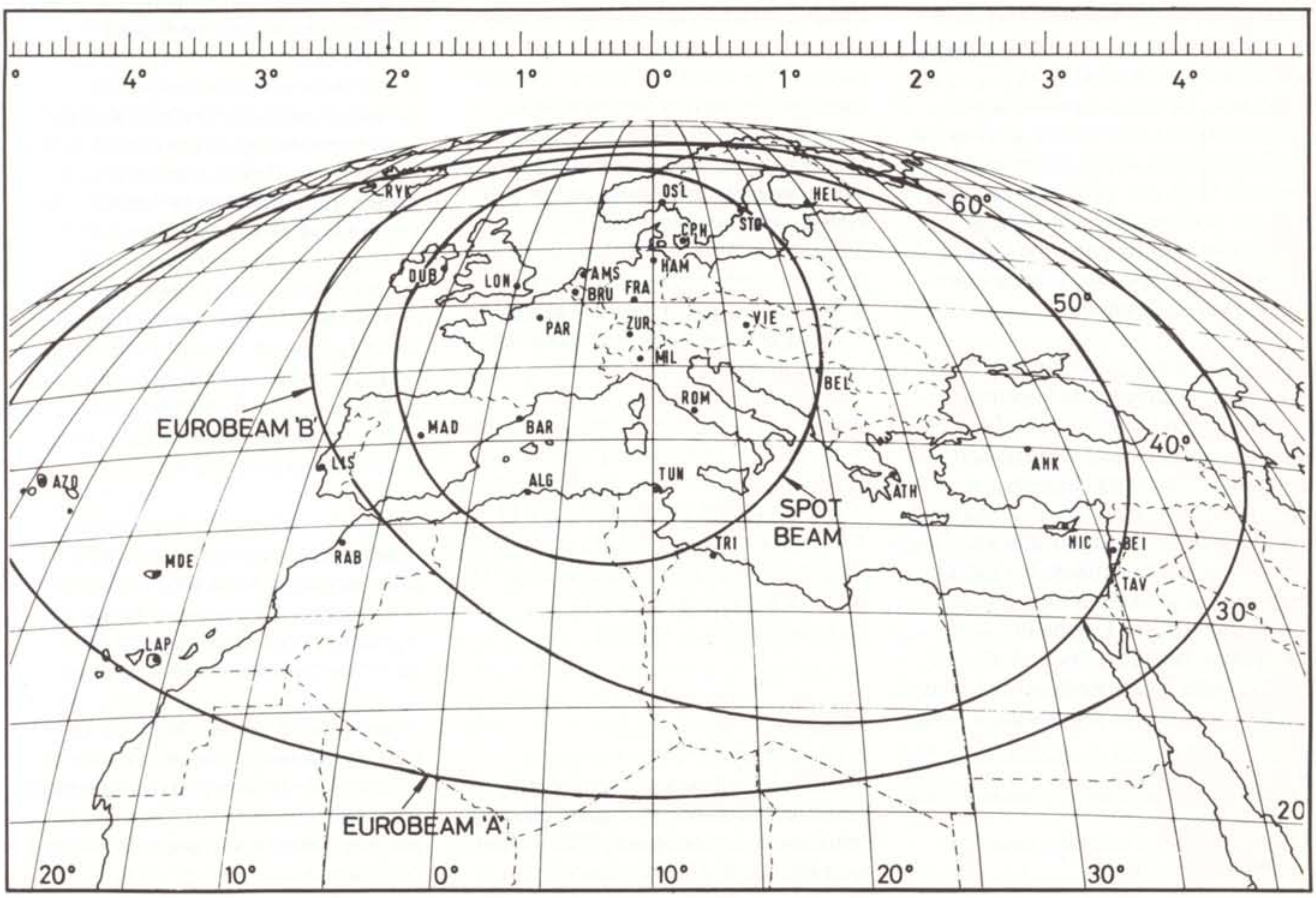
An important element of the OTS utilisation programme was to develop and test the Time Division Multiple Access (TDMA) system, which would be used later in the operational ECS network for telephony traffic. The TDMA system was to be based on 60 Mbit/s and 120 Mbit/s digital transmission and employed the larger (approx. 15 m diameter) earth stations of the PTT Administrations.

Early experiments were aimed at measuring the earth-station–satellite–earth-station loop using high-speed digital modulation at 120 Mbit/s and 60 Mbit/s. Later tests involved a number of earth stations in TDMA mode, and still later tests employed full telephony systems with trial public use of the satellite via the European telephony network. All of this work was carried out in co-operation with ESA by the European telecommunications administrations. The earth stations involved were at Fucino (Italy), Bercenay-en-Othe (France), Goonhilly (Great Britain) and Usingen (Germany).

OTS's Eurobeam antennas were designed to provide coverage for all of the member states of the European Broadcasting Union (Fig. 3). In addition to Central Europe, the footprint covers Eastern Europe, Northern Africa, the Atlantic Islands, Iceland and the whole of Scandinavia. It was always envisaged that the European Communications Satellite (ECS) system, when established, would permit the free and flexible exchange of television programmes between countries. In particular, it was planned to replace the Eurovision system of the European Broadcasting Union (EBU), which was based on terrestrial microwave links, by a satellite system. OTS provided the necessary transponders and coverage to enable the satellite system to be prepared.

The earth stations at Bercenay, Fucino, Goonhilly and Usingen took part in analogue and digital television transmission tests through OTS, which started in November 1978. The test procedures were defined jointly by the EBU, ESA and the CEPT. The results were very satisfactory and led to the establishment of end-to-end technical standards, which were later applied to the ECS operational system.

Television distribution to cable-head receiving stations became an increasingly



important part of the OTS utilisation programme throughout the life of the satellite. The spot-beam coverage of the 120 MHz wide transponders (Fig. 3) and the available satellite power produced a high-quality television picture when received in a bandwidth of 36 MHz by a 3 m-diameter earth station. Such earth stations are relatively inexpensive and require no tracking because of their reasonably wide beamwidth (0.6°). A number of programme-distribution companies obtained permission to run pilot TV-distribution networks on OTS which later generated significant demand for ECS satellite channels.

During OTS's lifetime hundreds of news events were relayed to national and international television networks via the satellite. Small transportable earth stations were employed which transmitted the pictures of the event and its commentary to the satellites. The major earth stations were also able to receive downlink signals from OTS for distribution. All of these events, which included World Cup football, visits by the Pope, financial summits, meetings of Heads of State, etc., demonstrated the ability of satellites to provide flexible coverage of world events, and have led to the more established techniques now in use with the ECS system.

In the later phases of the life of OTS, the importance of digital data transmission for business and scientific uses became apparent. This mode of transmission was particularly interesting because it highlighted the possibilities of using small, relatively inexpensive earth stations close to or at the user's premises. The initial experimental networks were promoted and financed by the European Commission and ESA. The first of these was the Stella* experiment, which linked together high-energy physics laboratories in Europe and enabled scientists to control and obtain results from experiments carried out at remote facilities. A similar experimental network known as Spine* enabled remote-sensing data to be exchanged online between interested institutions in Europe via the satellite. The transmission speed was 2 Mbit/s and the data throughput 1 Mbit/s for both experiments. These network experiments were followed by other business-oriented experiments, including the European Video-conference Experiment (EVE) conducted by Eutelsat signatories between France, Germany, Italy and the United Kingdom. The success of these experiments led to the decision to include a business-services repeater package with two orthogonal channels on the second and subsequent flight models of ECS.

In all the fields of satellite communications, OTS has acted as a means to experiment with and establish new services. The telephony system, the EBU television exchanges, the television-programme distribution, the outside-broadcast links, and the business services which are now operational on the ECS system, owe much to the OTS programme. Also, many of the earth-station designs and related equipment developed for OTS have been at least partly applicable to the operational ECS system.

Lastly, and perhaps most importantly in the European multinational environment, the cooperation developed between the Agency, Eutelsat and the various PTT Administrations in the course of the OTS Utilisation Programme has created a firm basis for the future of satellite communications in general.

Results

In the interests of further improving reliability for subsequent commercial missions, the detection of some payload-hardware shortcomings by OTS proved extremely useful. These included:

- the short lifetime of one travelling-wave tube (TWT), traced to improper potting material, resulting in improvements on ECS
- lifetime limits experienced with some electronic power conditioners for TWTs, allowing design corrections for ECS
- self-switch-off of some TWT amplifiers, leading to the incorporation of automatic restart devices on ECS.

During the End-of-Service (EOS) tests, it was demonstrated that most performance parameters were not significantly affected by the nearly six years spent in orbit by the payload.

Systems concept

– Redundancy philosophy: Benefiting from the foreseen redundancy concept, it was always possible to maintain, or return the spacecraft to, operational status when various unexpected events were experienced. The fact that functional redundancy was provided proved extremely useful in some critical devices. The characteristics of the various design concepts could be compared and, where necessary, corrections for future designs implemented. The value of this has already been demonstrated by the successful operation of four commercial spacecraft for Eutelsat and Inmarsat. Similarly, the performances of the ECS and Marecs spacecraft are continually assessed by ESA to identify further improvements, where necessary, for models still to be launched.

– Operational flexibility: The freedom to adapt certain parameters proved to be extremely useful for coping with early unknowns and unexpected behaviours, e.g. battery control, power-transfer-assembly drive and thruster settings.

– Automatic onboard correction: The extensive protection system for coping with possible failures that could endanger the mission proved very successful for attitude-control and power-conditioning protection.

* Stella = Satellite Transmission Experiment Linking LAboratories
Spine = SPacecraft Information Network Experiments

– Conservative margins for expendables or degradation effects: The conservative margins employed for solar-array, battery, and component degradation due to irradiation proved useful and allowed some refinement for later missions.

– Trade-off of flexibility versus complexity of operation: It has been shown that the choice of automatic functions and protections, all of which can be inhibited from the ground, was essentially correct. The basic techniques of quick attitude recovery have been demonstrated on OTS as part of the EOS test programme, and are being studied further for possible use on ECS and Marecs spacecraft.

Attitude and orbit control
– Alternative attitude control: 'Smooth' attitude control through solar sailing was exploited successfully following the main operational period of OTS. This concept has been adopted in a modified form for the Eurostar satellite by Satcom International.

– Plume impingement: Windmill torques were experienced due to the impingement of the yaw thrusters on the solar panels. Corrective actions have been identified, such as breaking manoeuvres into smaller increments, timing them for favourable array positions, or automatic correction of disturbance torques (as implemented on ECS).

– Pointing: To cope with disturbing effects as a result of the varying IR radiation profile with season or meteorological events, the OTS sensor designs have been improved by narrowing the IR band detected for later satellites.

Reaction control
– Disturbance torque during NSSK: Because gas is generated inside the reaction-control system, venting of thrusters by priming prior to a manoeuvre is now a standard procedure.

– Lifetimes of thrusters: The catalyst used in thrusters can become contaminated. This has led to the use of additional thruster redundancy on ECS. Alternatives would be the use of all-metal tanks or larger thrusters.

– Thruster leaks: A temporary leak from a thruster on OTS, presumably due to blocking particles, has led to filtering and cleanliness improvements on subsequent programmes.

Thermal control
– Temperature rise: A higher than expected temperature rise on OTS, probably caused by unforeseen contamination of radiators, has led to improvements on subsequent spacecraft. Their design has also been adapted to a higher final absorptivity. The accuracy of thermal predictions has been improved.

Power generation and control
– Solar-generator degradation: The natural reduction in generator power with time in orbit proved to be considerably lower than assumed nominally. The radiation dose inside the spacecraft, observed by a dedicated experiment monitoring radiation damage to semiconductors, was also lower than expected.

– Solar-generator insulation: It appears that in the presence of long-term additional stresses (e.g. electrostatic discharges), the strength of the insulation between solar cells and the solar panels needs to be improved.

– Battery performance: After close to six years in orbit, the battery shows no degradation in capacity, which is thought to be a benefit of the battery-management technique employed (e.g. no overcharging, but regular reconditioning, and trickle charging) and the moderate depth of discharge (42% of actual capacity).

Conclusion
OTS and its associated Orbital Test Programme have successfully paved the way for the operational system of European Communications Satellites (ECS) for Eutelsat. The ECS platform design was also adapted for the implementation of the Marecs system now used by Inmarsat. Other European telecommunications satellites have also been derived from the basic OTS/ECS technology and experience, such as Telecom-1, Skynet-IV, Eurostar and DFS.

The assessment of the in-orbit behaviour of ESA's telecommunications satellites has therefore led and is continuing to lead to improvements in performance, to the benefit of satellites soon to be launched, now in development or yet to be designed. In this way, considerable expertise has been developed in Europe, both within ESA itself and in industry. A major benefit is the strengthening of the position of European space industry vis-a-vis the international competition.

Current Difficulties of Buying Insurance for Space Ventures

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There is presently a certain inability to assess the financial risks of space ventures in view of the relatively small number of launches and the rapidly changing technology. The situation is further complicated by past failures and the resulting accumulated losses. Improved cooperation and understanding between underwriters and customers is therefore required to overcome the current difficulties. Underwriters need to provide greater transparency and clarity in their rate structures so that the client can ascertain precisely what he is paying for. On the other hand, the purchaser must also provide the technological information that will help to restore confidence in underwriting circles. As in the past, the Agency will continue to make its contribution in this respect.

The past

For a relatively long period between 1964 and 1975 ESA's predecessor organisations, ESRO and ELDO, followed the basic government concept of self-insurance, which has the advantage of being cheap. The programmes at that time, had a purely scientific or experimental orientation and there was, moreover, no readily available space insurance market. Consequently, the question of whether or not to take out insurance never arose.

In 1975 a drastic change occurred, brought about or rather imposed by NASA, which at that time changed its policy regarding launch-service agreements. In the 1960s these agreements had not held the customer liable for third-party indemnification. By 1975 , however, NASA felt that the US taxpayer could no longer bear this risk. After long negotiations, a compromise was reached requiring ESA to take out third-party-liability insurance for an amount of $100 million per launch. This was how the Agency came to be involved with the insurance market and with the brokers, who immediately began a marketing effort to promote satellite launch insurance. At about the same time the Geos launch failure occurred and the disadvantages of the 'self-insurance approach' were highlighted by the funding difficulties encountered by certain governments for the replacement satellite. In this context it should also be mentioned that, at a later stage, the Agency entered into agreements with well-defined obligations towards other entitites such as Inmarsat and Eutelsat. If Member States did not have the flexibility to increase budgets as required in the case of failures, the only other solution was to take out insurance for the related risks. The limitations of the self-insurance approach and the lack of funds on the part of certain governments to cover possible failures therefore made commercial insurance a necessity.

Following the advice of its brokers, ESA insured its Orbital Test Satellite (OTS). It so happened that this first insured launch ended in the Atlantic, as the American rocket exploded after lift-off. This was the first experience for underwriters of ESA as a client and our Delegations very much appreciated their first experience of space insurance. To some extent the $29 million involved served a publicity and marketing purpose, because some Delegations who had earlier been opposed to insurance were thereby convinced of its merits.

Since then ESA has taken insurance cover for a total of nine satellites, at rates that were deemed reasonable; around 7–9% of the insured sum for US launches and 10–13% for the first Ariane flights.

In 1982 ESA lost a Marecs-B satellite, which was insured for $20 million, bringing the total compensation from insurance to $49 million, against premiums totalling far below this sum at that time.

The principle of taking out insurance is favoured by ESA whenever a failure could prejudice the completion of an on-going programme or, more importantly, if a guaranteed service to another entity, i.e. a

Figure 1 – Failure of the American Thor-Delta launcher shortly after lift-off in September 1977, which destroyed OTS-1

customer, could be jeopardised. On the other hand, scientific missions are not insured, the argument being that they are unique opportunities that cannot be repeated, and therefore a replacement would make no sense. Looking at it from a purely budgetary point of view, one can of course conclude otherwise.

The aim of the 'policy making' in the past has been to achieve appropriate protection at a minimum cost. Consequently, great emphasis has been placed on low rates, even if this led in some cases to difficulties in completing the placing and achieving the required coverage. Cost reductions have also been obtained by taking partial cover or a second-failure cover only. Partial cover has been used in particular when another spare satellite was available, for example in the case of Meteosat, so that only the costs of another launch were insured. Second-failure insurance has also been used when there was another spare available and/or the failure could be absorbed by the space-segment system. However, this concept leaves the customer without cover if the first flight is a success and one might have to review the situation and subscribe to another policy thereafter, as was done in the case of Marecs. After the launch of Marecs-A, Marecs-B was no longer covered under the second-failure scheme and was therefore, fortunately, insured under a separate policy. All in all, the implementation of such formulae with the aim of reducing costs whilst maintaining appropriate protection requires a certain vigilance on the part of the customer.

As the Agency, based on past experience, intends to insure other satellites and launches in the future, it is closely following the development of the market.

Current developments

There are three areas of concern associated with current developments; these relate to:

- policy wording
- rates
- reactions of underwriters.

Policy wording

In the past the drawing up of the policy wording was a routine matter. In essence a sum insured was agreed upon, a failure definition in accordance with the appropriate technical criteria was established, and this was surrounded by some routine legal wording. The wording did not seem to require special attention, payments being made quickly after a failure.

However, as the market situation became less favourable, the wording became subject to unilateral modification by underwriters trying to reduce their responsibilities. As a typical example, ESA had earlier succeeded in excluding any rights of subrogation against Agency subcontractors, irrespective of any possible gross negligence on their part. This was an important point because it meant that the insurance covered our subcontractors without reservation, releasing them from placing certain product-liability insurances. Underwriters subsequently withdrew this provision, claiming that they needed to be entitled to subrogation since ESA had itself the possibility of recourse against subcontractors in the event of gross negligence in accordance with ESA's

Common Conditions. The latter is true, but it is significant that this attitude on the side of the insurers only emerged once the market became more difficult.

Another example is that for placings made subject to 'the agreement of the draft wording' – normally to be accepted as a matter of routine – underwriters took advantage of the existing Lloyd's procedure to withdraw from the initial subscription at a very late stage prior to launch. Such a withdrawal for reasons other than the policy wording is an abuse of the Lloyd's system. The only means of guarding against this in the future is to reach agreement on the draft policy wording from the outset and to make the initial placing on this basis. Such policy standardisation would inspire more confidence on the part of the customer in the amount of placing achieved, and provide better protection against last-minute surprises.

In the light of the above experiences, there is concern about policy wording in the future. For example, it has been suggested that 'agreed' value policies will no longer be issued, with payment being made only on a proved-loss basis. This is unacceptable for the Agency. It is inconceivable that the sum of the indemnification be established, if not negotiated, after the event. This would lead to long disputes about the actual extent of the damage. It is felt that for a fixed-premium policy, a related fixed sum should become due in the case of a failure. The salvage and subrogation clauses of the policy should give underwriters sufficient protection against any 'overpayment'.

It has also been announced that in future spacecraft 'life' insurances will be valid for one-year periods only. Even if one can understand this philosophy to a certain extent, the meaning of life insurance in the sense of cover for the design lifetime of a satellite is substantially undermined if such cover is terminated on an annual basis and reactivated only under certain conditions, as determined by the underwriters. Moreover, the situation is aggravated by the fact that underwriters want to decide at a rather late stage whether or not to extend. This further reduces the meaning of life insurance and gives underwriters an escape should there be the slightest deficiency. A certain minimum lead time for these extensions is needed for administration purposes, it being unacceptable for a customer to learn at the last minute whether or not the extension will be 'granted'.

Rates

An important and often decisive element in the buying of insurance is price: a low rate encourages the decision to insure, whilst a high rate might lead to a calling into question of the usefulness of taking out insurance. The rate is a major preoccupation of both the client and the insurer.

In the past customers rarely criticised rates. Although not being in a position to understand how they were calculated by underwriters, they appeared to be reasonable compared with the assessment of launch-failure statistics. This was most probably due to competition among brokers and underwriters. ESA, therefore, considered it advantageous to insure for a number of launches.

Now the situation has changed. There is concern that rates will reach a level where it becomes more and more doubtful whether it is meaningful to insure at all. For these rates no detailed breakdown or justification is given, other than the much repeated references to past losses suffered by the market. This is not sufficient to make a potential customer accept a price level that he considers unrealistic.

Moreover, the rates applicable for future exposures are not readily available because of the underwriters' new tendency to make quotations as late as possible prior to launch. This means that the customer wishing to establish the cost for future insurance is left entirely at the mercy of market developments. Against this background of uncertainty, the potential buyer may obtain some preliminary information through the brokers which is not binding and subject

Figure 2 — Leading underwriter of the Ariel syndicate, Mr. E. Simms (left), discussing the 'right' rate with two prominent brokers, Mr. A. Pinsent (centre), Chairman of Leslie and Godwin Aviation Ltd., and Mr. C. Cook (right), Director, C.T. Bowring Ltd.

Figure 3 — Launch of the first Ariane-3 vehicle from Kourou on 4 August 1984, carrying two telecommunications satellites, ECS-2 and Telecom-1A, safely into orbit

to endorsement by the market at a later stage. This is a totally unsatisfactory situation for the buyers, who are confronted with a market that lacks transparency and reliability and which, in this sense, no longer fulfils its function.

Against this background, it is refreshing to note the initiative of one broker to create a self-insurance pool, grouping together a certain number of clients, for first-failure losses, and insuring the second failure only at a reduced rate compared with the regular market. Whether such a scheme works out or not, it certainly has the merit of trying to combat the current lethargy in the market and in this respect deserves credit.

Arianespace has also made known their dissatisfaction with the insurance market. They claim that the present rates do not represent a realistic analysis of the different risks presented by different launch vehicles and satellites, and that they have been unfairly penalised by the compensation of losses resulting from sources other than Ariane.

Underwriters

If the situation is unsatisfactory, the culprits from a buyer's point of view have to be the underwriters.

With hindsight it is obvious that rates were too low in the past. Not that they should have been at the current level, but it was a mistake to accept rates that were based solely on projected probabilities of failures without any contingency, and this for a relatively small series of launches.

With no statistical compensation over a large number of launches, these losses are largely the result of bad luck. Certain rates, i.e. launch rates of 6.5% and life rates of 1.25%, could have been higher. This would have reduced the currently accumulated losses and improved the present critical situation from which underwriters are now attempting to recover much too quickly.

The present difficulties cannot be overcome by additional over-detailed technical analysis alone. Such analysis is needed to arrive at a basic understanding of the technical functioning, but how can an outside expert, good as he may be, know more than a reputable manufacturer about possible deficiencies. This type of exercise may well lead to a rate that the underwriter feels is correct, but which will not necessarily be accepted by the market.

Some underwriters currently appear to be withdrawing from the market while the others request higher premiums. What should be pursued is a reassessment of the future on a realistically commercial basis. To improve relations with the customer, a breakdown and clear explanation of the various elements of the rates is needed, e.g. technical risk, commercial contingency, recovery of past losses, etc. However, no such proposals have been made so far, and this is proving a severe handicap for those currently planning to buy insurance for future projects. A marketing effort to clarify the present rate structure and to overcome the current uncertainty is required on the underwriting side.

Conclusions

It appears that for the near future customers will have to get used to a rate of 15–20% of insured sum for launch insurance. Should there be any further failures, the current imperfections of the market will become even more pronounced, the first repercussion probably being a further reduction in capacity. It is not felt that rates could increase beyond 20% because such rates would be unsaleable, causing alternative solutions to be sought (a return to self-insurance, government intervention, etc.). On the other hand, it is to be hoped that, provided further failure payouts remain limited, the market will re-stabilise at a rate of 10–15%, with additional insurance capacity being made available

'Weightless Space' as a Laboratory: The Spacelab D1 Mission

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'Gravity – No thank you!' or, expressed in the affirmative, 'Microgravity – Yes please!', may be taken as the motive for most of the more than 70 experiments planned for flight onboard the German Spacelab D1 mission in October this year. According to present planning, the Space Shuttle and its passenger Spacelab will be launched on 30 October from Kennedy Space Center in Florida. They will orbit the Earth for 7 days before landing again at Edwards Airforce Base in California. Approximately three hours after the launch the astronauts will float into Spacelab to activate the experiment equipment and begin their work.

The D1 mission has been financed by the German Ministry of Research and Technology in Bonn and is an all-German project. The Shuttle's flight will be controlled by NASA from the Houston Mission Control Center. The experiment equipment aboard Spacelab will be controlled from the German Operations Control Center (GSOC) at Oberpfaffenhofen.

The retrieval and re-use philosophy that led to the development of Spacelab has been described numerous times before (see for example ESA Bulletin No. 36, pp. 6–11). Figure 1, however, serves as a reminder of the concept's application for scientific missions.

For Spacelab's operation, the mission and payload specialists work to a strict schedule, which lays down the sequence of experiment activities in great detail. They will work in two shifts, the 'blue' and the 'red', and whilst one shift works the other will rest. A team of project coordinators and scientists will be available at GSOC to provide help in carrying out the experiments onboard the orbiting laboratory.

With the help of data relayed from Spacelab to GSOC, the scientists will in some cases be able to gauge immediately how well their experiments are functioning. There will therefore be a possibility for communicating real-time

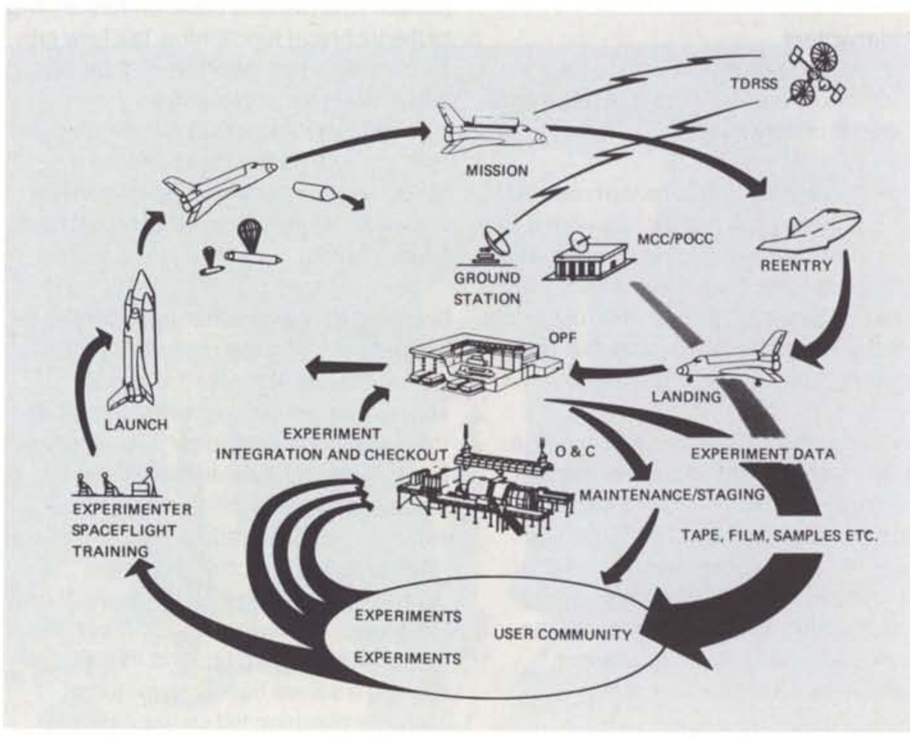


Figure 1 – Shuttle/Spacelab operating cycle

MCC/POCC = Mission Control Centre/Payload Operations Control Centre
OPF = Orbiter Processing Facility
O&C = Operations and Checkout
TDRSS = Tracking and Data Relay Satellite System

Figure 2 – The tracking and data-relay network for the Spacelab D1 mission

adjustments between GSOC and Spacelab. For communication between the Shuttle, NASA and GSOC, the network shown in Figure 2 is available.

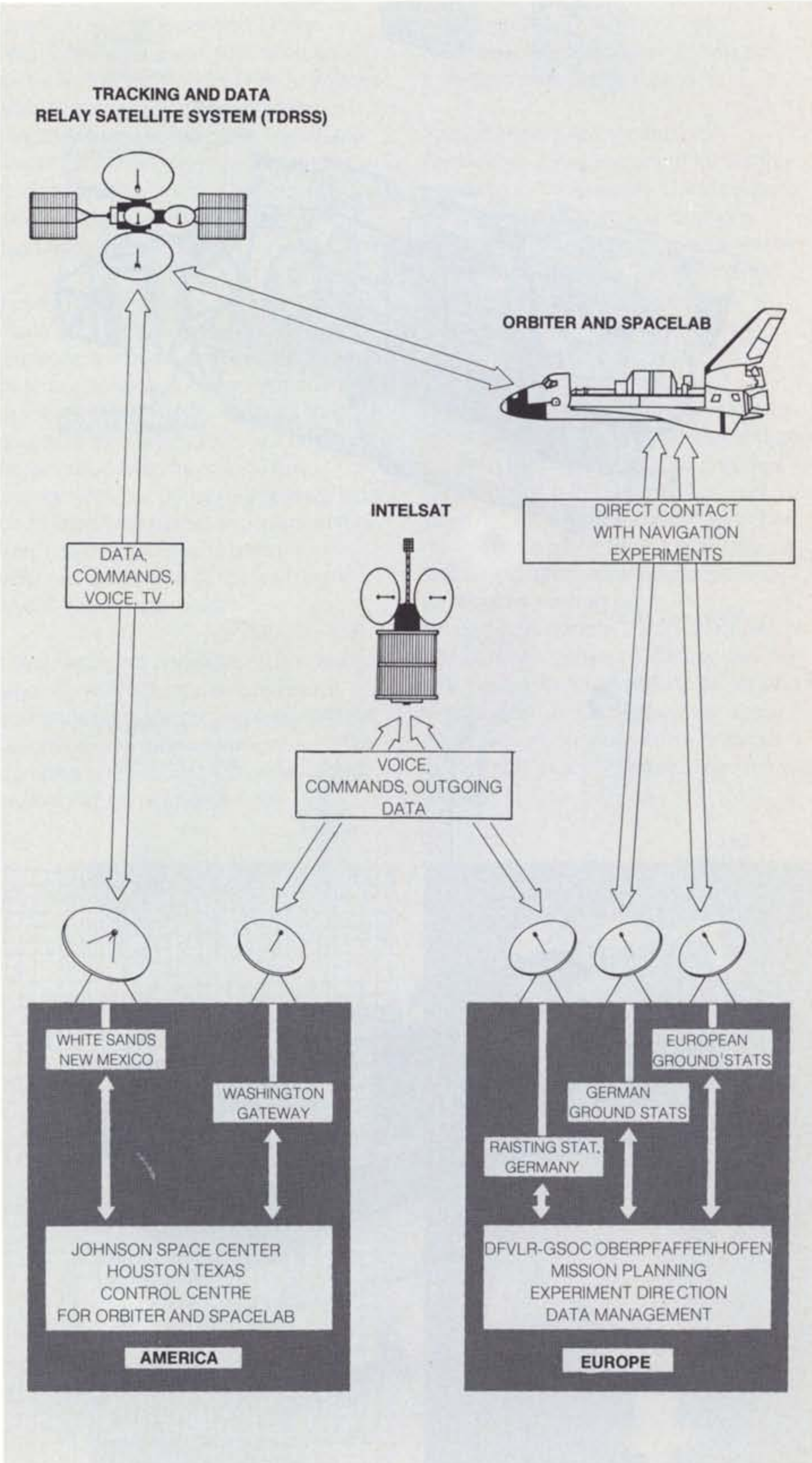
Upon Spacelab's return the experiment samples will be evaluated scientifically, with the help of the astronauts.

The D1 payload

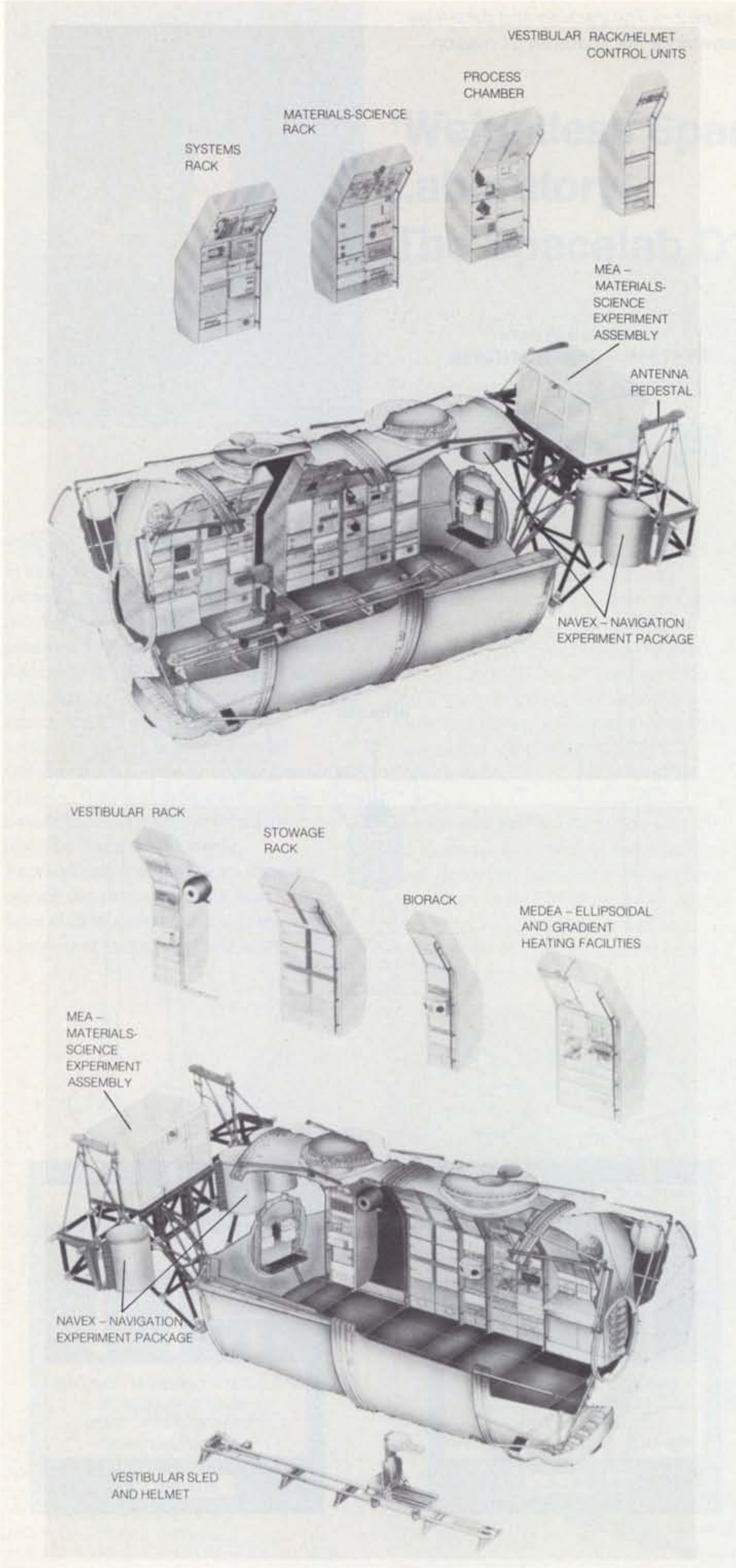
The so-called 'D1 payload' is made up of some seventy experiments from eight European countries and the USA. The experiments are housed in eight experiment facilities, six of which are provided by Germany and two by ESA. Most experiment facilities, those dedicated to materials and life sciences and those requiring manned intervention, are located inside the pressurised Spacelab Module. Other experiments are placed on a support structure behind the Spacelab Module in the Shuttle loading area.

The experiment facilities inside the Spacelab Module are accommodated in seven payload racks (Fig. 3), which can be broadly summarised as follows:

- The Materials-Science Double Rack (MSDR) contains experimental equipment for carrying out investigations in the fields of fluid physics, the solidification of metallic melts, and the growth of single crystals.
- The Process Chamber (PK) consists essentially of optical-diagnosis equipment and is intended for experiments covering both fluid physics and the solidification of transparent melts.
- Medea (MD)* contains payload elements for the melting and solidification of metallic and semi-conductor materials as well as a high-precision thermostat. This rack and its contents have been made specifically for the D1 mission and represent a sort of second-generation MSDR.



* A German acronym, which stands for 'Materials-Science Double Rack for Individual Experiments and Dedicated Apparatus'



Figures 3a,b – D1 payload configuration, with the long-module configuration providing room for five double and three single experiment racks

- Biorack (BR), contributed by ESA, is mainly intended for the investigation of cellular functions and developmental processes, i.e. biological experiments.
- The Vestibular Sled (VS) and its corresponding racks, provided by ESA, deliver the linear accelerations needed for investigation of the human vestibular organs (Fig. 4).
- A System Rack accommodates thermostated chambers both for botanic experiments and the cooling of furnaces in the other racks.

Other Spacelab racks being carried on the D1 mission provide storage space for experiment samples, etc. The experiment facilities outside the Spacelab Module are:
- The Materials Science Experiment Assembly (MEA), carrying five NASA experiments essentially made up of various furnaces and an acoustic positioning apparatus.
- Navex (NX), made up of cylindrical containers, with a caesium atomic clock and the necessary sender and receiver electronics (Fig. 10).

The research topics

The terms weightlessness and microgravity designate, more or less correctly, the fact that a mass orbiting the Earth can have no weight because the Earth's gravitational pull and the centrifugal force in that orbit compensate each other. Complete weightlessness cannot be achieved because the astronauts aboard move around, machines switch on and off, etc., causing small disturbances in the balance of forces. It has therefore become customary to talk of 'microgravity' rather than zero gravity.

The experiments that make up the Spacelab D1 mission have microgravity as their common denominator, implying that:
- there is no hydrostatic pressure in fluid (liquid and gaseous) media
- there is no natural convection
- there is neither particle sedimentation

nor buoyancy within liquids of differing density.

In turn, this requires that the Shuttle's orientation in orbit has to be such as to guarantee the lowest possible disturbances to the experiments.

Materials-science experiments

Fluid physics

The fluid-physics (also fluid mechanics) experiments on the D1 mission will address:

- capillarity
- interfacial fluid-flow
- diffusion, and
- critical-point phenomena.

Under the pull of gravity, liquid bridges formed by capillary action of the type shown in Figure 5 are deformed due to their weight sensitivity, resulting in a larger diameter at their lower end. Under microgravity, their shape is determined solely by surface stability criteria, and the liquid column becomes unstable if its height exceeds its diameter. The shape stability and oscillatory movements of such liquid columns are therefore of direct interest for crystal-growth technology.

Turning to the physics of interfacial flow, many questions remain open concerning Marangoni convection, which is caused by temperature and concentration gradients along liquid interfaces. In a ground-based laboratory it will normally be overshadowed by natural flow phenomena, but under microgravity it can be studied in its purest unperturbed form. Very high significance is being attached to this type of research by crystal-growth specialists.

Like Marangoni convection, diffusion is also normally affected by convective components in the ground-based laboratory. Under microgravity, a completely convectionless state may be realised which permits precise measurements of self- and inter-diffusional mass transport in metallic melts and nonmetallic liquids.

Precise knowledge of diffusion coefficients is very important for solving problems in, for example, solidification or the utilisation of chemical reactions involving fluids at high temperatures (i.e. salt melts as catalysts, salt electrolysis), and for various surface-treatment processes for metals, glasses and ceramics.

Critical-point phenomena play a role in processes involving fluids at the transition between their liquid and their gaseous states. Close to the critical point, very small density differences develop under the influence of the Earth's gravitational field which affect thermodynamic parameters such as pressure, temperature, density, specific heat, etc. In microgravity, there is no density layering and more accurate data can be obtained. Critical-point experiments are of direct practical consequence in, for example, energy conversion, chemical reactors and the like.

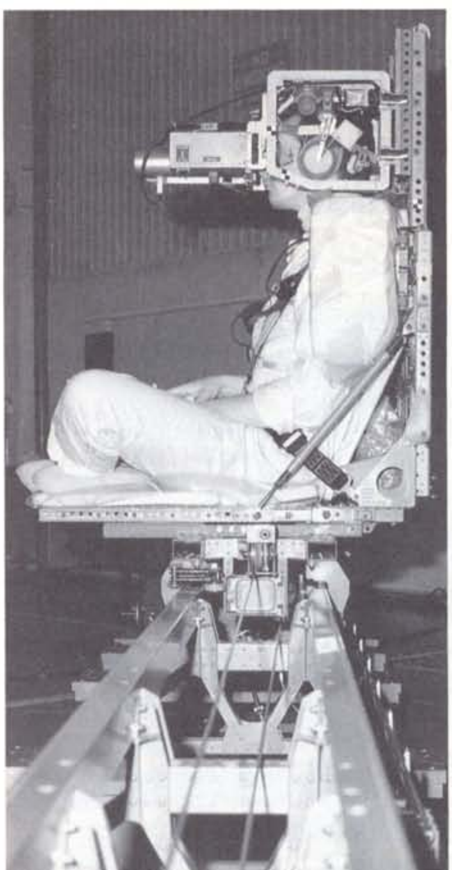
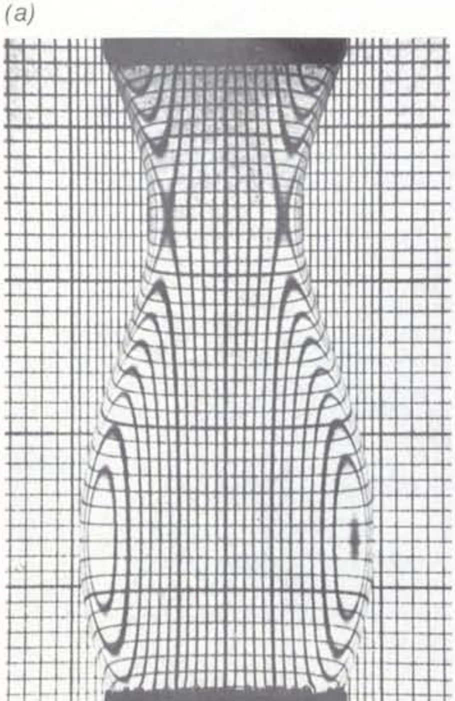


Figure 4 — The Vestibular Sled, and instrumented helmet, provided by ESA

(a)



(b)

Figure 5 — Columns of liquid provide interesting media for studying fluid-physics phenomena under normal- and micro-gravity.
(a) A silicon-oil column (80 mm long) immersed in a water-methanol mixture under normal gravity (1 g)
(b) A silicon-oil column (96 mm long) rotating (7 rpm) in microgravity during the first Spacelab mission (FSLP). (courtesy of I. da Riva & I. Martinez)

Fluid-physics experiments

Capillarity	Experimenter
Floating-Zone Hydrodynamics	I. Da Riva, Univ. Madrid, Spain
Capillary Experiments	J.F. Padday, Kodak Ltd., Harrow, UK
Forced Liquid Motions	J.P.B. Vreeburg, NLR, Amsterdam, Netherlands
Marangoni convection	
Surface-Tension Studies	D. Neuhaus, DFVLR, Cologne, Germany
Marangoni Convection	D. Schwabe, Univ. Giessen, Germany
Marangoni Flows	L. Napolitano, Univ. Naples, Italy
Marangoni Convection	A.A.H. Drinkenburg, Univ. Groningen, Netherlands
Convection in Nonisothermal Binary Mixtures	J.C. Legros, Univ. Brussels, Belgium
Bubble Transport	A. Bewersdorff, DFVLR, Cologne, Germany
Diffusion phenomena	
Self- and Inter-diffusion	H. Wever/G. Frohberg, TU Berlin, Germany
Thermal Diffusion	J. Dupuy, Univ. Lyon, France
Inter-diffusion	J. Richter, RWTH, Aachen, Germany
Homogeneity of Glasses	Chr. Frischat, TU Clausthal, Germany
Diffusion of Liquid Zinc and Lead	R.B. Pond, Marvalaud Inc., USA
Thermomigration of Cobalt in Tin	J.P. Praizey, CEN, Grenoble, France
Critical point	
Heat Capacity Near Critical Point	J. Straub, TU Munich, Germany
Phase Separation Near Critical Point	H. Klein, Cologne, Germany

Solidification experiments

Solidification front dynamics	Experimenter
GETS	A. Ecker/P.R. Sahm, RWTH Aachen, Germany
Aluminium/Copper Phase Boundary Diffusion	H.M. Tensi, TU Munich, Germany
Solidification Dynamics	S. Rex/P.R. Sahm, RWTH, Aachen, Germany
Dendritic Solidification of Aluminium-Copper Alloys	J.J. Favier/D. Camel, CEN, Grenoble, France
Cellular Morphology in Lead-Thallium Alloys	B. Billia/J. Favier, Univ. Marseille, France
Indium Antimonide-Nickel Antimonide Eutectics	G. Müller, Univ. Erlangen-Nuremburg, Germany
Containerless Melting of Glass	D.E. Day, Univ. Missouri-Rolla, USA
Solidification of Suspensions	J. Pötschke, Krupp, Essen, Germany
Particle Behaviour at Solidification Fronts	D. Langbein, Battelle-Institute, Frankfurt, Germany
Skin Technology	H. Sprenger, MAN Munich, Germany
Liquid Skin Casting of Cast Iron	H. Sprenger/I.H. Nieswaag, TH Delft, Netherlands
Solidification of Eutectic Alloys	Y. Malmejac, CEN, Grenoble, France
Solidification of Composite Materials	A. Deruyttere, Univ. Leuven, Belgium
Single-crystal growth	
Silicon-Crystal Growth by Floating Zone Technique	R. Nitsche, Univ. Freiburg, Germany
Melting of Silicon Sphere	H. Kölker, Wacker-Chemie, Munich, Germany
Doped Indium Antimonide and Gallium Indium Antimonide	C. Potard, CEN, Grenoble, France
Travelling Heater Method (GaSb)	K.W. Benz, Univ. Stuttgart, Germany
Travelling Heater Method (CdTe)	R. Nitsche, Univ. Freiburg, Germany
Travelling Heater Method (InP)	K.W. Benz, Univ. Stuttgart, Germany
Travelling Heater Method (PbSnTe)	M. Harr, Battelle-Institute, Frankfurt, Germany
Vapour Growth of Cadmium Telluride	R. Nitsche, Univ. Freiburg, Germany
Ge/GeI$_4$ Chemical Growth	J.C. Launay, Univ. Bordeaux, France
Ge-I$_2$ Vapour Phase	J.C. Launay, Univ. Bordeaux, France
Vapour Growth of Alloy-Type Crystal	H. Wiedemeier, Rens. Poly., Troy, USA
Semiconductor Materials	R.K. Crouch, NASA/Langley Research Center, USA
Protein Crystals	W. Littke, Univ. Freiburg, Germany
Composites	
Separation of Immiscible Alloys	H. Ahlborn, Univ. Hamburg, Germany
Separation of Immiscible Liquids	D. Langbein, Battelle-Institute, Frankfurt, Germany
Separation of Fluid Phases	R. Naehle, DFVLR, Cologne, Germany
Liquid Phase Miscibility Gap Materials	H.S. Gelles, Columbus, USA
Ostwald Ripening	H. Fischmeister, MPI, Stuttgart, Germany

Solidification
In the solidification experiments, the transition from liquid to solid, including the interaction of discrete particles with the solidification (growth or crystallisation) front, is to be studied. A good example of the intricacies of solidification in every-day life are the 'ice-flowers' formed on window panes in winter. The following questions arise:

- Where does the solidification start? In other words, from which points do the ice-flowers start growing? (A question of nucleation.)
- Why do the 'ice-flowers' develop such beautiful shapes? (A question of solidification-front dynamics.)

Locally differentiated cooling of the water leads to an inhomogeneous distribution of densities. Local density gradients cause natural convection. Under microgravity conditions, however, no natural convection will be encountered. This will allow the solidification process of numerous materials to be monitored under conditions of purely diffusive heat and mass transport and the basic laws of solidification to be tested against existing hypotheses and theories.

The solidification experiments planned for the D1 mission fall into three categories: solidification-front dynamics, single-crystal growth, and composite materials.

The solidification-front-dynamics category is concerned with the laws that govern the shaping of solidification fronts. Of special interest are the transitions between the individual types, and the general question that remains to be answered in all cases is to what extent stability criteria are affected by convection in close proximity to the solidification front.

Single-crystal growth may be described as a well-controlled solidification process. It is of great significance in the manufacture of semiconductor materials. Highly pure melts doped with small amounts of 'impurities', which give the semiconductor its electronic character, will be grown during the D1 mission using three different processes (melt growth, solution growth, and growth from the gas phase). The common objective is to produce homogeneously doped semiconductor materials for electronic and electro-optic applications (Fig. 6).

The D1 experiments concerned with composite materials are aimed at making dispersion-hardened materials directly from the melt, and thus possibly arriving at new types of alloys. A key question is 'Under what conditions are finely dispersed solid particles engulfed by the solidification front or else pushed ahead?' The answer to this question cannot be unequivocally established under normal gravitational conditions because particles are moved around unpredictably due to thermo-solutal micro-convection.

It would be particularly interesting if very fine particles could be homogeneously dispersed in a metallic single crystal to yield a new material with highly improved mechanical properties. The production of gas-turbine blades, for example, could profit from such knowledge (Fig. 7).

Life-science experiments
The second large block of experiments on the D1 mission belong to the biological and the medical disciplines. Distinction into different categories is more difficult than in the case of materials, but the biological experiments can be divided into those related to:

- cell functions
- developmental processes
- gravity perception by plants.

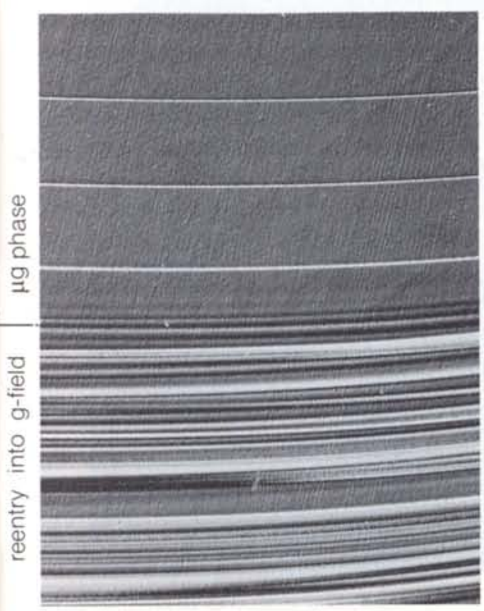


Figure 6 – Striations in single-crystal germanium have been shown to 'switch off' during microgravity-coasting (Texus rocket experiment). The remaining lines are artificial time markers (courtesy of H.V. Walter & J.J. Favier)

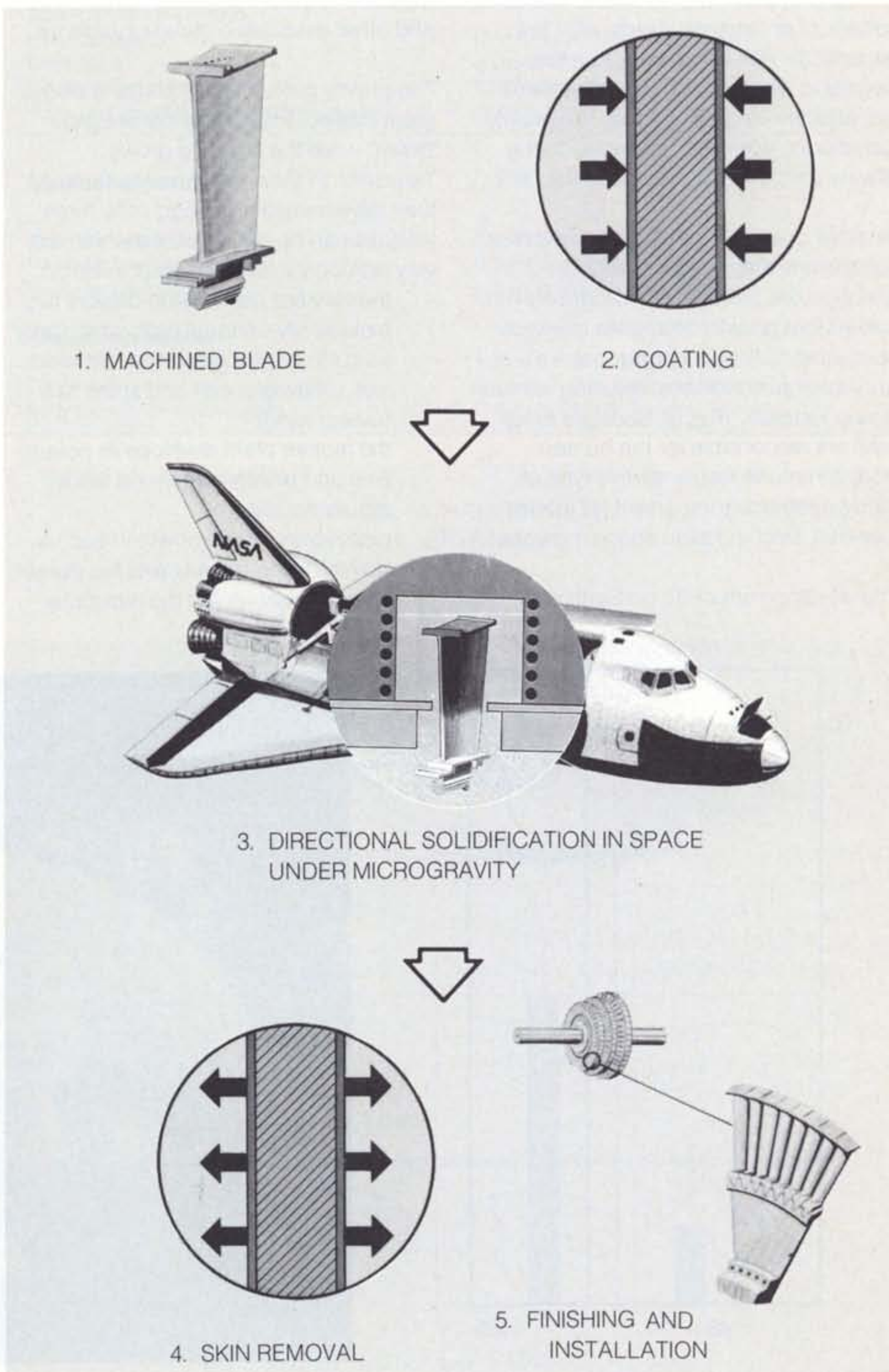


Figure 7 – Microgravity may make it possible to produce new types of strengthened super-alloy materials, for turbine blades for example, by employing advanced skin technology. Improvement of microstructure leads to increased strength, lifetime and temperature tolerance

Figure 8 – Human lymphocyte activity has been shown during the first Spacelab mission to be reduced by some 50% under microgravity (a); (b) shows a highly magnified lymphocyte particle (courtesy of A. Cogoli)

The cell-function experiments deal with gravity's influence on living cells and the effects of cosmic radiation. For example, circadian rhythm is to be investigated to study whether it is determined solely by the biological clock, or also by external time givers, such as gravitation, cosmic radiation, or magnetic fields. With few exceptions, little is known about the degree to which biological cell systems are affected by gravity. If they are gravity-dependent, where, for example, do the gravity-perceiving organs lie in the cell?

Another example from the area of cell functions is the growth kinetics of lymphocytes. Simulated microgravity has shown that growth decreases markedly compared to that under normal gravitational conditions, resulting in much slower reactivity (Fig. 8). Because these cells are responsible for the human body's immune response, this type of study is extremely important for future manned, long-duration space missions.

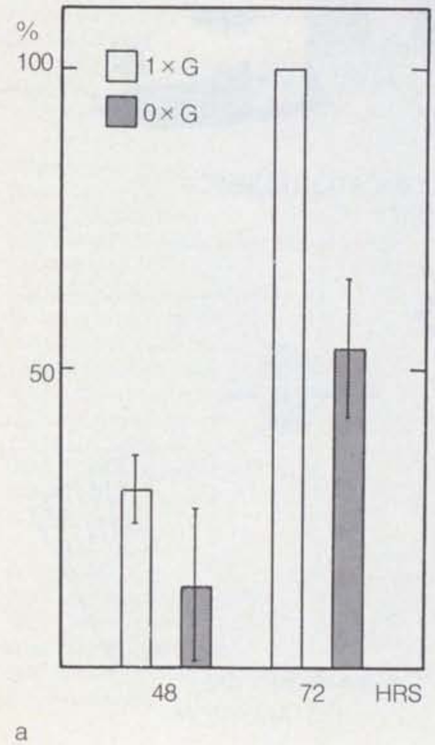
The development of life on Earth is necessarily influenced by gravity. One of the questions to be answered is to what extent gravity, cosmic radiation, or their combined action affect the development of the embryo. The experiments to be performed on fertilised frogs' eggs are expected to yield more insight into these and other associated genetic questions.

The gravity perception of plants is also of great interest. Plant roots always grow 'down', while the seedling grows 'upwards'. In the case of plants starting their development from egg cells, three features can be distinguished which are very probably influenced by gravitation:
- the very first cell division delivers two biologically unequal cells, which later yield the origins for the plant's root axis (underground) and spine axis (overground)
- the mother plant develops its polarity axis and gravity-perceiving tissue simultanously
- plants orient their growth in such a way that their polarity axis lies parallel to the gravity vector; the molecular mechanisms responsible for transforming the physical gravity signal into a physiological response are unknown.

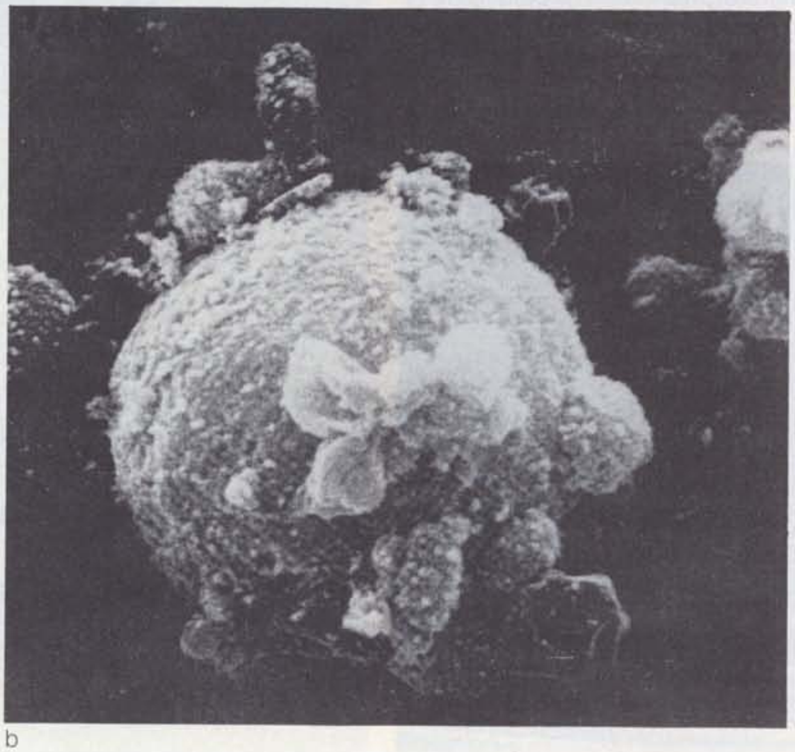
All three features will be investigated by experiments on the D1 mission.

The overriding question central to all medical experiments is: 'How does the human body adapt to microgravity, and is this adaptation reversible?' By answering this question, one may of course also learn what effect gravity has on the normal functioning of the human body.

Experiments carried out on earlier manned space flights have already provided some knowledge about the influence of gravitational forces, or more precisely the lack of them:
- astronauts 'grow' by approximately 3% in microgravity because no weight bears down on their spine;
- three quarters of all American astronauts have shown symptoms of so-called 'space-adaptation-syndrome', or space-sickness,



a



b

Figure 9 – The otolithic membrane reacts to acceleration forces and thus helps to adjust our balance; microgravity causes an irregular 'vestibular scenario'. If the eyes' information and that coming from the otoliths are not compatible, a 'visuo-vestibular conflict' arises (courtesy R. von Baumgarten)

because the balance organ in the inner ear is disturbed under microgravity;
- approximately two litres of blood are immediately transferred from the lower half to the upper half of the body under microgravity, because of the lack of hydrostatic pressure. The left chamber of the heart initially becomes enlarged, but reduces again in size after a while. Reductions in plasma and red-cell count lead to a 10 to 20% blood loss;
- bones lose calcium; after ten days under microgravity, the urine's calcium content is approximately 70–90% higher than normal and this calcium diminution process appears not to be completely reversible after the astronauts return to Earth;
- after approximately one month under microgravity, leg muscles lose about 20% of their strength, arm muscles about 10%.

The Vestibular Sled (Fig. 4) carried on D1 will permit the functioning of the vestibular organs and the inner ear to be studied in detail under in-orbit conditions. Experience so far indicates that rotational movements of the head, and thus the sensing of angular velocities, are unchanged under microgravity. However, linear accelerations disturb the normal inner ear (otolith system) functions (Fig. 9). Under normal conditions, calcareous particles exert a pressure on the otoliths, but not under microgravity. The Sled will impart precisely controlled linear accelerations to the human test subject, and an instrumented helmet (Fig. 4) will provide other physical stimuli (visual, and changing balance-organ temperature). The helmet will measure the functioning of the otoliths indirectly via the test subject's eye movement (optokinetic coupling) as well as other physiological responses. These measurements will provide important data on man's sense of balance which will help to explain the origin of space sickness, and hopefully also indicate how to circumvent it.

Biological experiments

Cell functions	**Experimenter**
Human Lymphocyte Activation	A. Cogoli, ETH Zurich, Switzerland
Cell Proliferation	H. Planel, Univ. Toulouse, France
Mammalian Cell Polarisation	M. Bouteille, Univ. Paris, France
Circadian Rhythm	D. Mergenhagen, Univ. Hamburg, Germany
Antibacterial Activity	R. Tixador, Univ. Toulouse, France
Growth and Differentiation of Bacil. Subt.	H.D. Mennigmann, Univ. Frankfurt, Germany
Effect of µg on Interaction between Cells	O. Ciferri, Univ. Pavia, Italy
Cell Cycle and Protoplasmic Streaming	V. Sobick, DFVLR, Cologne, Germany
Dosimetric Mapping Inside Biorack	H. Bücker, DFVLR, Cologne, Germany
Developmental processes	
Frog Statoliths	J. Neubert, DFVLR, Cologne, Germany
Dorso-ventral Axis	G. Ubbels, Univ. Utrecht, Netherlands
Distribution of Cytoplasmic Determ.	R. Marco, Univ. Madrid, Spain
Embryogenesis and Organogenesis	H. Bücker, DFVLR, Cologne, Germany
Gravi-perception of plants	
Gravi-Perception	D. Volkmann, Univ. Bonn, Germany
Geotropism	J. Gross, Univ. Tübingen, Germany
Differentiation of Plant Cells	R.R. Theimer, Univ. Munich, Germany
Statocyte Polarity and Geotropic Response	G. Perbal, Univ. Paris, France

Medical experiments

Graviperception of man	**Experimenter**
Vestibular Research	R. v. Baumgarten, Univ. Mainz, Germany
Vestibular Research	L. Young, MIT, Cambridge, USA
Adaptation processes	
Central Venous Pressure	K. Kirsch, Free Univ. Berlin, Germany
Tonometer	J. Draeger, Univ. Hamburg, Germany
Body Impedance Measurement	F. Baisch, DFVLR, Cologne, Germany

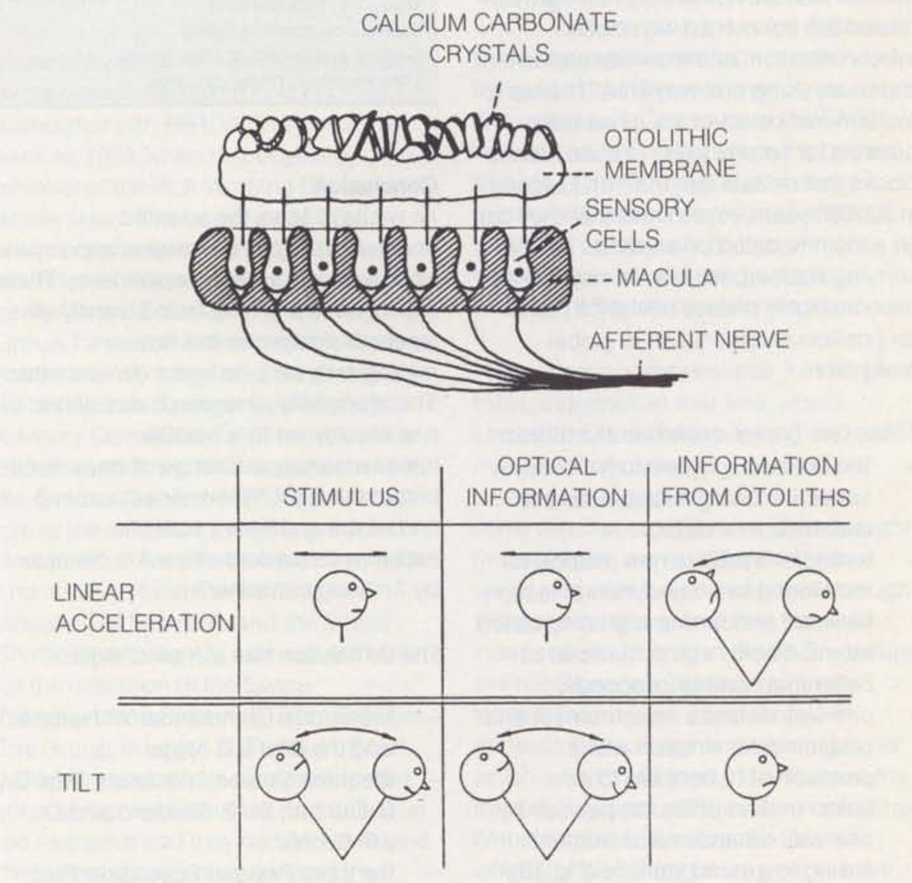
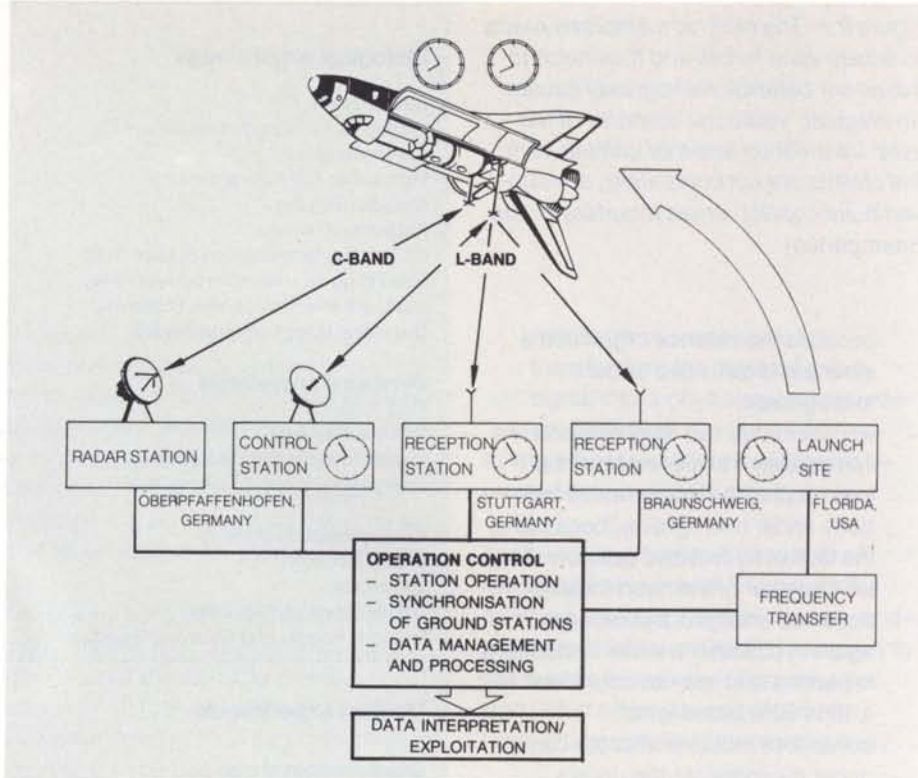


Figure 10 – The Navex communications experiments employ three experiment containers.



Gravity or 'weight' represents a basic human experience and we are largely unaware of how much our own coordinate system is oriented towards the 'feel of gravity'! We talk of 'above' and 'below', of 'vertical' and 'horizontal', and we walk around 'upright'. Our gravity sensation is thus not only a condition dictated by the physical body, but also manifests itself psychologically. There are therefore also experiments on the D1 mission concerned with psychological problems. For example, the 'feeling' for different masses of equal volume and how such masses can be distinguished under microgravity is the subject of one series of experiments. Another series tackles the question of the description of various gravitationally linked sensations.

Navigation experiments

The only two experiments onboard the D1 mission that are not directly microgravity-related are concerned with clock synchronisation, and the measurement of distances using one-way links. Thanks to modern microelectronics, it has been possible for several years to build atomic clocks that deviate less than one second in 300 000 years, yet so small that they can be accommodated on satellites. Satellites carrying such atomic clocks may one day become highly precise reference points for position determination in global navigation.

These two 'Navex' experiments address:

- the behaviour of caesium clocks in space, including measurement of relativistic time dilation;
- testing of a precise new method for monitoring two-way synchronisation between onboard and ground-based atomic clocks, with accuracies of better than ten nanoseconds;
- one-way distance measurement and position determination with a precision of better than 13 m;
- determination of Shuttle position by one-way distance measurement linking to ground stations (Fig. 10);
- determination of the ionosphere's effect on measurement precision.

Space–time interaction experiments

	Experimenter
Navigation	
Clock Synchronisation	S. Starker, DFVLR, Oberpfaffenhofen, Germany
One-Way Determination of Distance	D. Rother, SEL, Stuttgart, Germany
Psychological behaviour in microgravity	
Mass Discrimination	H.E. Ross, Univ. Stirling, UK
Spatial Description in Space	A.D. Friederici/J.M. Levelt, MPI/Univ. Nijmegen
Gesture and Speech in Microgravity	A.D. Friederici, MPI/Univ. Nijmegen
Determination of Reaction Time	H. Hoschek/J. Hund

Conclusion

As we have seen, the scientific endeavours of the D1 mission encompass approximately seventy experiments. These experiments originate from a variety of research disciplines, but have microgravity as a common denominator. This multiplicity of research disciplines has already led to a notable interdisciplinary exchange of ideas, even before the flight. Where else could one find so many different scientific experiments packed into a 4 m diameter by 7 m long container?

The D1 Mission has a crew of eight:

- the Shuttle Commander W. Hartsfield and the Pilot S.R. Nagel
- the three Mission Specialists: Prof. Dr. B. Dunbar, Dr. G. Blueford and Dr. J.F. Buchli;
- the three Payload Specialists: Prof. Dr. R. Furrer, Dr. E. Messerschmidt and Dr. W. Ockels.

The D1 mission planning is such that the Payload Specialists are an essential ingredient for its success. They are the eyes and ears for their scientific colleagues back on Earth and essential participants in the materials-science, life-science and medical experiments to be conducted. The First Spacelab Mission in 1983 has already demonstrated how important human intelligence, flexibility, and skill can be on these flights.

The Crew Interface Coordinator will be Dr. U. Merbold, who will be assisted by Dr. H. Strohmeyer and Dipl.-Ing. R. Lentzen. It is their job to ensure that a twenty-four-hour communication cycle is maintained between the operation centre(s) and Spacelab throughout what promises to be a very exciting mission.

It is hoped to present the overall results of the Spacelab D1 experiments to the public at a concluding symposium some nine to twelve months after the mission.

G. Colombo: A Pioneer of New Worlds – In memoriam

R.M. Bonnet, Director of Scientific Programmes, ESA, Paris

To be named Colombo was already something to live up to. It was not an immediate reaction on my part to identify Giuseppe Colombo as a possible descendant of the famous explorer. However, I soon recognised that he was himself an explorer in his own way: an explorer in science and in space. Indeed, it took me some time to discover the strong similarities, and also the curious differences, between Cristoforo and Giuseppe. Both were attracted by the frontiers of their Universe and both were at the same time very practical. Both knew that there is no enterprise, be it on a planetary or a universal scale, that does not require substantial and prolonged effort: effort to obtain the necessary funds and a fight to convince the authorities, sometimes meeting with failure and sometimes with success. Both were attracted by the West: Cristoforo headed for Portugal and Spain and Giuseppe to the new continent discovered by Cristoforo nearly 500 years ago. Both were attracted by America, although Giusseppe's travelling often gave us in Europe the impression that he was more often coming back from America than going there. Both he and Cristoforo possessed the inherent restlessness that characterises the creator and the discoverer.

In historical texts, Cristoforo is often described as vague, secretive and incoherent. I had more or less the same impression of a vague and incoherent, but certainly not secretive, character when I first saw Giuseppe at a meeting of ESA's Scientific Advisory Committee in 1976. My personal knowledge of him is based on those years when we worked together on that Committee, and on more personal contacts later on when we were both co-investigators for Giotto's camera.

Indeed, Beppi, as he was called familiarly by his friends, had been continuously associated with ESRO/ESA since as far back as 1963, when he became a member of the PLA Working Group, whose task it was to advise ESRO on future programmes in planetary science. In 1971, he became a member of the newly formed Solar System Working Group. I was at that time a member of the Astronomy Working Group myself, and we both joined the Agency's Scientific Advisory Committee (SAC) in 1976. After Beppi's term in the SAC was over in 1978, the Director General of ESA nominated him to the so-called 'Imaginators Joint Group', which was formed jointly by ESA and NASA to examine the long-term utilisation of Spacelab and the Space Shuttle and to identify user requirements for the extension of the Space Transportation System (STS) capabilities. The Group, in which G. Puppi, H. Bondi, J. Blamont and others also participated, soon recognised that their mandate was too restrictive and they decided to extend their ideas considerably, beyond the capabilities of the Shuttle system. They prepared a report, which unfortunately was never published. This was a pity because it contained many of the most advanced ideas and concepts that are now being discussed in the context of the long-term plans of ESA and NASA.

As I have already said, Beppi often seemed somewhat incoherent and, another similarity with Cristoforo, undisciplined. His statements often caused contention in the Committee and, when I took over Chairmanship of the SAC in 1978, he gave me some difficult times keeping the meetings in order and trying to extract the real 'meat' from our discussions. As Chairman of the SAC, I was determined to transform the general attitude of the Committee from that of quasi-systematic endorsement of the Executive's proposals, to that of more constructive advice based on critical analysis of the topics under discussion.

I remember a somewhat painful exercise that I undertook at that time, which consisted of carefully reviewing the minutes of all of the previous SAC meetings, trying to extract from them some semblance of independent thought (including my own). I still have these annotated minutes and as I read through them again I discovered that the really independent thinking in the SAC was that of Prof. Giuseppe Colombo himself. Indeed, the minutes often contained annexes expressing his 'dissenting views', which seldom reflected the attitude of the majority. I cannot resist quoting one of his complaints to ESA's Director General, which states: 'I thought we were to have a more substantial role in the long-term planning than to come to Paris to be fed from the organisation, both physically and spiritually. I thought we were also supposed to do some more imaginative and personal work. I did not intend to come to Paris just to say that I agree with the opinion of your Executive or the people you may think to consult from time to time'. No other sentences could better sum up the personality of this outstanding man.

Imaginative he was indeed! A genuine fountain of ideas and concepts, was how someone recently described him. Indeed, very few of the most innovative programmes or projects that are currently underway or are being considered at both NASA and ESA have not benefited either from his original inputs or at least from his enlightened advice.

His extraordinary mastery of the laws of mechanics led him to propose the most ambitious interplanetary and planetary missions. His ability in the field was recognised across the Atlantic, where he was a professor at MIT, was associated with Harvard (since 1962), and was nominated Distinguished Visiting Scientist at JPL. There were no bounds to his visions of how to drive spaceships around planets, how to plunge into the Sun after a bounce off Jupiter and how to accelerate interplanetary probes to several times their normal cruising velocity! As early as 1973, he mentioned the possibility of a spacecraft en route to Jupiter flying in the vicinity of an asteroid and of sending orbiters to Jupiter, Saturn or their satellites. Today, NASA has just decided that its Galileo mission should accomplish a flyby of the Amphitrite asteroid, and ESA and NASA are jointly studying a mission to Saturn and Titan (the Cassini project, described in ESA Bulletin 41).

His interest was not restricted to the area of flight mechanics alone, but particularly in the case of planets extended to their internal structure as determined through orbital or trajectory perturbations. In this framework, a Moon orbiter was, for him, a pioneering mission paving the way to a series of planetary orbiters.

As a restless advocate of planetary science, he would probably have been less dissatisfied than he was a few years ago to see that ESA's Long-Term Plan intends to put missions to comets and asteroids on an equal footing with astronomy and Sun-Earth relations.

'Travelling' in interplanetary space was one of his favourite muses, usually involving either a solar sail or an electric propulsion system. He in fact pushed ESA strongly into the development of such a system, which is now one of the strengths of the Agency's Technological Research Programme and which will allow us to consider possible asteroid missions in the not too distant future. He was also a strong advocate of missions to comets.

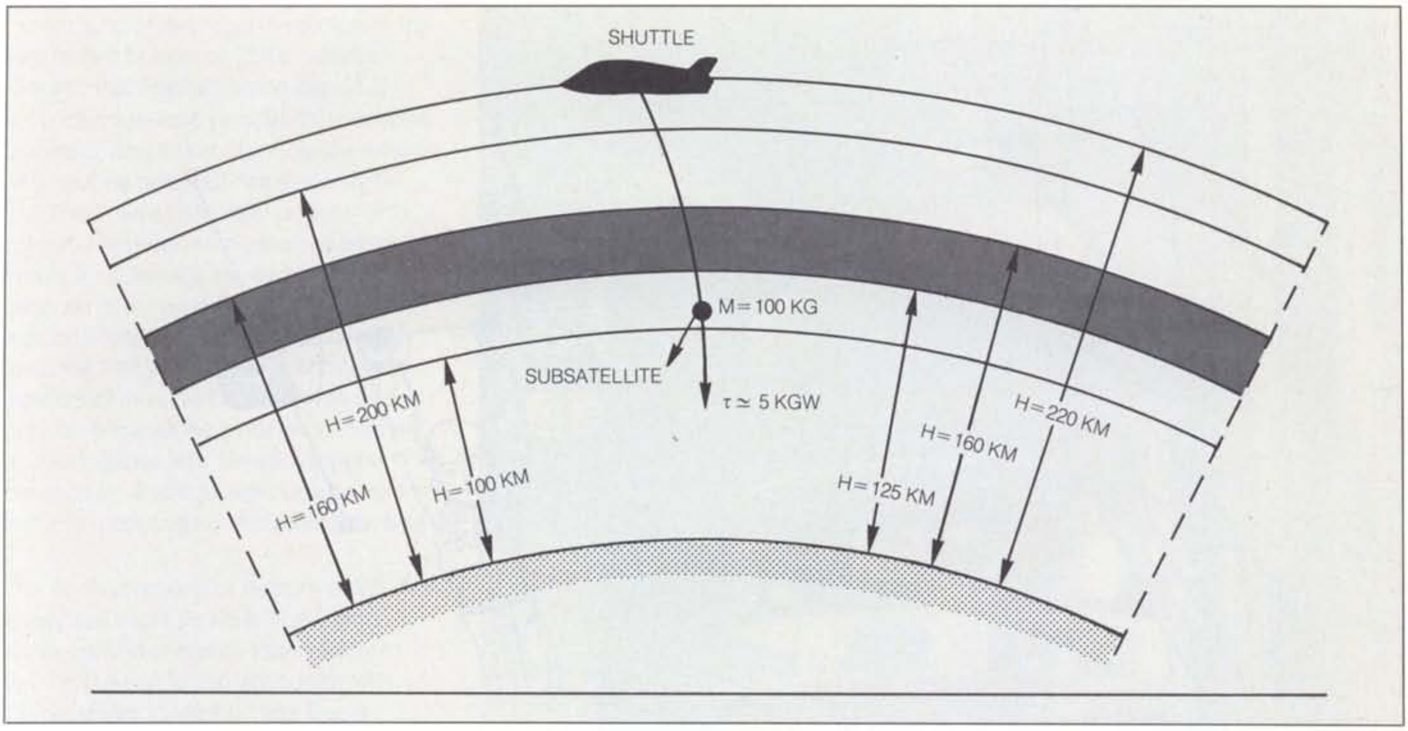
He was a man who always looked further and further ahead. In astronomy, the Very-Long-Baseline Interferometry (VLBI) technique, with all its potential, but also its precise mechanical challenges, attracted his attention. Again, he foresaw the interest of the technique, not only because it would contribute to major advances in astronomy, but also because it offered a powerful tool in the area of geodynamics. Jumping from radio to optical interferometry, he was one of the first, if not the first, to point out to ESA the tremendous potential of spaceborne optical astronomy interferometers. Again, this has come up recently in ESA's Long-Term Plan as a major development to be pursued, in order to capitalise on the potential that has built up in the past years in Europe based on observations conducted from the ground.

Certainly, one of his major contributions lies in the area of Space-Shuttle and Spacelab utilisation. I had the privilege of being present when he described his ideas in this domain and it will remain a unique experience. In his intellectual exercise, the Shuttle looked like a small toy with which he played as a young boy would play with an electric train. The most famous example of this imaginative activity is the concept of tethered satellites, which is now a joint programme between Italy and NASA.

The original concept for these satellites was that a tether, connected to the Shuttle, in its normal orbit, at one end and to the satellite at the other, would be deployed over a length of several tens of kilometres. The subsatellite would thus be suspended below the Shuttle and able to reach down to altitudes of about 100 km above the Earth's surface (Fig. 1). The abilities of this system to probe the upper atmosphere and perform various electromagnetic measurements in the ionosphere, are considerable. The problems posed by such a system are not, however, trivial. I very well remember the engineers at the beginning of the studies conducted by ESA showing the amazing shapes drawn in space by the tether, which is far from being a stable system. Many factors had to be considered, such as deployment velocity, Earth, Sun and Moon gravitational fields, air drag which is very important at the altitudes considered here, solar radiation pressure, the length and flexural stiffness of the tether itself, and the attitude of the subsatellite. The studies showed that the concept was realistic under certain conditions, the major problem being the heating of the wire and of the subsatellite due to air drag. Indeed, the first trial of a space tether is planned for a Shuttle flight in 1987, but for this first attempt the cable will be only 10 to 20 km long. The crew for this flight will probably include the first Italian astronaut.

A particular application of the concept was the so-called 'Dumb-bell Project' proposed by Beppi in 1975 and studied by ESA in the course of 1976. It consists of two spacecraft connected by a tether and launched into a polar near-Earth orbit. The system was conceived to determine gravity-field anomalies and variations due to upper-mantle convection, tides and sea level, by measuring the variations in

Figure 1 — The proposed Space Shuttle 'skyhook' scheme

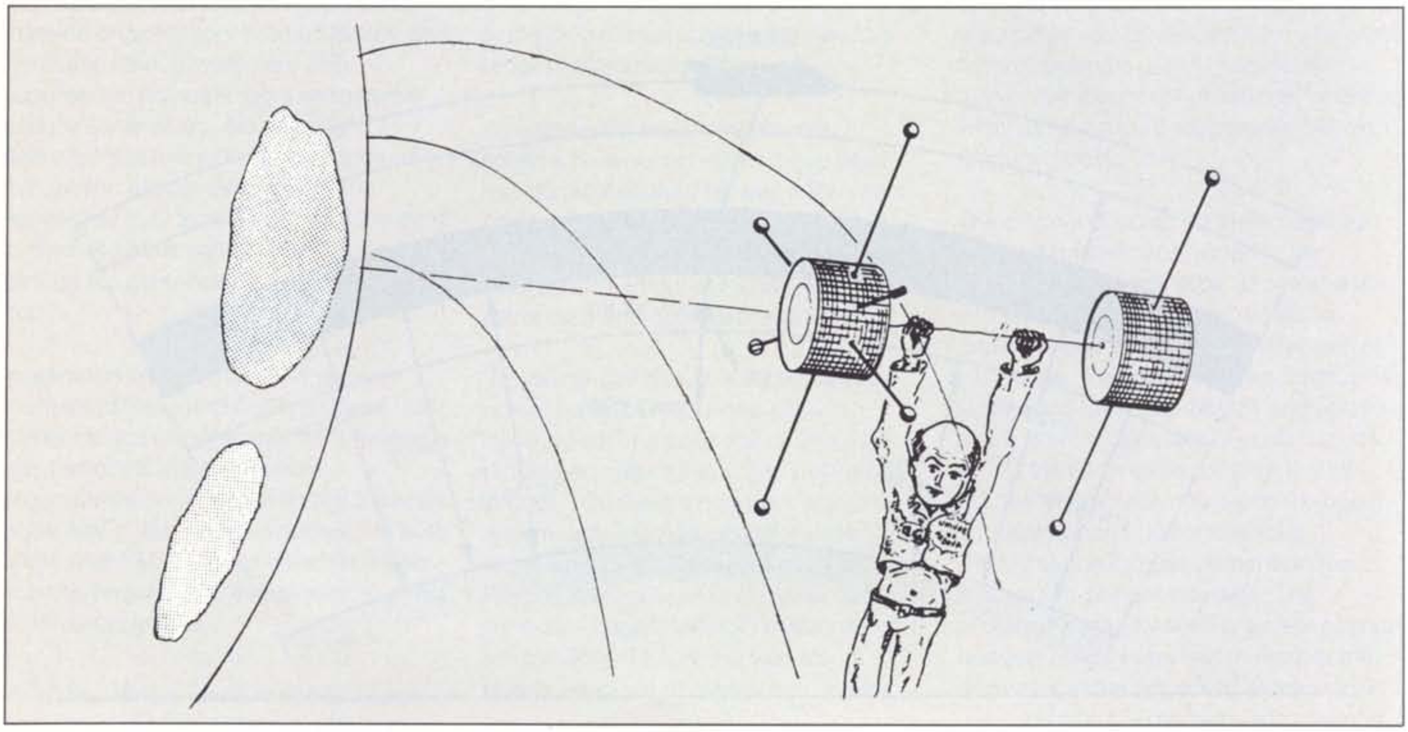


tension induced in the tether by the gravity-gradient perturbations. The dumb-bell system could also be used to perform magnetospheric studies, the two satellites performing passive and active experiments simultaneously, with the possibility of their being aligned along the same field line. Beppi's ideas were continually dazzling in the course of the study, and the engineers involved from ESA have certainly not forgotten this unique intellectual and highly stimulating venture (Fig. 2). It was in fact too dazzling at the time, because the study was unfortunately not progressed to project approval.

Tethered satellites are but one example of Beppi's imagination regarding utilisation of the Space Shuttle. It is true to say that he was always an admirer of US technology and the capabilities of the Space Transportation System, and its potential future developments excited him a great deal. The technology for the lidar, for example, which Spacelab can easily implement, was of particular interest to him, not only because of its innovative character, but also because of its applications in geophysics and atmospheric, oceanic and solid-Earth physics. In this area again, the use of subsatellites as retroreflectors for the laser beam was suggested by Beppi and this is in fact a very powerful tool indeed for atmospheric research and for gravity-field-anomaly detection through satellite-to-satellite ranging. This is a further clear example of how he could so cleverly exploit the advent of new technology by incorporating it right in the core of its imaginative complex scientific system designs.

It was in the framework of ESA's activities in planning the utilisation of the Space Transportation System and in the context of the growing interest in space stations that the Agency called upon Guiseppe Colombo to be part of its Imaginators Joint Group, as mentioned earlier. Who could have been more appropriate than him to be a part of this Group? He was, in addition, one of the earliest advocates of the development of a Space Station. In retrospect, the Group's predictions have indeed proved correct for the medium term. In fact, as I have already said, most of their imaginative ideas are now incorporated in ESA's and NASA's future plans. But their intellectual exercise covered a much broader time span, and, although some of their ideas may look extravagant today, they may not be so in the course of the next century. It is worth recounting some of the more extraordinary ones, such as colonisation of the Moon and of Mars, the 'sling-shot' technique using Jupiter's gravity to send a spacecraft to the outer reaches of the solar system with a trip time comparable to that needed to go to Saturn, or the utilisation of a matter-antimatter anihilation photon engine to accelerate a space vehicle to a substantial fraction of the velocity of light. Diverging from the real world, the Group also imagined a system aimed at controlling the input of solar flux to the Earth, which was made up of several million spacecraft, each equipped with 1 km-sized mirrors, located at the Lagrangian point L_1 and controlled statistically in position and orientation in order to increase or reduce the amount of

Figure 2 – 'Artist's impression' of the concept of Guiseppe Colombo's Dumb-Bell Project



flux impinging on specific areas of the Earth. Was it not Giuseppe who proposed a direct application of this system to the 'climatisation' of Sicily, which he probably considered too hot a spot in this world?

The problems of climate, meteorology and earth-resources studies were of the highest importance for him. As I have already said, he was a practical man and he found it difficult to see space science developing unless it could bring benefit both in the area of new technology developments and in applications. Hence his interest in lidars and gravimetry techniques in connection with the Earth-environment and geophysics disciplines. In fact, some of his colleagues thought he was going a little too far in this direction, because, like all human beings, he had his own personal biases. For example, he had some intrinsic difficulties with a few proposed programmes, such as the astrometry mission, now called Hipparcos, the Solar Grazing-Incidence Spectrometer (Grist) and, last but not least, the Out-of-Ecliptic mission, now renamed Ulysses. On the first, he questioned the scientific interest of the mission on the basis of the predicted precision of the measurements. He certainly underestimated, in my opinion, the tremendous potential of the project from the astrophysical point of view, which was later to be evidenced by the enormous support it obtained from the scientific community. On the second (Grist), he would probably not have admitted that the inclusion of the mission in the ESA programme could have undermined the possibility of introducing the Solar Probe later on. This latter project was obviously in his mind when he so thoroughly objected to the Out-of-Ecliptic mission, as proposed by ESA and NASA, which did not include a Combined Solar Probe Component [Annex to SAC(76)11]. His argument was that there were a number of cometary missions being studied at NASA that implied out-of-ecliptic trajectories. In this, he has now been proved incorrect! He was also afraid of the cost of the mission and did not consider it sufficiently justified, especially at a time when space research should be directed more and more to the solution of human problems. He never discussed how the Solar Probe, or a combination of the Probe with the Out-of-Ecliptic mission, would withstand similar criticism. Rightfully, however, he emphasised the gain in the scientific return of a combined mission. Indeed, this combination is considered a high priority item in ESA's long-term report 'Space Science Horizon 2000' and is also attracting interest in the USA. However, neither NASA nor (a fortiori) ESA could afford such a mission before the twenty-first century.

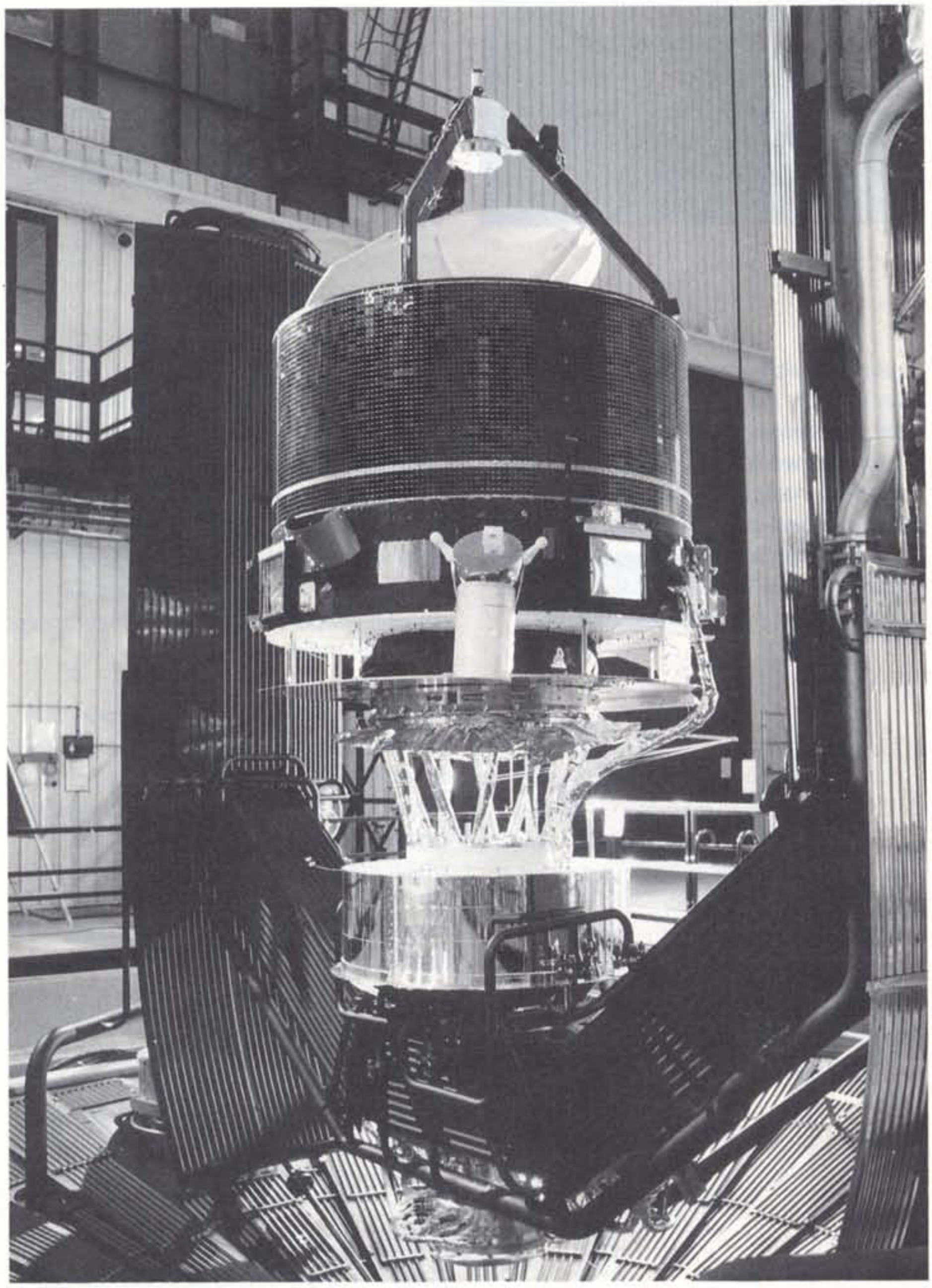
He was certainly unjust when he criticised the European scientists for planning scientific missions based on conventional technology rather than developing systems that he himself considered of first priority, such as advanced propulsion systems (in which ESA is now investing considerable effort), and when he generalised in saying that 'space research has lost its position of privilege' in fostering technological development, a statement totally contradicted by space industrialists. I am not so sure either whether he was fundamentally sincere in his criticism of the Space Telescope and

Exosat, and of their cost in relation to the very limited budget of ESA's Science Programme. After all, being biased is not a characteristic peculiar to Giuseppe Colombo, and this is probably the reason why nobody resented him and why he remained one of the most popular and colourful figures among European and American scientists. He was popular because of his prodigious imagination, fed continuously by an intense curiosity about all that was new and about the frontiers of the unknown. He was also popular because he behaved humanely and with generosity. He was popular because he was courageous and held no fear of expressing his thoughts in public.

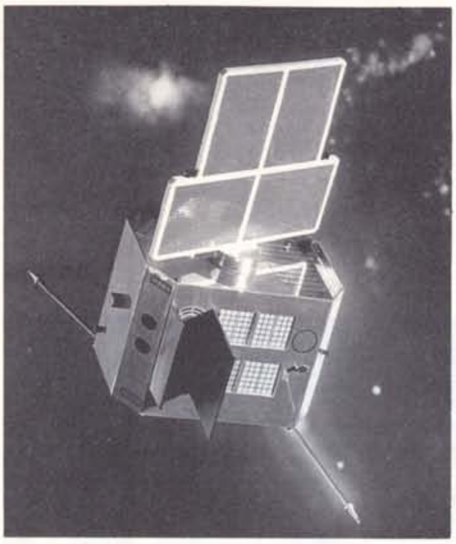
The announcement of Beppi's death was a very sad event for ESA. The Giotto spacecraft has recently taken off from French Guiana for an encounter with Comet Halley in March 1986. Beppi participated a great deal in the genesis of this mission (Fig. 3). He and I were co-investigators on the multicolour camera, which will attempt to obtain detailed pictures of the nucleus of the Comet. We may reflect on the strange coincidence that both he and Giotto di Bondone, apart from being worldwide celebrities, contributed much to the fame of their beautiful city of Padua. Both were artists in their own way and both were scientists in their own way too. It is sad that the uniqueness of the Giotto encounter with Halley will not be observed by the person who proposed the mission called 'Happen', which stands for Halley Post-Perihelion Encounter, and from which Giotto derives.

In 1981, Guiseppe Colombo was in Padua when the Inter-Agency Coordination Group met for the first time. He will not be here when the Group meets there again in the autumn of 1986 after the encounter. His memory will remain a long time with all those who know that the real vocation of science is to break down the frontiers and to discover the unknown, and is based on the rare and difficult bringing together of imagination, rigorousness and the development of new techniques.

Figure 3 – The Giotto spacecraft, launched on 2 July to rendezvous with Comet Halley, a pioneering mission derived from just one of Giuseppe Colombo's many innovative proposals



Acknowledgement
My thanks go to J. Collet, G. Duchossois, G.P. Haskell and V. Manno from ESA who so kindly provided me with some of the material on which this article is based.



Exosat: Two Years In Orbit

A. Peacock, Exosat Project Scientist, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

D. Andrews, Exosat Observatory Manager, ESOC, Darmstadt, Germany

Exosat has now completed its second year in orbit, having performed over 2000 observations of X-ray sources. Major discoveries have come primarily from observations of stars in our own galaxy. In particular the observations of compact objects such as neutron stars in binary systems have provided a wealth of data for the scientific community.

The Exosat mission, launched in May 1983, has now completed its second year in orbit, and has performed about 2000 observations. Most results to date have involved the observation of stars in our own galaxy. At a recent ESA/ESLAB conference held in The Hague and devoted to X-ray astronomy, over 100 scientific papers relating to Exosat results were presented.

The single most important discovery so far, and one which is unique to the Exosat mission, is the detection of quasi-periodic millisecond pulsations in some classical bright X-ray sources. These sources, which are thought to contain a neutron star in a binary system, have been observed many times in the past by other astronomical satellites. The Exosat mission, however, with its long uninterrupted coverage, afforded by the deep orbit, coupled with the high timing accuracy and effective area of the Medium-Energy Experiment aboard the spacecraft, has been the most powerful observer.

The first quasi-periodic millisecond pulsation was discovered in the galactic bulge source GX5-1 by an ESA scientist, M. van der Klis. The source showed intensity-dependent quasi-periodic oscillations at a frequency of 20 to 40 Hz. The variations in the frequency with the star's X-ray intensity prohibit a simple model of a rotating neutron star. A possible explanation is that we are observing material orbiting the neutron star. The frequency we observe is the beat frequency between the material moving in a Keplerian orbit and the rotation frequency of the neutron star. The remarkable power spectrum of GX5-1 is shown in Figure 1, where the peak at 20 Hz is clearly observable.

Since this initial dramatic discovery, other sources have been observed to exhibit this phenomenon. For example, Cyg X-2, a compact neutron star in a binary system in the Cygnus constellation, has been observed to show quasi-periodic oscillations in the frequency range 30 – 50 Hz. Recently, X-rays from Sco X-1, the brightest X-ray source in the sky, were observed to show quasi-periodic pulsations with a frequency of 7–17 Hz. This is a particularly historic detection, since Sco-1 was the first extra-solar X-ray source discovered in the early 1960s, giving birth to the discipline of Cosmic X-Ray Astronomy.

Since those times the nature of the source has remained a mystery. The Exosat discovery places the neutron-star nature of this object on much firmer ground.

A number of new X-ray stars, 'transient' X-ray sources have been detected by Exosat when manoeuvring from one observation to the next. When this occurs, the observation programme is restructured in real time and the spacecraft immediately manoeuvres back to the approximate position of the new X-ray star. About eight such new stars have now been discovered by the Exosat observatory team at the observatory centre in ESOC.

A typical example of the success of this type of procedure was the discovery by A. Parmar of the Exosat observatory team of a new X-ray source Exo 0748-676. The light curve of this source is shown in Figure 2. The new star was discovered in February 1985, and showed bursts, irregular intensity dips and periodic total eclipses. The star's position, determined by Exosat's X-ray telescope, was immediately communicated to all the optical observatories worldwide. The Steward Observatory in Arizona and the European Southern Observatory in Chile rapidly identified the star's optical counterpart.

The X-ray data indicated a binary period of the order of 4 h, typical of a low-mass X-ray binary system. Between 20 and 30 bursts of X-rays have also been observed from this source. Four such bursts are shown in Figure 2. These bursts are thought to result from a thermonuclear explosion of material which has fallen onto the surface of the neutron star. The study of this type of object provides fresh insight into the physics of matter accreting onto compact objects.

As Exosat moves into its third year, future observations will naturally concentrate on obtaining more details of millisecond periodicities in galactic compact X-ray sources to build on the recent discoveries. This will provide us with a far better understanding of the physics operating in the accretion of matter onto a neutron star. This in itself will test the laws of physics under extreme gravitational conditions.

A more extensive article will appear in the next issue of ESA Bulletin (No. 44, November 1985)

Figure 1 — The power spectrum from the source GX 5-1. The peak at 20 Hz is clearly apparent

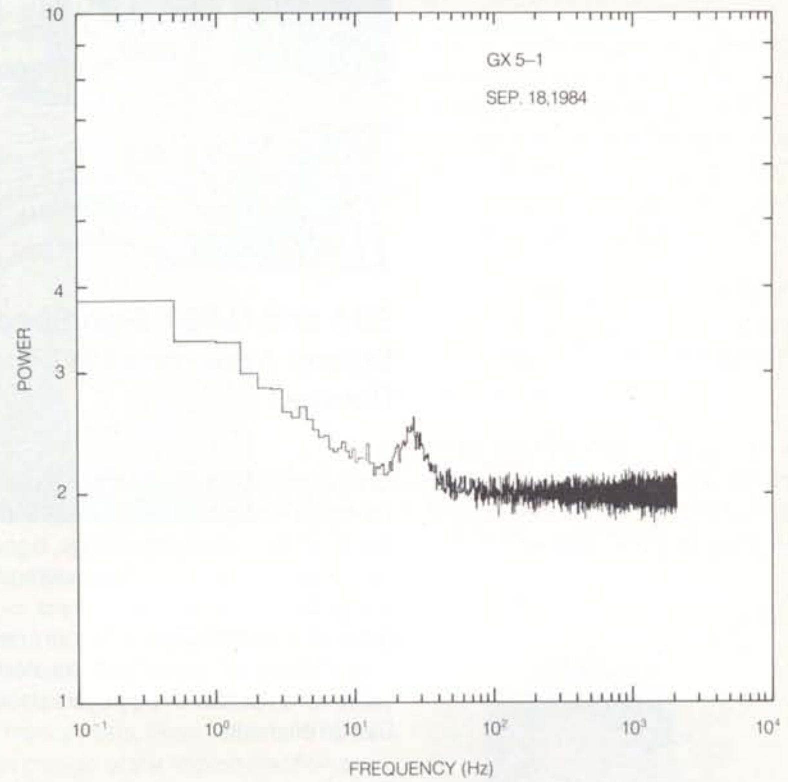
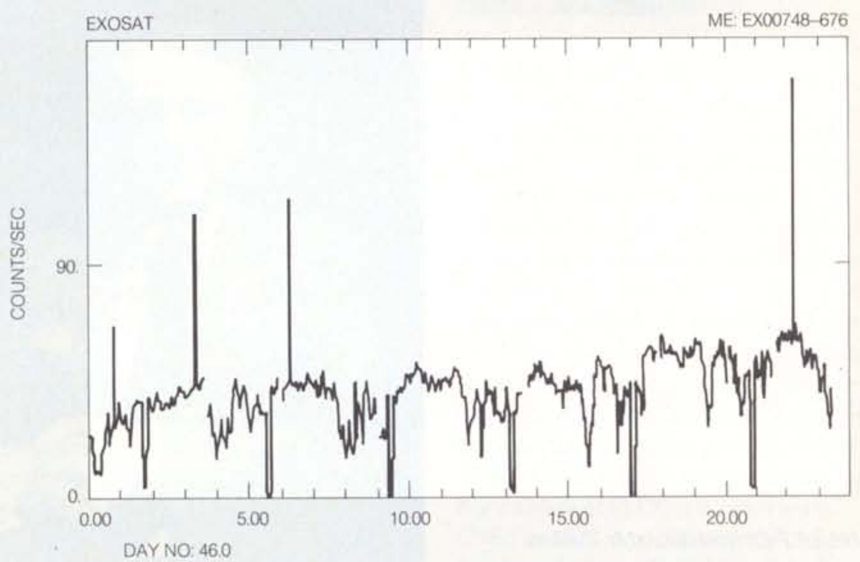


Figure 2 — The X-ray light curve, as observed by the Exosat Medium-Energy Experiment, of the new star Exo 0748-676. Dips, bursts and regular total eclipses are all apparent



In Brief

ESA and NASA Sign Space Station Agreement at Le Bourget

On 3 June 1985, ESA's Director General, Professor Reimar Lüst, and the NASA Administrator, Mr. James Beggs, signed the Memorandum of Understanding for a cooperative programme covering detailed-definition and preliminary design studies to be carried out over the next two years for a number of potential Space-Station elements.

The ceremony took place in the ESA Pavilion at the Le Bourget Air Show and was followed by a Press Conference.

ESA's contribution to the permanently manned Space Station could consist of: a pressurised module that could be used as a manned laboratory; free-flying payload carriers for both low-inclination and polar orbits, to be used for experimental purposes; a servicing vehicle; and a resources module that could provide both the pressurised module and the platforms with electrical power, and cooling and stabilising systems. ESA-managed studies will also cover such areas as ground facilities for mission preparation and support, and a data-transmission system.

The NASA Administrator, Mr. James Beggs (left) and ESA's Director General Professor Reimar Lüst

New ESA Directors Nominated

The far-reaching decisions taken by the Ministers of the ESA Member States at the Council meeting held in Rome on 30 and 31 January 1985 resulted in a series of ambitious programmes to be undertaken in all fields of space research and technology over the next 15 years. It has therefore been decided to strengthen the Agency's Directorate, in particular by the creation of an Earth Observation and Microgravity Directorate and a Telecommunications Directorate. Moreover, in view of the magnitude the Columbus Programme is likely to attain during the coming years, a Directorate specifically dedicated to this programme has been established.

The ESA Council, at its meeting on 11 and 12 June, nominated the following to these posts:

- Mr. Philip Goldsmith (United Kingdom), Director of Earth Observation and Microgravity Programme
- Mr. Giorgio Salvatori (Italy), Director of Telecommunications Programme
- Dr. Fredrik Engström (Sweden), Director of the Columbus Programme.

In addition, Mr. Marius Le Fèvre (France) has been appointed Director of ESTEC, ESA's Space Research and Technology Establishment at Noordwijk in The Netherlands. The Agency's Technical Director, Prof. Massimo Trella, has been nominated Inspector General.

Mr. Philip Goldsmith
Born in Huddersfield, England on 16 April 1930, Philip Goldsmith graduated in physics from Pembroke College Oxford in 1957. He started his professional career at the Atomic Energy Research Establishment. In 1967, he joined the Meteorological Office as Head of the new Cloud Physics Branch. He was appointed Deputy Director of the Meteorological Office in 1976, and was responsible for research into physical meteorology, including the Office's involvement in the Meteosat and ERS programmes. Since 1982 Mr Goldsmith has been Director of the UK Meteorological Office, responsible for research.
He is a past President of the Royal Meteorological Society (1980–1982) and of the Commission for Atmospheric Chemistry and Global Pollution of the International Association of Meteorology and Atmospheric Physics (1979–1983)

Mr. Giorgio Salvatori
Born in Trieste on 22 June 1927, Giorgio Salvatori studied physics at the University of Trieste and telecommunications in Rome. Has been with Telespazio for more than twenty years. From 1966 to 1972, he was in charge of the implementation by Telespazio of a new antenna system at the Fucino station. From 1972 to 1982 he was responsible for the company's medium-term planning and international relations, in particular with ITU, Intelsat, Eutelsat and IMCO. Since 1982 he has been Executive Assistant to the Director General of Telespazio.

Mr. Salvatori was also involved in PNUD-funded studies on tele-education with the use of DBS satellites in South America. He was Chairman of Commission 'A' of the Inter-Governmental Conference in Paris in 1982, charged with the preparation of the Eutelsat Convention.

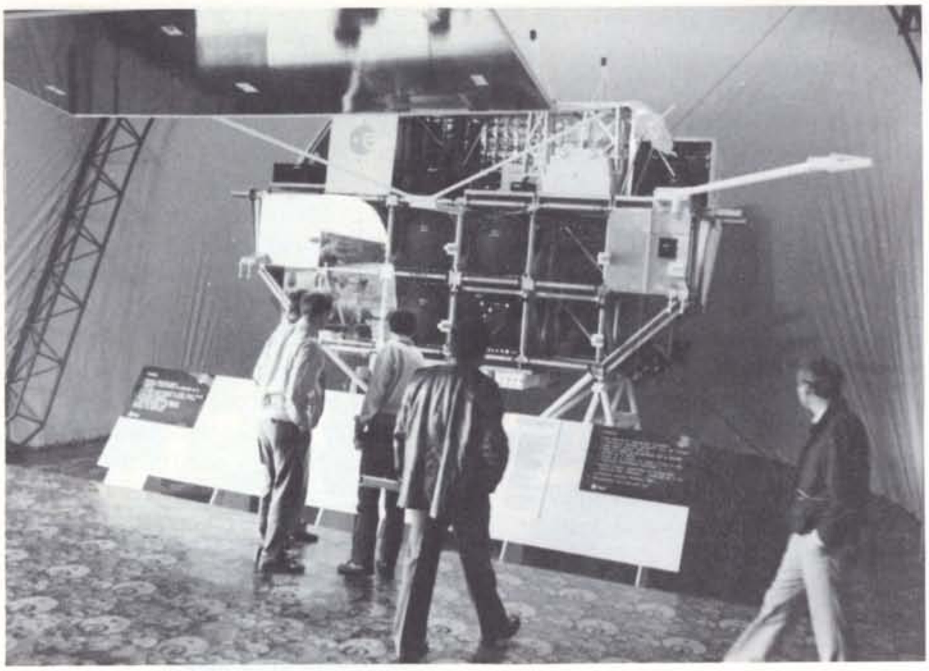
Dr. Fredrik Engström
Born in Karlskrona, Sweden in 1939, Fredrik Engström studied sciences at Stockholm University, where he attained his masters degree in 1964 and his doctorate in 1971. He started his career as project manager with the Space Technology Group where he was mainly involved in managing sounding-rocket launchings. Between 1965 and 1970 he was an ESRO Fellow at Culham Laboratories, and a Research Assistant at the Stockholm Observatory. In 1970 he joined Teleutredningar AB, where he was involved in space projects.

Since 1972 he has been President of the Swedish Space Corporation, and also, since 1982, Chairman of Satellite Image Corporation.

From 1977 to 1979, Mr. Engström was Chairman of ESA's Remote-Sensing Programme Board and since 1979 has been a Swedish Delegate to the Agency's Council.

Mr. Marius Le Fèvre
Born in Vitré, France on 7 April 1932, Marius Le Fèvre graduated from the 'Ecole de l'Air' in 1954. He started his career as Launch Pad Director at France's Colomb-Bechar launch site, where he participated in the Véronique launcher programme. From 1961 to 1970, he was with the Sounding-Rocket Division of CNES, where he was involved in the setting up of a mobile launch pad. He was responsible for the Diamant/Diapason satellite launch campaign. From 1970 to 1973, he was responsible for security and flight safety at ELDO. He returned to CNES in 1974, and is presently Director of the Guiana Space Centre in Kourou.

ESA at Le Bourget



This year's Le Bourget Airshow, the 36th in the series, was of particular importance for ESA, coming as it did just a few months after the Ministers of the Agency's Member States had approved an ambitious new programme of activities.

In its 600 m^2 pavilion, ESA's display highlighted the transition from the present to the future with a series of models (both full-scale and 1:10) of spacecraft, orbital elements and launchers.

In the manned space field, the present was represented by a full-scale model of a Spacelab Pallet, the unpressurised instrument carrier that forms part of the overall Spacelab system. Visitors to the pavilion were also able to see the European-developed pressurised supply module, the 'Igloo', used when Spacelab flies in a 'Pallet-only' configuration. The Igloo contains the subsystems (e.g. data-handling, thermal control, and power-distribution equipment) that are usually housed in the main Spacelab Module and which are essential for the operation of experiments, the collection of results, etc.

Another item of equipment developed in Europe within the framework of the Spacelab Programme and used for the first time during the Spacelab-2 mission was also on show, namely the Instrument Pointing System (IPS). The IPS is to be used particularly for astronomical observations, for which it is absolutely essential to ensure that an instrument (e.g. a telescope) is kept pointed at a particular object in space with the greatest possible precision and stability. The IPS system can orient payloads weighing up to 7000 kg with an accuracy of 1 arcsec, or 1/36 000th of a degree.

Spacelab has been Europe's first venture in the manned space field, and hence its first step on the road towards a Space Station. The next step will be the European Retrievable Carrier, Eureca, scheduled for launch in 1988. A free-flying instrument carrier to be launched from the Space Shuttle, Eureca will carry a payload consisting mainly of experiments in the microgravity sciences. During the six months it will remain in orbit, it will gradually lose altitude and will rendez-vous with the Orbiter, be retrieved and returned to Earth at the end of this period. From the technological point of view, Eureca provides a basis for the development of the free-flying platforms that will form part of the future in-orbit infrastructures, including the Space Station. A full-scale model of Eureca was on show, together with a 1:10 model of the pressurised module Columbus, which could well become one of the European elements of the Space Station.

Other areas of ESA activities on show included: Giotto, the space probe, launched on 2 July (see pages 14–18) and due to fly by Halley's Comet in March 1986. Telecommunications was represented by full-scale models of the direct-broadcast satellite Olympus, scheduled for launch in 1987, and of the operational European communications satellite, ECS. One-tenth scale models of the European launcher Ariane, in its more powerful Ariane-4 and Ariane-5 versions, were on display.

Notes from the Director General's Press Conference at Le Bourget

Some fifty journalists – a very good indication of the interest being shown in ESA's work and plans – plied the Agency's Director General Professor Lüst, and Mr. Bignier and Dr. Bonnet, two of ESA's Programme Directors, with searching and pertinent questions when the Director General held a Press Conference in the ESA Pavilion at the Le Bourget Air Show on 31 May 1985.

The questions ranged across the full ESA programme, and Professor Lüst took the opportunity to summarise ESA's progress towards fulfilling the decisions taken by the Ministers in Rome last January.

On the ongoing projects, he explained that the Giotto payload would include the most complex camera ever flown, more sophisticated even than the Voyager instrument. The mission to Halley's Comet could be a major step in international cooperation, with ESA at the heart of events.

The July flight of Spacelab would see the Instrument Pointing System (IPS) and the Igloo given their chance to add to the successes of other Spacelab elements; and of course the German D1 mission later in the year would carry several ESA instruments, and be the first flight for the second ESA astronaut, Dr. Wubbo Ockels.

The effect that Ariane was having on space transportation systems needed no emphasis, but by December, when the second launch pad, ELA-2, came into operation in Kourou, the European launch capacity and its ability to increase the frequency of launches would be greatly enhanced. The inaugural Ariane-4 launch was still on schedule for 1986 and would carry three 'passenger' satellites.

All other ongoing programmes were progressing satisfactorily.

Obvious interest centred on Columbus, and the part Europe will play in the Space Station. It was clear that no decision could be expected until March 1986. In the meantime, during Phase B1, Europe was assessing its options, and with full agreement of NASA, work continued on the pressurised module, the platform, and the resources or service module. The Agency laid emphasis on the necessity to go ahead with the pressurised module: this was seen as essential in turning the political will of Europe for autonomy in space into reality.

The decision to accept the Ariane-5 P model, which incorporated the HM60 cryogenic engine, was explained in some detail. By 1995, Japan and the USA would have improved expendable launchers on the market. Of the three Ariane options, that derived from Ariane-4 would be too conservative; the full cryogenic solution contained a very high risk factor, and would not be available in time. The proposed solution would match the competition in both performance and timing.

With its cryogenic stage and large solid boosters backed by a system and launcher services of proven worth, Ariane-5 would carry on in smooth succession to the present family of European launch vehicles.

This discussion led naturally to the possibilities of Europe entering the manned spaceflight transport market. Hermes was complementary to Ariane-5, and while it remained a French project for the moment, the way was open for 'Europeanisation' in a few years' time. Looking further ahead, the prospects for reusable winged vehicles were exciting, and the UK was keeping the Agency informed of progress on Hotol (Horizontal Take-off and Landing).

The Science Programme remained at the core of Europe's space endeavours. It allowed Europe to go to the limit of current technology and state-of-the-art scientific instrumentation. From it flowed much that could be used in the long-life applications satellite systems.

The Cluster and Soho Phase-A studies are nearing completion and have attracted possible collaboration with the USA and Japan. The Mars orbiter (Kepler) Phase-A studies have been completed, and the possibilities of a flight at the same time as the NASA Mars mission, and the feasibility of combining the scientific objectives, and an exchange of scientific data are under review.

Pre-Phase-A work on several missions – Cassini, Lyman and Quasat – continues, as does the formulation of ideas for several of the 'Cornerstones' on which the Science Programme 'Horizon 2000' is based.

The Agency is participating in the USSR's Phobos mission to Mars in 1988 to the extent that ESA Space Science Department has made an experiment proposal and is associated with two others from Germany and Switzerland.

Probing questions were asked about Eureca/Eureka and possible overlaps. The Director General made it clear that the scope of Eureka was not yet fully known, but he could envisage a number of areas under Eureka which would be of interest to ESA.

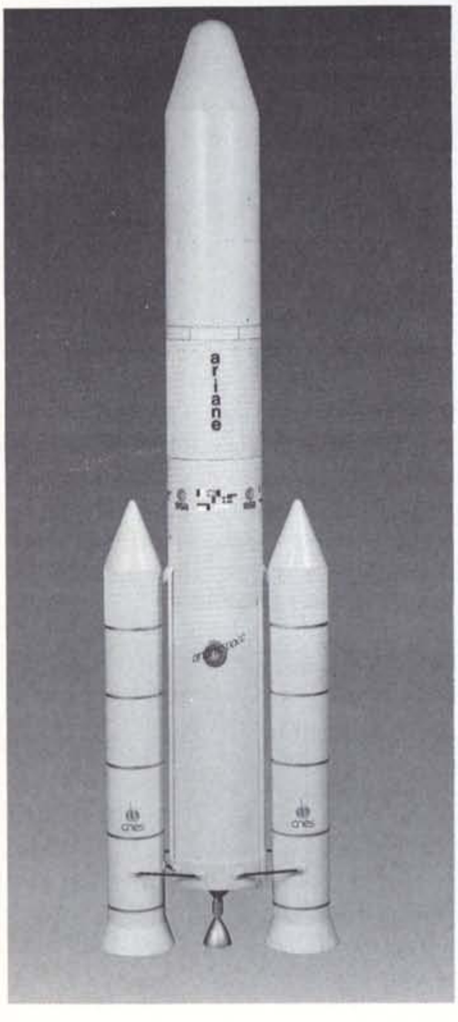
In his reply on the possibility that the USA Strategic Defense Initiative could drain away European engineering skills, Professor Lüst accepted that there was not an unlimited supply of qualified engineers in Europe. To retain them Europe had to offer attractive and exciting work, and he felt that the European space programmes would be stimulating enough to do that.

Finally, while accepting that Europe could never compete financially with the USA in non-military research, Professor Lüst pointed out that, through ESA, European countries had proved themselves able to work together towards common goals, and to match, competitively, the other major space powers.

Resolution on the Ariane-5 Preparatory Programme

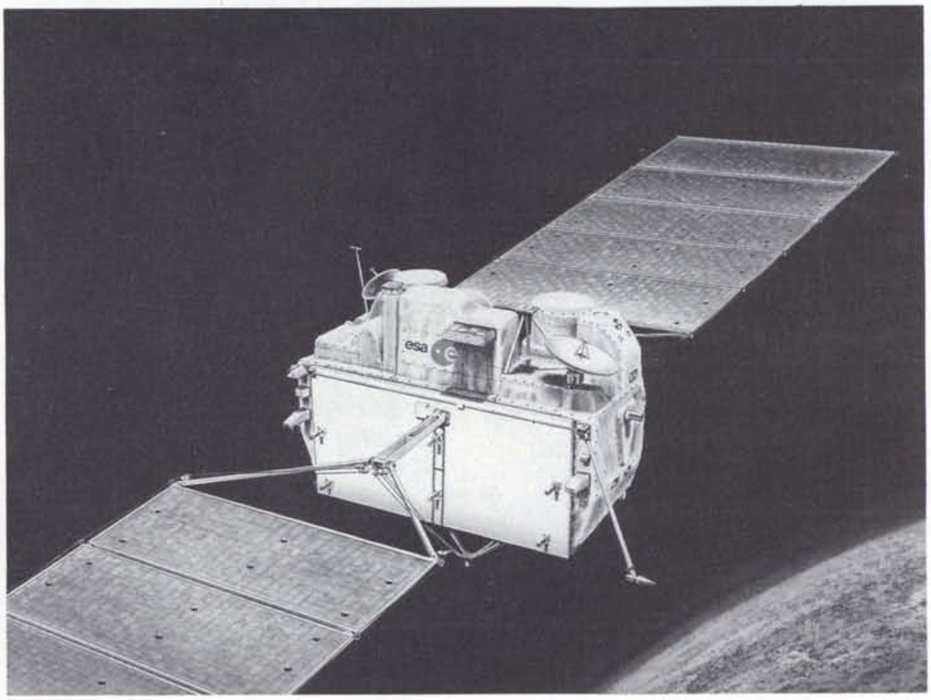
Pursuant to the Resolution approved at Ministerial Level on 31 January 1985 and in particular its paragraph which 'welcomes and endorses the proposal to undertake, as an optional programme in the field of space transportation systems, the development of the Ariane-5 launcher, equipped with the large cryogenic engine HM 60, with a view to completing it by 1995', on 12 June the ESA Council approved the execution of an Ariane-5 Preparatory Programme. This programme incorporates the preparatory programme for the large cryogenic HM 60 engine.

This decision represents a step towards one of the objectives assigned to the European space programme, namely that of strengthening the European space transportation capacity to meet the foreseeable requirements of users within and outside Europe and to remain competitive with space transportation systems existing or planned elsewhere.



The G. Colombo Fellowship

The European, and indeed the worldwide, space science community suffered a severe loss with the death, in February 1984, of Prof. Giuseppe Colombo, one of its staunchest supporters (see page 77 of this issue). In recognition of Prof. Colombo's extensive and valuable contributions to space science, space flights and space navigation, ESA has created a 'Giuseppe Colombo Fellowship' to be awarded to a European scientist or engineer of a very high ability in an area relating to space mechanics, basic or applied sciences. The fellowship will be awarded, following a competitive selection process, for a one-year tenure at either a European or an American Institute, preferably one at which Prof. Colombo worked himself.

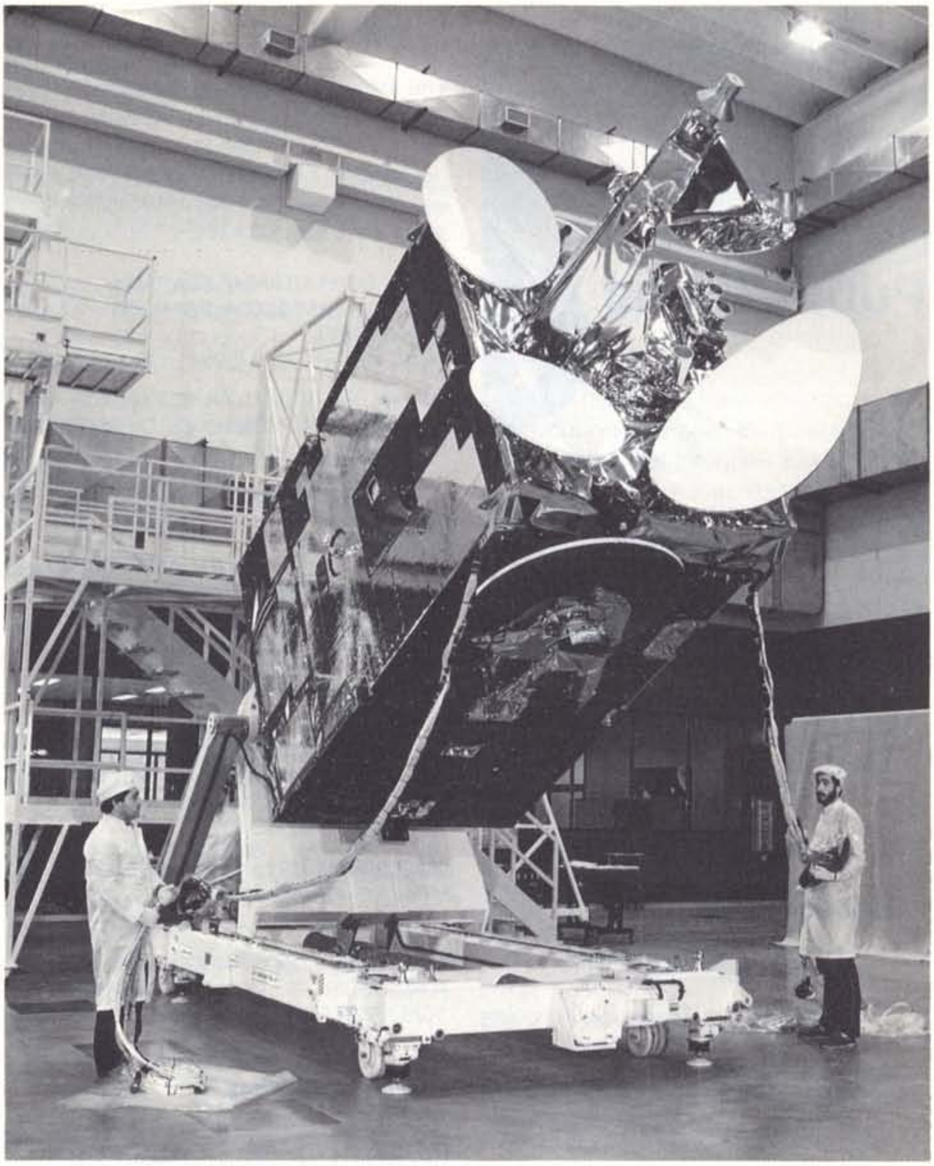


Industrial Contract for Eureca Signed

On 14 June 1985, the industrial contract for the development of the European Retrievable Carrier, Eureca, was signed by Mr M. Bignier, ESA's Director of Space Transportation Systems, and Dr. O. Heise, Executive Vice President and President of Space Systems Group, MBB/Erno. Under the prime contractorship of MBB/Erno some 24 European industrial firms will be involved in carrying out the development work. Delivery of the flight-unit to NASA is scheduled for the end of 1987, for launch by the Shuttle in March 1988 and recovery six months later.

The first Eureca payload will consist mainly of experiments in the microgravity sciences (life and material sciences) and will be completed by a limited number of experiments in space science and technology. Work on the payload is proceeding in parallel, with facilities being developed in European industry and the experiments themselves by national institutes or space agencies. Delivery of all payload elements to MBB/Erno is currently scheduled for early 1987 for integration on Eureca prior to its shipment to the United States.

European Broadcasting Union (EBU) and ESA Sign Agreement on Use of the Olympus Satellite



A major step forward in European collaboration took place on Tuesday 28 May 1985, when ESA and the EBU signed an Agreement at the EBU's Geneva Headquarters concerning use of Olympus, the Agency's first Direct-Broadcast Satellite (DBS), which is due to be launched in 1987.

The Agreement was signed on behalf of ESA by its Director General, Prof. R. Lüst, and for the EBU, by its President, Mr. A. Scharf (ARD) and one of its Vice-Presidents, Mr. G. Waters (RTE).

The EBU was signing on behalf of four of its members – ARD (Germany), NOS (Netherlands), RTE (Ireland) and RAI (Italy) – which have formed a Consortium for the coordinated use of Olympus for the broadcasting of a pan-European television programme.

Under the terms of the Agreement, the members of the EBU consortium (open to other members still wishing to join) will have free access for a three-year experimental period to one of the two 12 GHz broadcasting transponders that Olympus will carry as part of its payload. The other transponder will be available to the Italian broadcasting organisation, RAI, with which a cooperative Agreement has already been signed.

LATE NEWS LATE NEWS LATE NEWS LATE NEWS...

Spacelab-2 Launched

On 29 July at 23.00 h local time, Spacelab-2 was successfully launched from Kennedy Space Center with the Space Shuttle Challenger, after a delay of 1 h 30 min. because of problems with a solid rocket booster. The launch initially looked perfect but after approximately 5 min. one of the Shuttle's main engines shut down. With the other engines performing nominally the Shuttle reached an orbital altitude of about 50 miles lower than nominal. This discrepancy was later corrected, and an almost nominal orbit was achieved.

This 7-day mission is the first flight of Spacelab in pallet-only mode, with subsystems such as computers and data handling equipment contained in the pressurised 'Igloo'. The mission, carrying a total of 13 experiments from six scientific disciplines, is also the first flight of the Instrument Pointing System (IPS).

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table and using the Order Form inside the back cover of this issue.

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The following papers have been published in ESA Journal Vol. 9, No. 2:

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SMITH W L & KELLY G A M

USE OF DOPPLER RADAR AND RADAR NETWORKS IN MESOSCALE ANALYSIS AND FORECASTING
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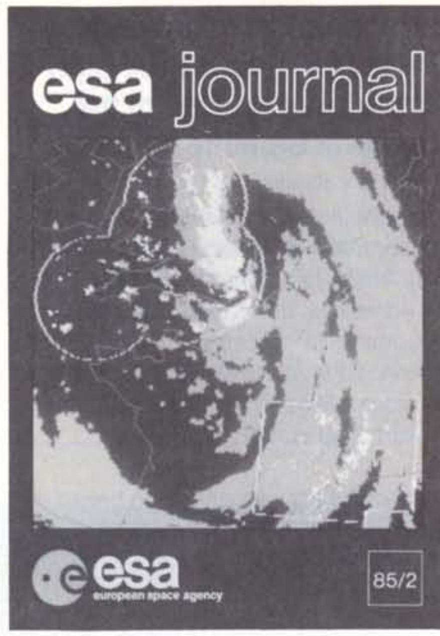

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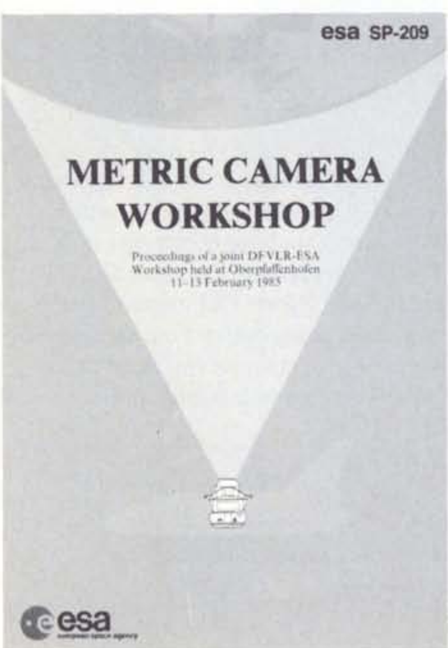

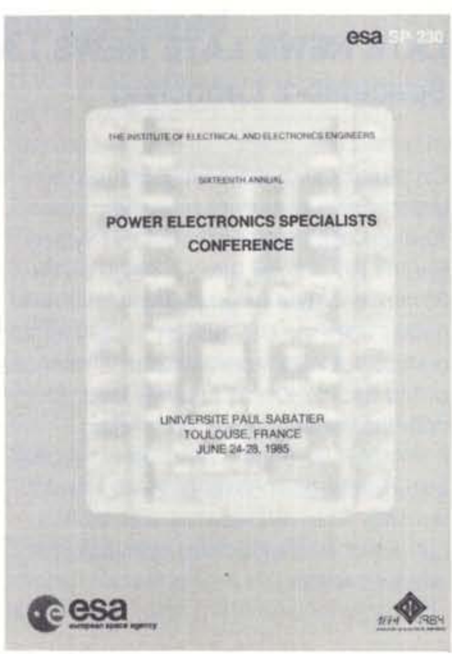

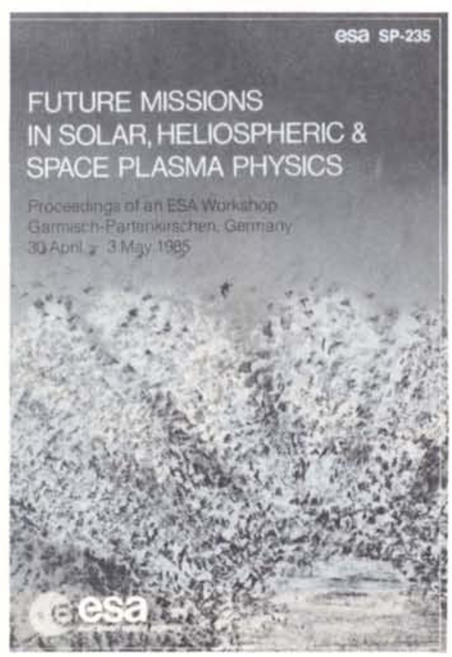

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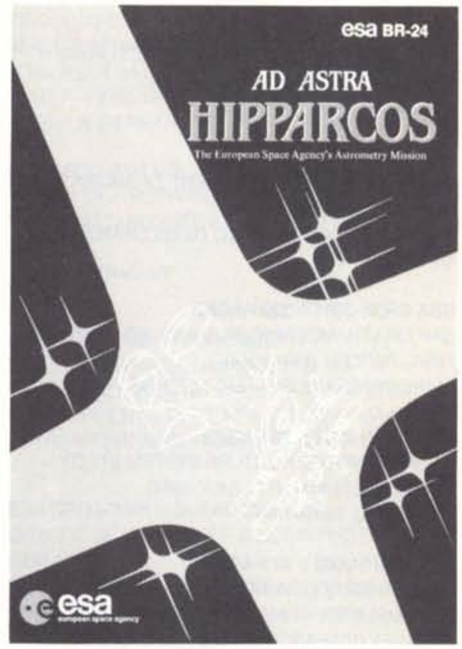

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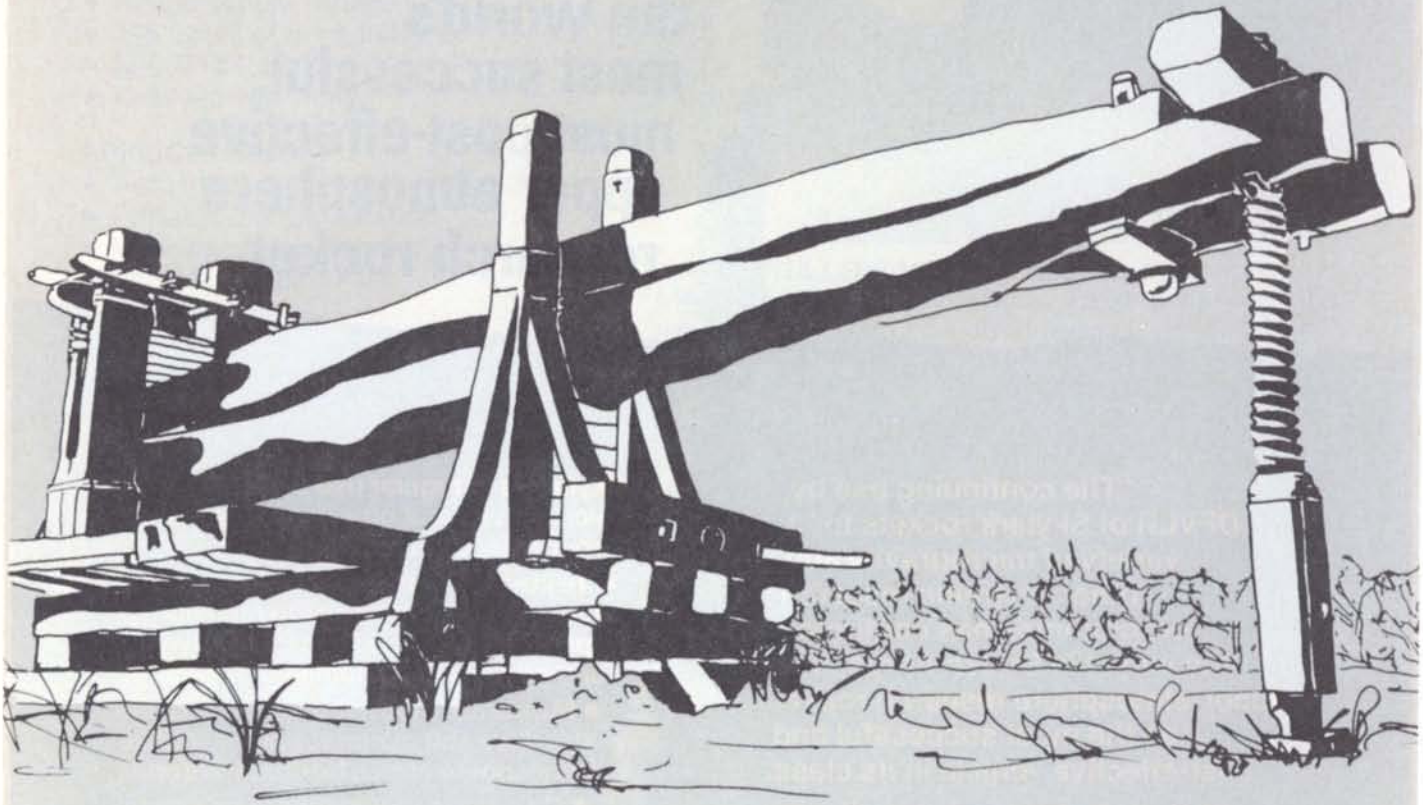

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