esa bulletin

number 27

august 1981

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 is an Associate Member of the Agency. Canada and Norway have Observer status.

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 ESOC, 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: Prof. H. Curien (France).

Director General: Mr. E. Quistgaard.

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 est un membre associé de l'Agence. Le Canada et la Norvège bénéficient d'un statut d'observateur.

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

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

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

Le Directoire de l'Agence est composé du Directeur général, du Directeur des Programmes scientifiques, du Directeur des Programmes d'Applications, du Directeur des Systèmes de Transport spatial, du Directeur technique, du Directeur de l'ESOC et du Directeur de l'Administration.

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie.

Président du Conseil: Prof. H. Curien (France).

Directeur général: M. E. Quistgaard.

esa bulletin

no. 27 august 1981

contents/sommaire

Front cover: The third, completely successful, launch of Europe's Ariane from the Guiana Space Centre

Back cover: Three-dimensional representation of particle intensity distribution measured by the low-energy proton experiment on ISEE-3

Editorial/Circulation Office
ESA Scientific and Technical Publications Branch
c/o ESTEC, Noordwijk, The Netherlands

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Editorial Assistants
Jacqui Mort, Gabrielle Lévy

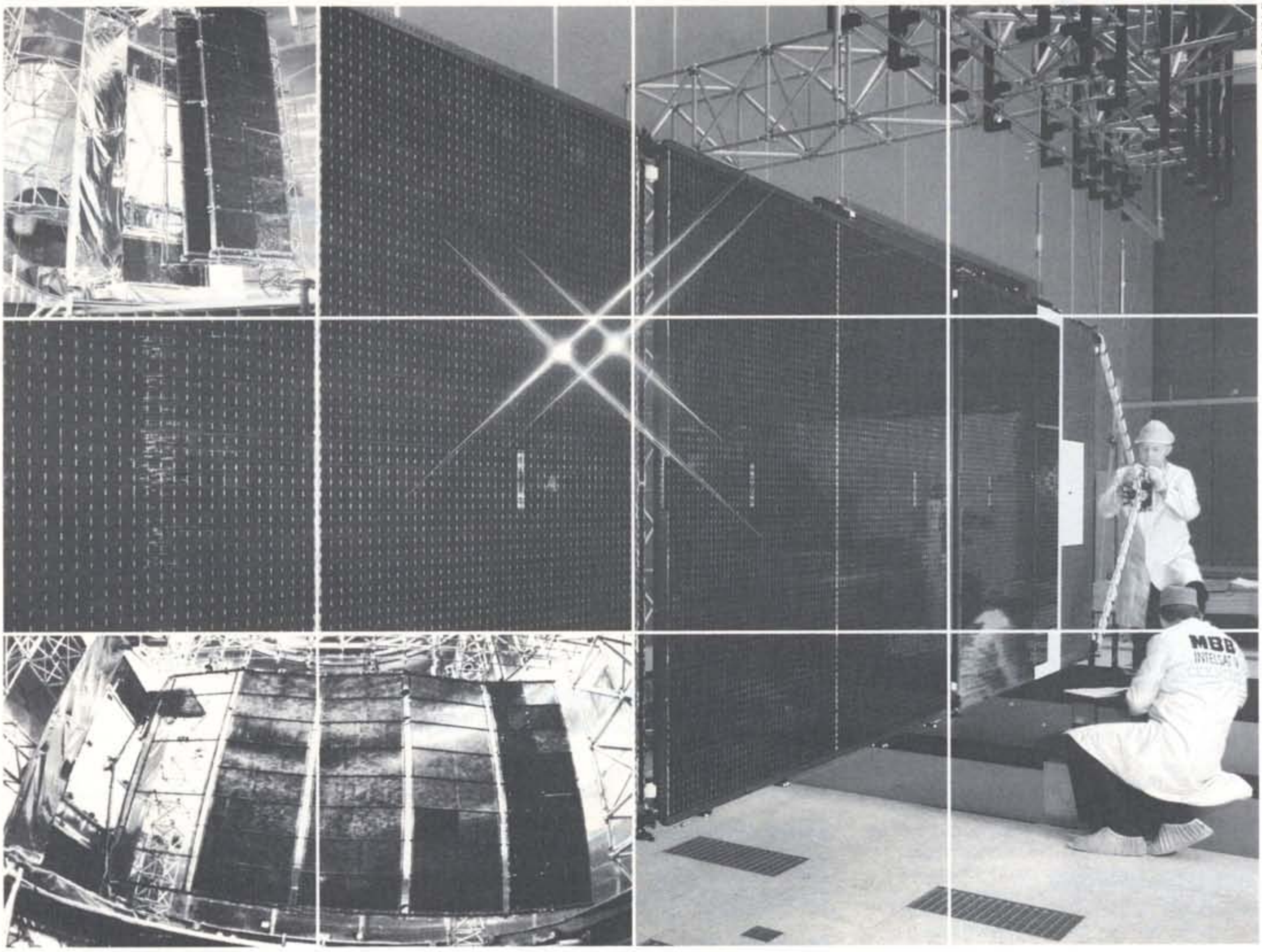
Layout
Carel Haakman

Advertising Agent
La Presse Technique SA
3 rue du Vieux-Billard
CH-1211 Geneva 4

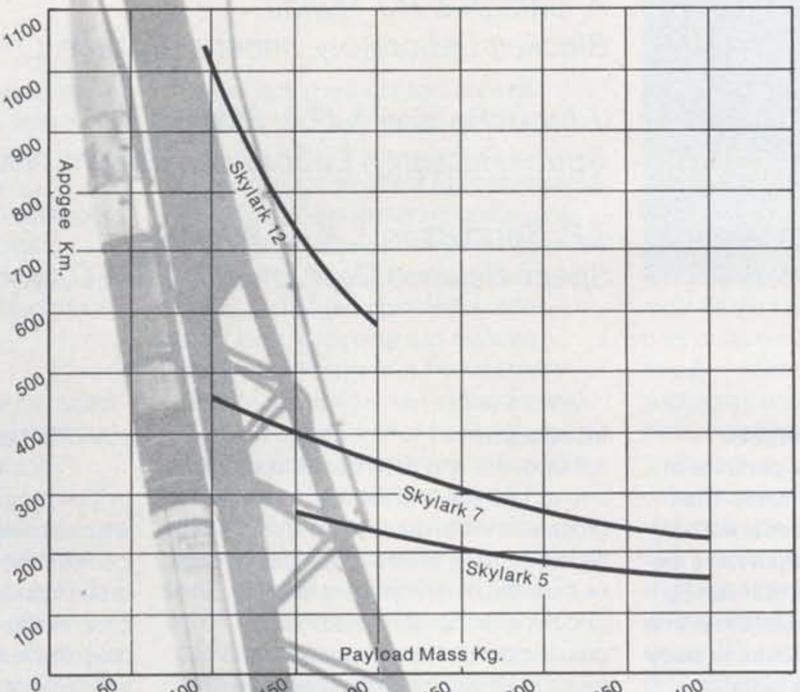
Printed in The Netherlands by ESTEC Reproduction Services 811536
ISSN 0376-4265

european space agency
agence spatiale européenne

8-10, rue Mario-Nikis
75738 Paris 15, France


MBB
INTELSAT V

Skylark...



the *immediately available* platform for zero-gravity and other experiments in space

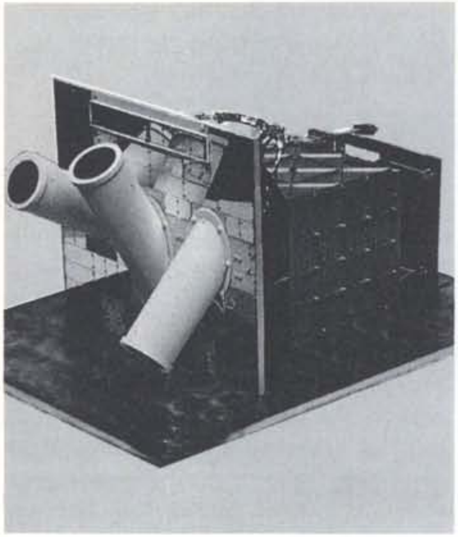
Skylark upper-atmosphere research rockets have proved their dependability and versatility in some 400 launchings over 20 years. Today they are enabling scientists in the Federal Republic of Germany, Sweden and elsewhere to carry out experiments under microgravity conditions and so test in advance the practical value of future research on Space Shuttle. Skylark payload/altitude options range from 100 to 400 kgs payload and from 150 to 1,050 kms altitude, with up to 7 minutes' useable time for microgravity experiments into metallurgy, ceramics, optical glasses, fluid dynamics, physics and chemistry generally.

For more detailed information, please complete the coupon.

Marketing Manager,
British Aerospace Dynamics Group,
Space & Communications Division,
GPO Box 5, Filton,
Bristol BS12 7QW, England

BRITISH AEROSPACE
unequalled in its range of aerospace programmes
DYNAMICS GROUP

Please send details of SKYLARK research rockets.
Name
Organisation
Position
Address
Nature of research



Energetic Particles in the Heliosphere – Results from the ISEE-3 Spacecraft

A. Balogh & R.J. Hynds,
Blackett Laboratory, Imperial College, London

J.J. van Rooijen & G.A. Stevens,
Space Research Laboratory, Utrecht, Netherlands

T.R. Sanderson & K.-P. Wenzel,
Space Science Dept. of ESA, ESTEC, Noordwijk, Netherlands

The existence of highly energetic, electrically charged atomic particles in space – and impacting the earth – has been known for many decades, but only since space exploration began have we come to recognise fully the rich variety of these particle fluxes. One of the prime aims of space science has been to study the observable parameters of these energetic particle fluxes in order to discover their origin and unravel the physical processes that govern their propagation through space. These investigations constitute one of the main branches of astrophysical research. Within this field, we describe in the following some new results based on observations obtained by our instrument on the ISEE-3 spacecraft.

Introduction

Astrophysics is in essence the study of energy sources and energy-conversion processes in the universe. The sun, a star typical of many others in the galaxy, is for us both the most important energy source and the one that can be studied in greatest detail. The many and varied forms in which it releases energy are the subject of wide-ranging experimental, observational and theoretical investigations.

A particular form of energy output from the sun is the continuous emission of high-velocity plasma, constituting the solar wind, which drags out with it the magnetic field from the surface of the sun. The solar wind and the extended solar magnetic field within it define and structure the electromagnetic properties of interplanetary space. They also interact strongly with the magnetic fields of those planets which, like the earth, possess one, resulting in the creation of magnetospheres around those planets. The solar wind remains the dominant agent in a very large volume around the sun – the heliosphere – the boundaries of which are as yet unknown and have not been encountered by any of the deep-space probes on their way to the outer reaches of the solar system.

Our particular research project has been undertaken to investigate the properties of a well-defined energetic-particle population in interplanetary space. Our observations, and the results to be described, are intimately connected with the structure and properties of the interplanetary medium as defined by the flow of the solar wind.

In the enormously wide energy range in which accelerated (i.e. energetic) particles can be observed, covering about 15 orders of magnitude, our interest is concentrated in the two orders of magnitude at the lower end of the spectrum of particle energies. To be precise, we are interested mainly in protons, the most abundant energetic particle species, in the energy range from about 30 keV to 1600 keV.

With our instrument we can observe three different particle populations originating in the heliosphere. Their sources are the sun, the earth's magnetosphere and the interplanetary medium itself, at, or close to, shock waves propagating through it.

The most dramatic source of energetic particles in the heliosphere is the solar flare, which is an abrupt emission of energy from a small area on the solar surface. Although the energetic processes leading to, and occurring during solar flares have been the subject of intensive observations and theoretical studies for many years, many questions still remain unanswered.

While most of the directly observed energy output from solar flares is in other forms, we know that many of the larger and at least a few of the smaller ones result in the emission of at times very intense fluxes of energetic charged particles. Such flare-associated fluxes are obviously present in our observations. Their presence in interplanetary space is relevant for us as the input for further energy-conversion

Figure 1 – The formation of shock waves in interplanetary space: (a) driven by material ejected during a solar flare, and (b) at colliding streams in the solar wind

processes. Indeed, in the energy range of interest to us, the propagation path of the particles through the interplanetary plasma so much modifies their characteristic features that any attempt to relate them directly to the original processes on the sun is fraught with difficulties and is likely, at this stage, to remain somewhat speculative.

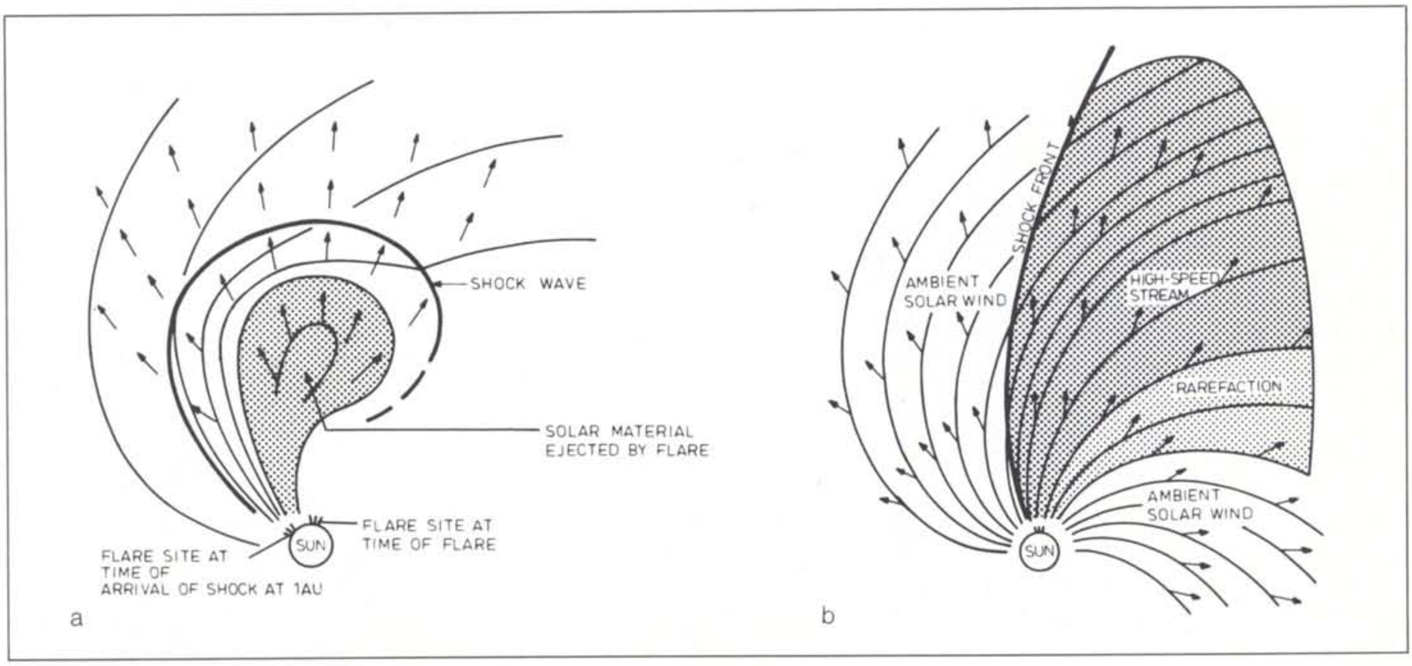
Energetic-particle fluxes are also created in the interaction processes between the solar wind and planetary magnetospheres. Some particle fluxes, occasionally with high intensities, are ejected from the neighbourhood of the planet, and so can contribute to particle populations observed even at great distances from the planet. This effect has been clearly observed in the case of both the earth and Jupiter, two planets with well developed and active magnetospheres. Our investigations into these particle fluxes in the case of the earth are described below.

The third source of particle populations in the heliosphere is associated with interplanetary shock waves. Its nature and its potential importance are the subject of much ongoing debate and considerable theoretical and experimental effort.

The question is, what energy conversions take place in interplanetary space as a result of both large and small irregularities in the flow of the solar wind, and involve energetic-charged-particle fluxes? In particular, it is important to establish whether shock waves in the solar wind – created either on the sun in the eruptive process of solar flares or by colliding solar-wind streams of different velocities – are the initiating agents and power sources of energising processes for creating certain populations of energetic particles. A detailed answer to these questions is important and has far-reaching consequences, not least because shock waves are generated throughout the galaxy on many different scales and could be considered as prime candidates for generating a significant proportion of cosmic rays originating outside the solar system. Also, a large proportion of energetic particles, emitted from the sun at the time of solar flares, could be accelerated close to the flare site by shock waves generated in the solar atmosphere by the blast of the solar flare.

Observations in space over the last ten years have provided convincing but often indirect evidence that shock waves indeed accelerate charged particles. However, it has not been possible to settle the question beyond doubt and to interpret correctly all the observed phenomena. In most cases it is only possible to observe at one, or at most at a very few isolated points in space at any given time, where spacecraft with the correct instrumentation happen to be. As the process in space apparently has dimensions on the scale of the earth/sun distance, or at least a significant fraction of it, it is virtually impossible to construct all but the crudest picture of a shock wave propagating through interplanetary space. It is also clear that the relevant processes depend on many factors, not all of which can be either estimated or measured, and the interplay of many parameters introduces a great variability in the observations.

Progress in understanding energetic-particle fluxes associated with shock waves can only result from careful evaluation of observational possibilities, detailed analysis of all the relevant data,



preferably involving a number of spacecraft, and imaginative synthesis into a coherent overall picture.

Shock waves and the earth's bow shock

It is appropriate at this stage to give some details on both the origin of shock waves and the structure of the earth's environment in order to define the broad context in which our investigations of interplanetary energetic-particle fluxes take place.

Shock waves in interplanetary space can arise from at least two distinct causes. Firstly, solar flares are normally accompanied by the ejection of a large amount of material from the solar surface. As the ejected material blasts its way through the solar atmosphere and the solar wind, a shock wave is generated in front of it. Such shock waves are routinely observed in the vicinity of the earth after most large solar flares. It is characteristic of such shock waves that behind them the remnant of the originally ejected material, the driver gas, can usually be identified. These shock waves have been observed at large distances beyond the orbit of the earth by the outbound Pioneer and Voyager spacecraft. A schematic of a flare-generated interplanetary shock wave is shown in Figure 1a.

Another mechanism for generating shock waves in interplanetary space finds its origin in the fact that the flow velocity of the solar wind is not uniform over the surface of the sun. Often there are areas on the solar surface from which the flow velocity is substantially higher than the average (400 km/s). Since the sources of solar-wind streams of different velocities are all anchored to the sun, as the sun rotates the faster spiralling streams catch and compress the preceding slower ones and an interaction region is generated. Because of the rarefaction of the solar wind as it expands away from the sun, the boundaries of the interaction regions become shock waves, usually at distances beyond the orbit of the earth. The frequently observed stability of the source regions of the solar wind over several of the 27-day rotation periods of the sun leads to the same pattern of interaction regions being swept repeatedly past the earth. These so-called 'Co-rotating Interaction Regions (CIR)' dominate the structure of interplanetary space beyond the earth's orbit (Fig. 1b).

It is possible to consider a third, somewhat speculative, mechanism for generating shock waves, which could be the result of ejection of material from the upper atmosphere – the corona – of the sun. Such mass ejections, first noted from Skylab, are not related to solar flares and are difficult to detect. There is at present an unexplained discrepancy between the frequency of mass ejections and the number of shock waves potentially arising from this source.

It is a rather special shock wave that forms the outer boundary of the earth's domain in space. This shock wave is stationary in the solar wind, as it is formed by the latter as it flows round the obstruction in its path represented by the earth's magnetic field. Inside this bow shock the flow of plasma becomes irregular; the earth's magnetic field is compressed at the sunward side and elongated at the back, generating a long tail of stretched out magnetic field lines. As neither the flow of the solar wind nor the magnetic field carried within it are uniform, their interaction with the earth's magnetic field results in many dynamic, time-varying phenomena, the most spectacular of which are the aurora. Among many other less spectacular, but physically significant phenomena, the emission of energetic-particle bursts upstream into interplanetary space has been closely investigated by a number of research groups in the past few years. The difficulty in understanding the details of the process lies mainly in the highly time-varying and nonuniform structure of these bursts in space.

The spacecraft

Our instrument, the Low Energy Proton experiment, is part of the scientific payload of ISEE-3, one of the three spacecraft in the joint ESA/NASA International Sun-Earth Explorer programme, initiated in 1971/72. ISEE-3 was launched in 1978 into a novel and so far unique orbit, around the so-called Lagrange or libration point (L_1) between the sun and the earth, where the heliocentric motion of the spacecraft remains in dynamic equilibrium with the gravitational forces of the sun and the earth. The spacecraft's distance from the sun is very nearly constant, at about 1.5 million km, and as the earth orbits around the sun ISEE-3 always remains in front of the earth (Fig. 2). Its observations

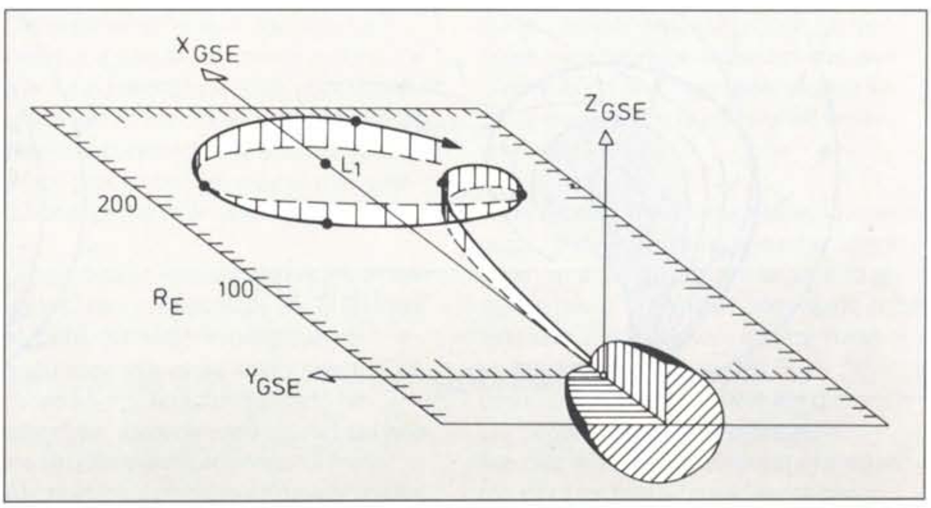


Figure 2 – The trajectory of the ISEE-3 spacecraft to its orbit around the libration point (L1) of the sun-earth system

therefore correlate well with earth-bound observations. The relatively small distance from the earth – at least in interplanetary terms – ensures a good link for relaying observational data to the tracking stations and the volume of data retrieved from the spacecraft has remained at a consistently high level since launch. ISEE-3 is therefore in several respects an ideal platform from which to monitor interplanetary phenomena.

The instruments on the spacecraft perform observations that can be correlated to construct a fairly complete picture of interplanetary conditions just ahead of the earth. Comprehensive analysis of the observations has been greatly helped by the provision of a so-called 'data pool', in which some of the preliminary data from all the instruments on board have been collected, and issued to all investigators.

The Low Energy Proton experiment
The experiment was conceived, designed and built to extract the maximum of information on the distribution function of the low-energy-proton component of the heliospheric energetic-particle population. Physical processes acting on a particle population are best described by their effect on the spatial and temporal evolution of its distribution function. The concept of the distribution function, defined as the number of particles moving with a certain velocity in a certain direction at a given point in space and time, was introduced because it is neither useful nor possible to study in detail what happens to an individual particle: we are interested only in the collective behaviour of large numbers of them.

In practice, the instrument counts the number of protons incident on it, sorting them into various energy (and therefore velocity) intervals, performing this function in a number of different directions. A measure of the quality of such an instrument lies in the resolution with which the distribution function and its time evolution can be deduced. Our instrument is able to measure 180 sample points every 16 s, an unprecedented rate for the energy interval in question.

The particle-sensing detectors of the instrument (Fig. 3) are contained in three identical telescopes, inclined at different angles relative to the spin axis and designed to restrict the directions from which particles can impact on the detectors. As the spacecraft spins, with one rotation every 3 seconds, the three telescopes scan in different directions in space. This allows us to resolve particle fluxes in different directions. Each complete spin of the spacecraft is divided (electronically) into eight equal angular sectors. Protons incident on the three telescopes are thus counted independently in the resulting 24 directional intervals. Each incident proton is also counted according to its energy, in eight nonoverlapping but adjacent energy intervals or energy channels.

There are a number of technical reasons why our particular energy interval had not been more thoroughly explored in the past. In our case, a number of favourable factors have combined to make the experiment possible.

Firstly, the ISEE-3 spacecraft contributes a novel orbit, a high-rate data link, and a stable attitude in space. This last factor has been crucial, because it has allowed us to point our telescopes so that no sunlight, which could destroy the measuring capability of the detectors, could fall within their viewing directions.

The weight, size and power consumption of space instruments are always severely limited, but advances in technology have allowed us to pack in more and better electronic circuitry on ISEE-3 for signal processing.

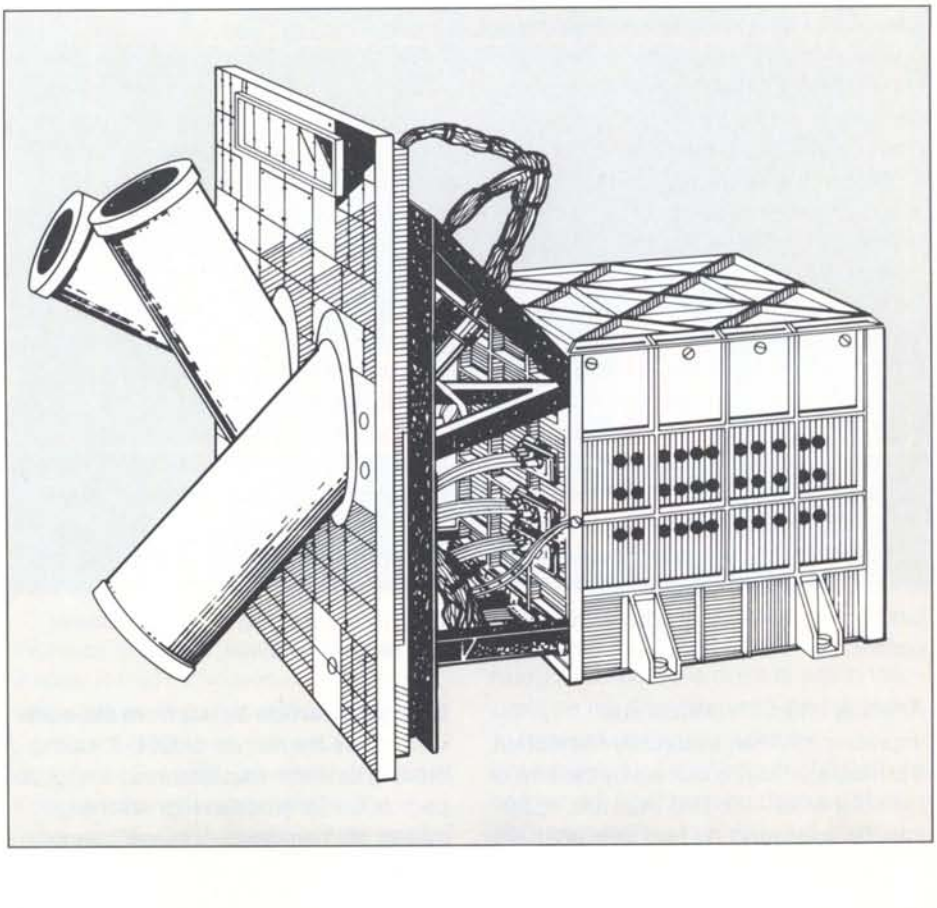
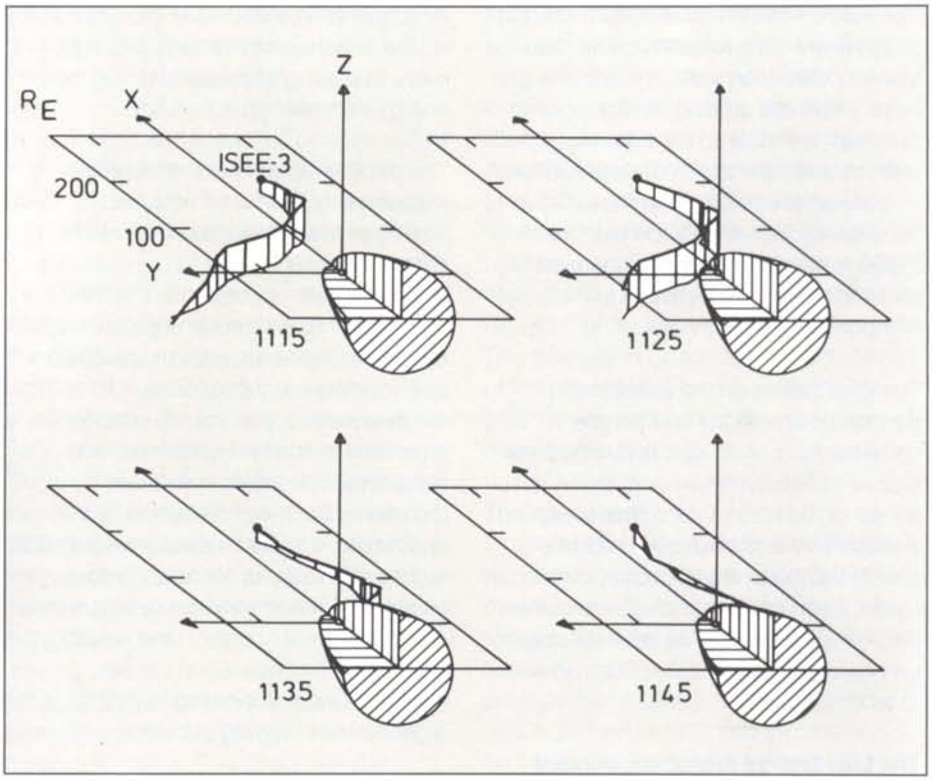


Figure 3 – The Low Energy Proton experiment

Figure 4 – Traces of the magnetic-field connection paths at the position of ISEE-3. In the upper figures no connection exists between the spacecraft and the magnetosphere. In the lower figures the magnetic highway is established and protons beamed from the magnetosphere are detected by the experiment



A very high priority in the design of the instrument was given to the unambiguous detection of the lowest possible particle energies, reducing electronic noise in the instrument by cooling the detecting system to −20° to −30°C. The three proton telescopes containing the particle detectors and their associated signal amplifiers are mounted on a 'cold-plate' and thermally isolated from the rest of the instrument and the spacecraft (Fig. 3).

After almost three years of trouble-free operation, the instrument has already gathered a vast amount of interesting data, allowing the investigating team and a number of external collaborators to study in detail many previously unexplored, interplanetary physical processes.

Results of observations
Before describing our results, it is useful to review briefly some of the characteristics of the distribution function of the energetic-proton population as they influence our approach to interpreting our observations. The fundamental physical fact here is that electrically charged particles in a magnetic field move in helical orbits around the lines of force. As a result, in any large-scale magnetic field, such as the extended field of the sun in interplanetary space, the flow of particle populations is structured by the lines of force of the field. Hence the distribution function of charged particles (at a given energy), which implicitly describes their flow, also reflects the structure of the magnetic field. In a smooth, uniform magnetic field the distribution function is usually symmetric around the field lines. The interplanetary field, on the other hand, is neither very uniform, nor is it smooth. Therefore, the distribution function is, at best, only approximately symmetric.

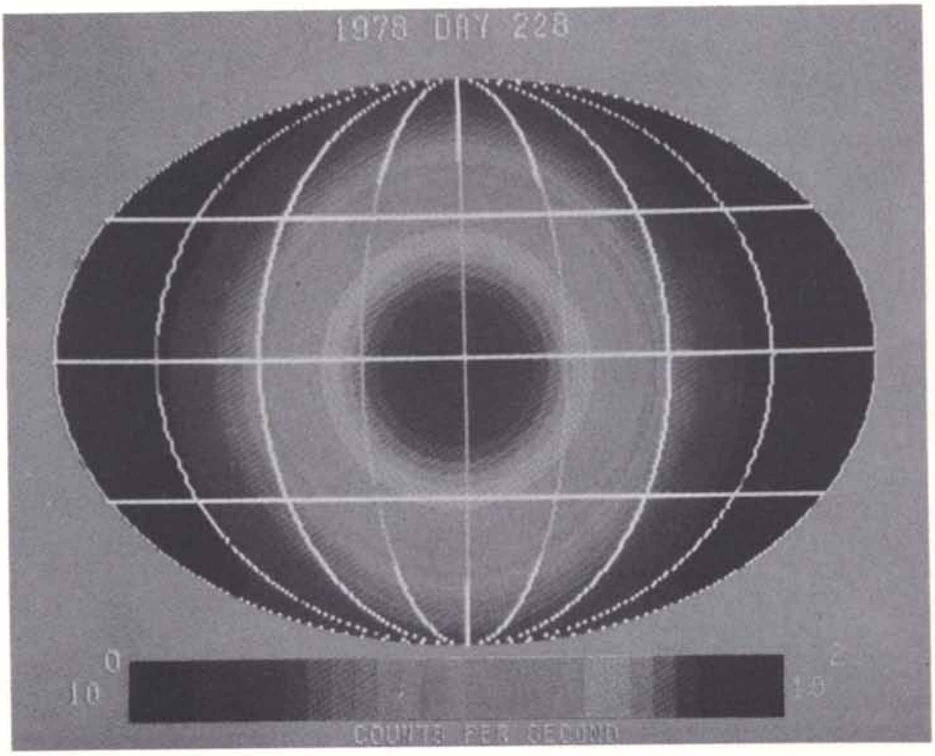
A further effect of considerable importance is that, as already mentioned, the magnetic field is carried by the flow of the solar wind – the field lines are 'frozen' into the solar wind. As field lines are swept past the spacecraft and our instrument at 400 km/s, the distribution function, which may be symmetric around the magnetic field lines, appears to us, as stationary observers, as very nonsymmetric. To obtain the distribution function structured by the moving magnetic field lines, we transform our observations to those an observer moving with the magnetic field lines would make. This transformation is far from trivial, but because we measure simultaneously 180 points on the distribution function seen from the spacecraft, we are able to determine the transformed distribution function with so far unequalled precision. We have therefore concentrated on the study of those interplanetary phenomena for which this capability of our instrument can be best exploited.

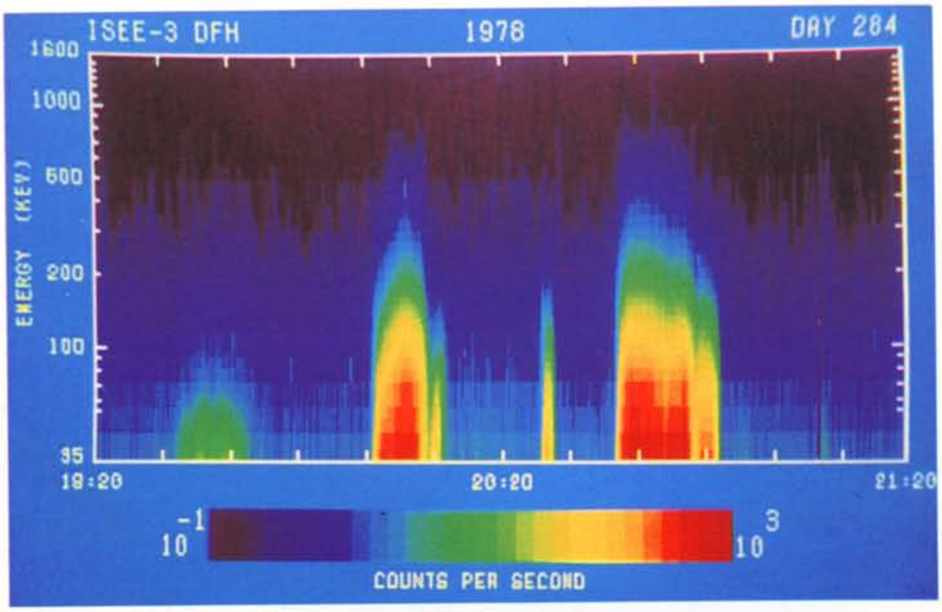
Energetic-particle bursts from the earth
Well before the launch of ISEE-3, earth-orbiting satellites had observed energetic-particle bursts (sudden high-intensity events) in interplanetary space clearly originating from the earth's magnetosphere. These observations were made at distances from which the magnetosphere still appears as a large 'object'. However, it was also anticipated that such events would almost certainly disappear at the proposed orbit of ISEE-3, about 1.5 million km from the earth. Contrary to this expectation, burst events were observed throughout the spacecraft's journey to its eventual orbit, although they became less frequent as the distance increased. It is now clear that given a magnetic 'highway' to guide them, energetic particles 'beamed' from the earth's magnetosphere reach the position of the spacecraft and are observed by the experiment, as well as by other instruments on the spacecraft which observe other aspects of the phenomenon.

This is a somewhat unexpected, but thereby all the more interesting subject to investigate and one which has already proved very fruitful.

Figure 5 – Three-dimensional representation of the proton intensity distribution showing the beam-like flow of particles along the magnetic field during an upstream burst event from the direction of the earth. The axes are aligned so that the interplanetary magnetic field is at the centre of the picture. (this illustration is reproduced in colour on the back cover of this issue).

Figure 6 – Series of energetic-particle bursts originating in the earth's magnetosphere





Our investigations have focused on the physical processes involved in the propagation of energetic protons from the earth and on deriving a model for the spatial structure of the bursts.

Analysis of a large number of burst events has shown that a necessary, and apparently sufficient condition for us to observe the bursts is that the direction of the interplanetary magnetic field must be such as to connect the spacecraft to the earth's magnetosphere by a magnetic-field 'highway'. By 'tracing' the magnetic field line observed at the spacecraft back towards the earth, it is possible to diagnose whether or not the field line is connected to the magnetosphere. Such a set of traces is shown in Figure 4.

The burst event itself is quite impressive: the proton telescopes suddenly observe a high-intensity beam, directed from the earth (Fig. 5). The sudden rise in intensity is followed by some minutes of relatively constant flux and then, as suddenly as they appeared, the particles disappear. There are often a number of events of different duration in quick succession (Fig. 6). By closely examining the flow patterns of energetic protons in these events, in particular the asymmetries in the distribution function, we have been able to propose a model for the large-scale structure of the bursts.

Whatever the source of energetic particles near the front side of the magnetosphere, the result is a sheet- or slab-like region of space filled with particles. The slabs are quite thin, at least on the interplanetary scale, and we can only observe the particle beams when the slab is swept past the spacecraft, tied to the interplanetary magnetic field line which is connected to the earth's magnetosphere.

Another aspect investigated in detail has been the influence of conditions in the solar wind on the way in which particles in the burst propagate along the magnetic 'highway'. This study has a dual aim. Firstly, it can establish whether the 'highway' is smooth or not. Here the answer is that it is indeed mostly smooth, with particles travelling without any significant 'accidents' or trajectory deviations. Secondly, we are studying just how particles are accelerated in the interplanetary field, whatever their origin. This is very important because we can rarely observe at the point at which the particles are first energised, and we have to extrapolate to the source by accounting for the effects on the particles of their journey from source to point of observation.

Figure 7 – Intensity of low-energy proton fluxes, as a function of time, measured in different energy intervals. The increase was caused by the passage of the interplanetary shock wave

Energetic particles and interplanetary shock waves

The simplest analysis of energetic-charged-particle fluxes involves studying their intensity as a function of time and relating the observed variations in intensity to the occurrence of other, conceivably connected, phenomena. In the case of interplanetary shock waves there can be no doubt at all: at their passage, they are almost always accompanied by a noticeable increase in the intensity of low-energy proton fluxes. This effect is less frequently observed at higher energies, although it was at these energies that a possible connection between shock waves and the energising of charged particles was first noted. In fact, one of the reasons for exploring the lower end of the spectrum of energies was to study this connection, as it could reasonably be expected that lower energy particles would be more affected by the sudden change in interplanetary conditions represented by the passage of a shock wave.

Shock waves are detected by instruments measuring the solar wind and the magnetic field. (Interplanetary shock waves also affect the earth's magnetic field and at their passage geophysical observatories around the world note a characteristic change in the magnetic field, followed by a disturbed period referred to as a magnetic storm.) From measurements on board the spacecraft a number of parameters characterising individual shock waves, and which are essential for a meaningful analysis of observations of associated charged-particle effects, can be deduced*. Since the launch of ISEE-3, two or three shock waves have been seen every month, i.e. about 30 per year, and this represents a respectable body of observations for establishing their common features.

Two such common features have been known for some years:

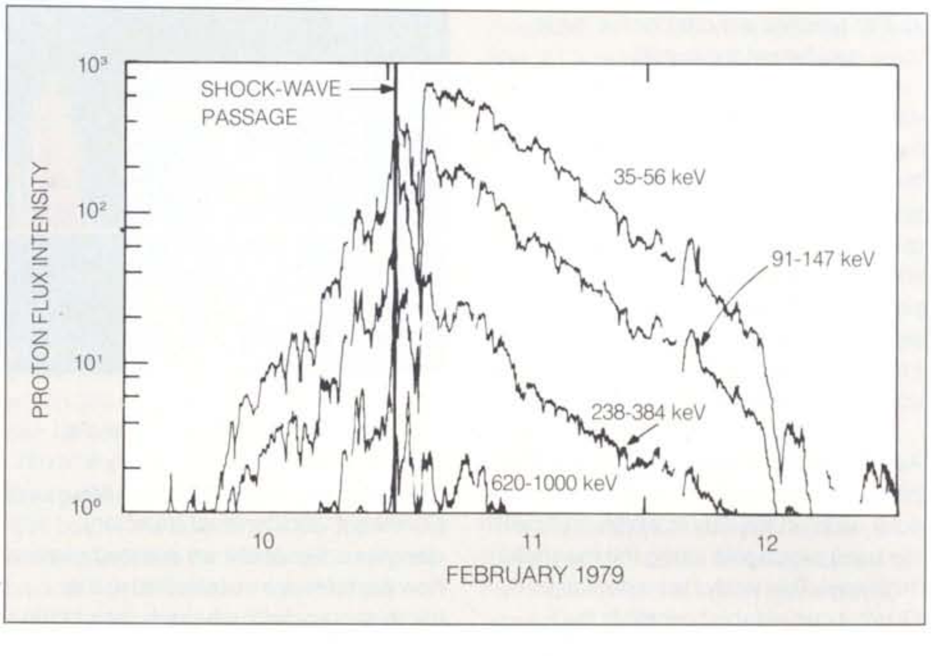
- a rather broad increase in intensity lasting from many hours to a day or two around the passage of the shock wave
- short, sharp spike-like increases, lasting only a few minutes, in close proximity to the shock wave itself.

It has been suggested by a number of authors that the longer lasting intensity increases are caused by the continuous generation of spike-like fluxes of particles energised at the shock wave, which then broaden in time as the shock wave travels from the sun.

However, we must not prejudge the issue of whether the shock wave is indeed a source of energy for the increased flux of low-energy particles that we observe in its vicinity. The difficulties in tackling this problem conclusively have already been mentioned in the introduction. To put it simply, we can say that the shock wave is the active agent in the energisation process of particles, if it can be established that the observations pinpoint it as the source of the fluxes.

If particles could be seen to flow from the direction of the shock wave both before and after its passage, this would be a strong indication that the shock wave were indeed their source. This is in fact what we observe. A shock-wave-associated event that has been studied in detail is illustrated in Figure 7. This event presents a number of interesting features, not the least of which is the fact that the flow of protons is consistently directed away from the shock. The stability of the flow is remarkable in this case because shortly after the shock passage the interplanetary magnetic field reversed its direction. This reversal is not connected with the shock wave, which had clearly propagated through it some hours prior to our observations. Despite the reversal of the magnetic field, the particle flow, which is constrained to remain along the magnetic field lines, was still observed from the direction of the shock wave.

Because the sun is known to be a source of particles, it may be suggested that the shock wave only acts as a barrier to hold back the particles generated on the sun and which simply travel with the shock wave. This may well happen to some extent, but our observations are again in

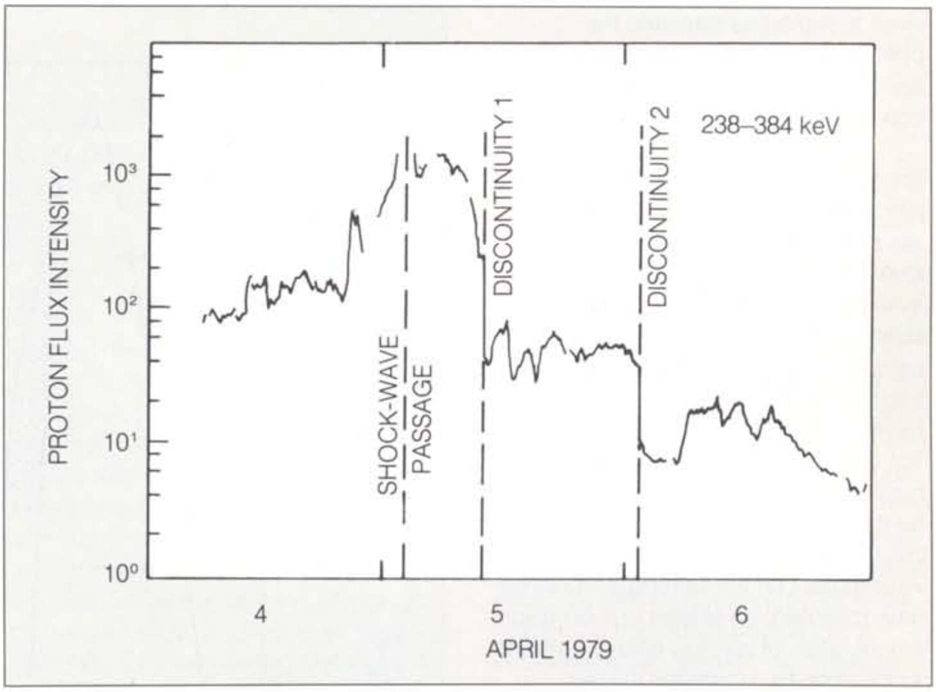


* The provision of relevant data by the investigating teams responsible, respectively, for the magnetometer (Dr. Smith of JPL) and the solar-wind instrument (Dr. Bame of LASL) has been of invaluable help to us here.

Figure 8 – Intensity of proton fluxes measured around the passage of a shock wave shows sudden decreases when abrupt changes in the magnetic field, which protons energised close to the shock wave could not penetrate, are swept past the spacecraft

Figure 9 – Spike-like intensity increase of protons freshly energised at the passage of a shock wave

favour of the shock wave being the source of the proton flow. The flow of the solar wind often carries within it discontinuities in the magnetic field which originate from the surface field of the sun. Low-energy protons of interest to us cannot cross these discontinuities easily, if at all, but the shock wave can blast its way through them. Figure 8 shows a particular shock-associated event during which two such discontinuities were observed in the solar wind after the passage of the shock wave. The fluxes are clearly very different on the two sides of both discontinuities, and in both cases the intensity is higher on the side of the shock wave. It has been concluded that the protons were energised close to the shock wave and were then prevented from moving from the side close to the shock wave to the sunward side of the discontinuities.



The spike-like intensity increase close to the shock wave is yet another argument for identifying the shock wave as an active power source for energising processes (Fig. 9). A model to explain this phenomenon has been explored by a number of research workers and is generally accepted to represent at least some of the processes that occur in association with shock waves. There is, however, still debate about its relative importance in the energy-conversion processes taking place in association with the shock wave.

An alternative process has also been proposed: it relies on the fact that particles colliding with the shock wave gain a small amount of energy in each collision. In order to ensure that many energising collisions can take place, the model assumes that as the particles move away from the shock wave after each collision, they are reflected back onto it by irregularities in the lines of force of the magnetic field. This model has also been proposed to explain the much larger scale energisation processes in supernova explosions in the galaxy. The potential similarity between physical processes

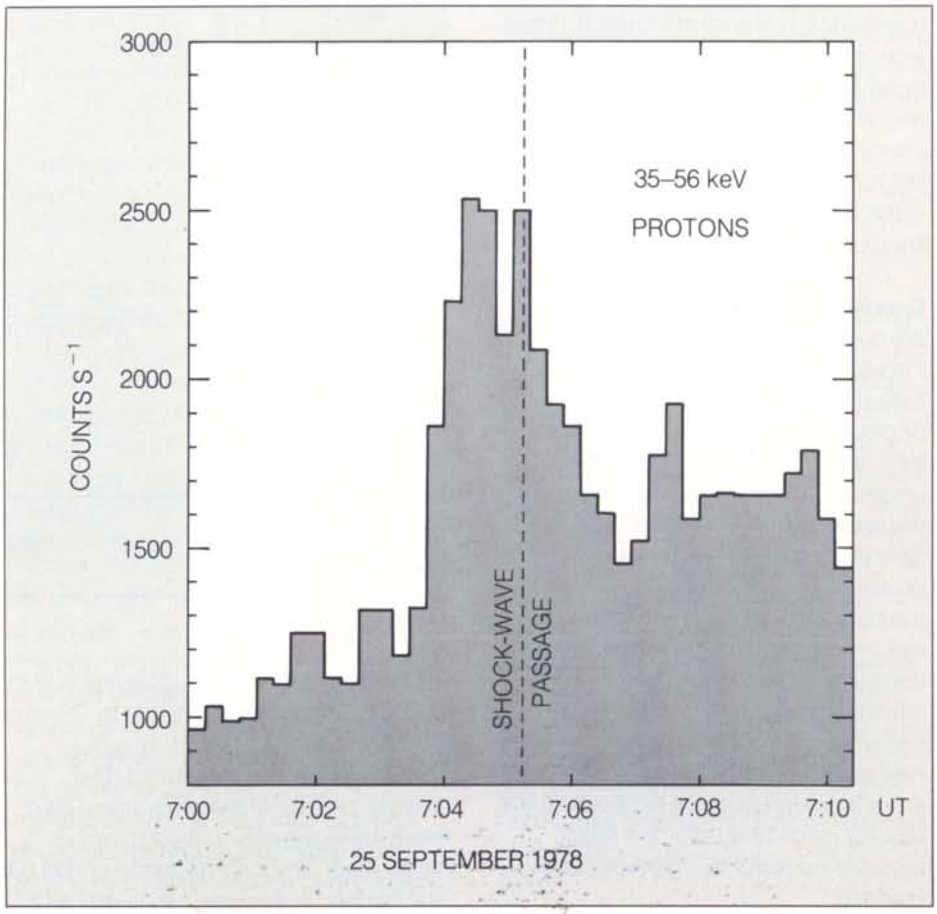
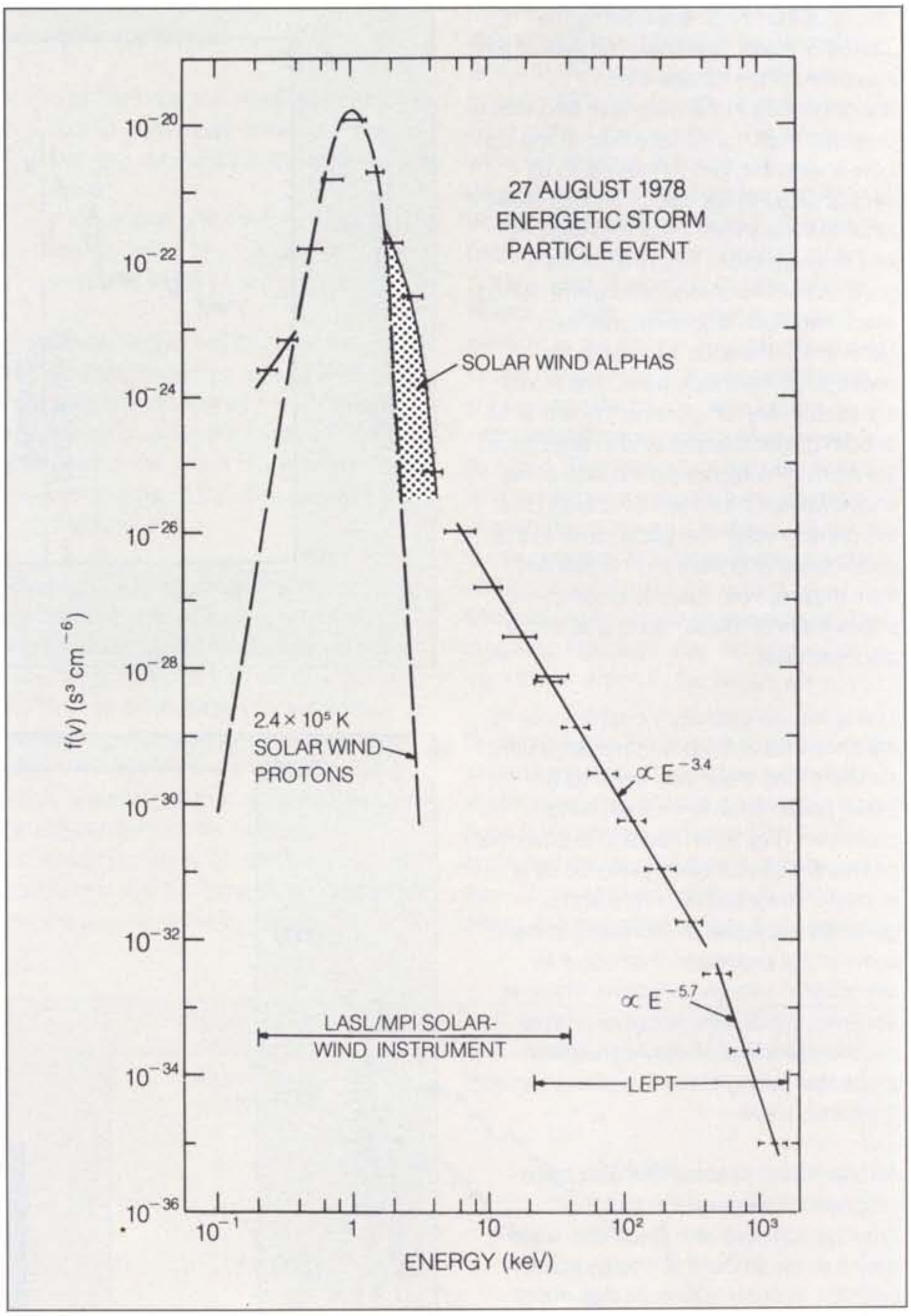


Figure 10 – Energy spectrum of solar-wind and energetic protons showing continuity between the two populations over many orders of magnitude in intensity and energy. Such observations point to the solar wind being the source of particles energised in interplanetary space



close to exploding stars and the phenomena actually observed in the earth's neighbourhood underlines the importance of research in this field.

The source of particles to be energised by processes associated with the shock waves remains to be conclusively identified. The only source continuously available is the proton component of the solar-wind plasma. However, these particles are not energetic enough to fit into the models mentioned above . We have to identify other processes which first energise at least a relatively small number of solar-wind protons sufficiently for the shock wave itself to act on them. In collaboration with the plasma investigators on the same spacecraft we have identified, on at least one occasion, a population of very low energy particles which appeared to bridge the gap between the solar wind and the energised protons that we have observed. This observation is shown in Figure 10. More work is in progress to determine just how general the phenomenon is. The primary acceleration process for solar-wind protons is likely to be found in the wave-like magnetic-field irregularities observed in the region of space disturbed by the shock wave.

Conclusion

We have tried to communicate some of the painstaking experimental and theoretical work being carried out in one particular field of space exploration. Interplanetary space, the broadly understood environment of the earth, is the scene of many energetic processes. Space exploration has opened many new perspectives and it is impossible to ignore the complexity of the phenomena of which we have become aware. Work in the research fields described above is continuing and further progress in understanding, as well as discoveries of new phenomena are to be expected from more thorough analysis of observations already made and from new space missions currently being prepared or planned.

As a footnote it is worth observing that the ISEE programme was initiated by ESA and NASA in 1971/72, at which time our instrument was also designed. The scientific results of the programme have been emerging only in the last two or three years. The long gestation period has not harmed in any way the novelty and usefulness of the observations. Both decision-makers and scientists associated with the ISEE programme have shown that it is possible to live with the long development periods associated with the complex projects of mature space science.

Large-Area Histograms from Meteosat Images

K.O. Röska, Meteosat Data Management Department, European Space Operations Centre (ESOC), Darmstadt, Germany

From multichannel Meteosat images one can build multidimensional histograms that improve one's feature identification and interpretation capabilities. Two-dimensional histograms of large, meteorologically uniform areas are presented here as examples of the technique, together with a method of automatic feature identification that is relatively modest in terms of computer needs.

Images from line-scanning satellites like Meteosat must be computer-composed onto a video display or other imaging system to allow the human interpreter to identify such ground features as rivers, forests, mountains, etc. Moisture in the atmosphere blurs the picture somewhat in the infrared spectral band, and especially in the water-vapour channel. Most high clouds can be clearly seen in all three channels – visible, infrared and water vapour – while the visible and the infrared channels show a strong correspondence to features at surface level. The water-vapour channel best reflects the state of the earth's atmosphere, uninfluenced by small features on the earth's surface.

The images shown in Figures 1a–c were taken by Meteosat-1 at 1200 GMT on day 297 in 1979.

The images themselves are composed of picture elements, or pixels, each of which has a certain grey value. It is the local distribution of the pixels that ultimately produces the image. For ease of interpretation, the clouds in the infrared and water-vapour images have also been displayed in light tones, by inverting the grey scales.

An alternative means of examining the information content of the images of Figures 1a-c is by producing histograms in which the frequency with which the various grey values occur in each image is taken as an indicator of what is seen in the picture or some sector of it. A monodimensional histogram can be produced from each Meteosat channel (one for the visible, one for the infrared, and one for the water vapour). The features from which the extreme grey values originate are known: in the visible channel, for example, the sea is dark and clouds are bright; in the infrared, clouds are cold and the hottest values stem from land features (desert). The originators of the intermediate grey-scale values cannot always by identified with certainty; some 'clusters' in the histogram point to the existence of, say, medium-high clouds, while in some cases land and sea have the same temperature or clouds and land areas have the same brightness. There is therefore still a degree of uncertainty as to the extent to which different features contribute to the intermediate parts of the histogram.

By using images of the same area in more than one channel, one can construct multidimensional histograms in which features that exhibit different characteristics in at least one observing channel can be clearly distinguished. For practical reasons (memory and display), one usually does not venture beyond a two-dimensional treatment of the data, extracted from two of the three Meteosat channels.

During daytime the infrared/visible histogram yields the best target separation, though even the infrared/water-vapour histogram, which can be obtained even at night, resolves some differences in cloud formation. It is doubtful, however, whether the clusters over land regions in the infrared/water-vapour histogram are significant for interpretation purposes.

Meteosat images of the earth's disk
Figure 1(a) Visible (VIS)

Figure 1(b) Infrared (IR)

Figure 1(c) Water vapour (WV)

Figure 2 – Different meteorological regions of the earth's disk

Interpretation key for infrared/visible and infrared/water-vapour histograms

Figure 3 – Histogram for the Mediterranean region

Figure 4 – Histogram for the central African region

Figure 5 – Histogram for the central Atlantic region

Figure 6 – Histogram for the south-west Atlantic region

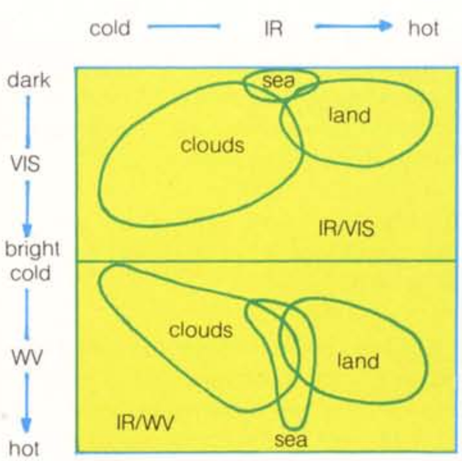

1a


1b

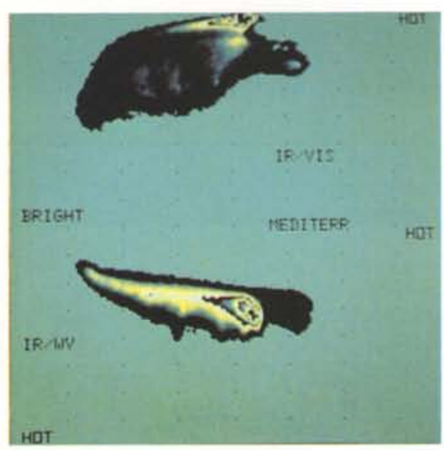

1c

The infrared/visible and infrared/water-vapour histograms shown in Figures 3–6 are for different meteorological regions of the earth's disk identified in Figure 2. They have been smoothed and logarithmically scaled in order to show also the less dominant features. The scaling of the video display is such that the highest values always appear dark and the intensity wraparound draws the contour lines of the third dimension (the height of the histogram). The arrows in the interpretation key point in the direction of increasing radiometer values as measured by Meteosat (remembering that

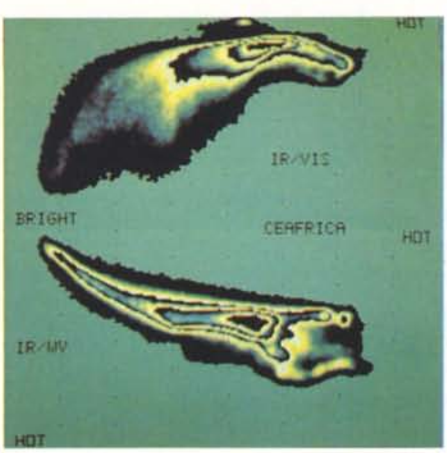

2



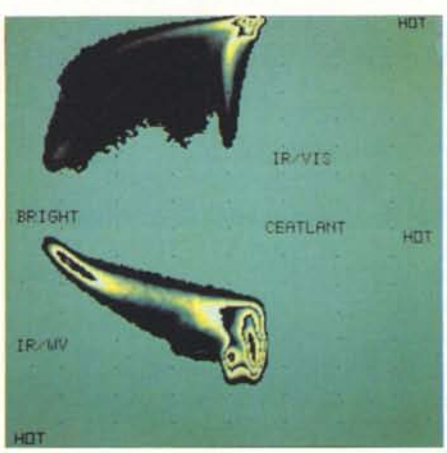
Interpretation key



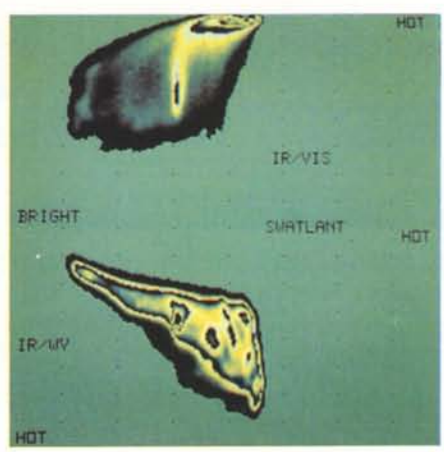
3



4



5



6

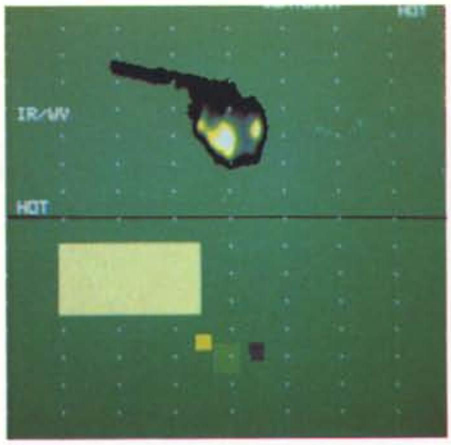
Figure 7 – Meteosat images of the south-east Atlantic region (1000 × 1000 pixels)
(a) Infrared (IR)
(b) Water vapour (WV)

Figure 8 – Infrared/water-vapour histogram and interpretation table for the south-east Atlantic region

Figure 9 – Artificial image developed via the histogram interpretation table

Figure 10 – Infrared/visible and infrared/water-vapour histograms (two dimensional) of the complete earth's disk as viewed by Meteosat

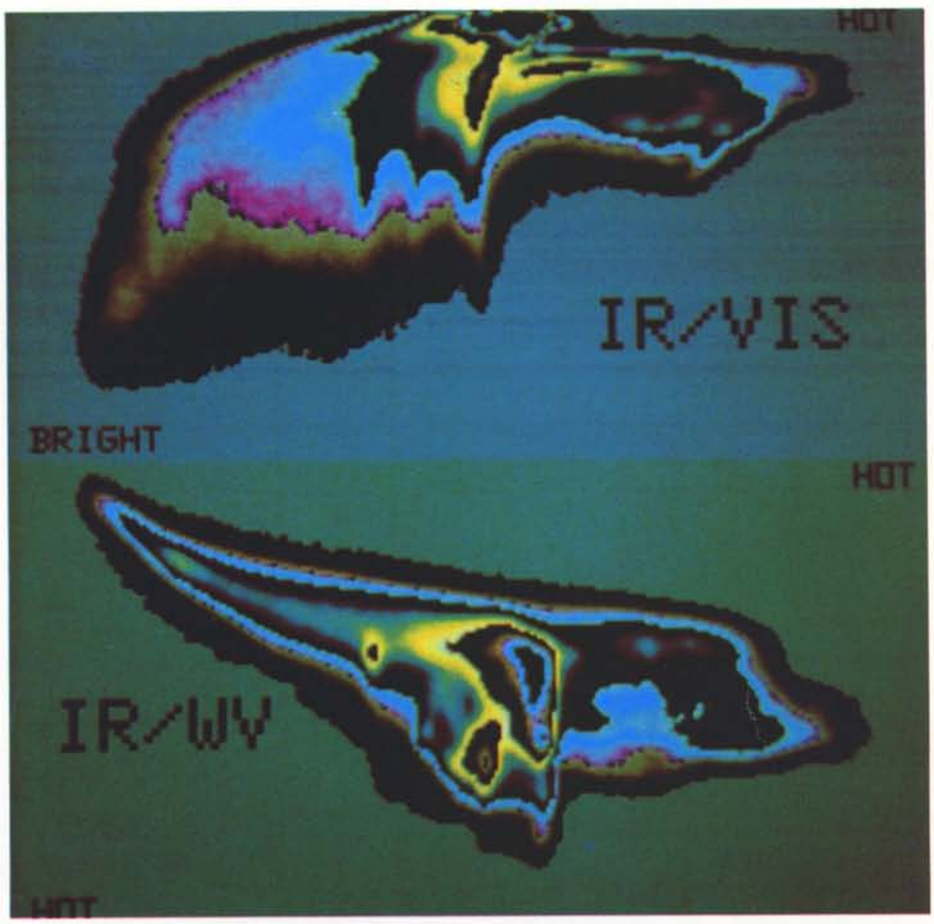

7a



8


9


7b



10

bright clouds are cold). The grid points are equidistant radiance steps. The differences in appearance of the histograms reflect the differing meteorological features/behaviours in the various regions

Histograms of the sort shown here should provide future meteorological studies with an improved interpretation capability. A trial run has been made for a region in the south-east Atlantic, off the coast of Africa (1000 × 1000 pixels) (Figs. 7a,b). The interpretation squares below the infrared/water-vapour histogram (Fig. 8) define the radiometric regions of the different features (clouds and sea). Based on this interpretation table and the infrared and water-vapour images in Figure 7, an artificial image (Fig. 9) has been constructed showing the local extent of the features; the colours in this artificial image define the nature of the features. As one can see from the sequence of images in Figures 7 and 9, the major features have been correctly interpreted.

Figure 10 shows two-dimensional infrared/visible and infrared/water-vapour histograms constructed from Meteosat images of the earth's disk.

The Value of Sounding-Rocket Flights in a Materials-Science Microgravity Research Programme

U. Huth, Directorate of Space Transportation Systems, ESA, Paris
P. Clancy, Instrument Technology Division, ESA Technical Directorate, ESTEC, Noordwijk, Netherlands

Sounding rockets have proved to be a most helpful tool for conducting microgravity research in preparation for future Spacelab experiments. Each flight provides 5–10 minutes of low-gravity conditions (10^{-4} g), and five such flights have already been made in the framework of the German/Swedish Texus programme. In view of the positive results obtained, ESA has proposed to its Member States that sounding rockets should form part of the Microgravity Research Programme which is currently under discussion.

Goals of materials-science research under microgravity

The objectives of materials-science research work under microgravity conditions vary widely, their common denominator being the almost complete absence of sedimentation and buoyancy, gravity-driven convection and hydrostatic pressure. These basic consequences of terrestrial gravity have implications for fluid systems in general and the community actively involved in microgravity experiments therefore includes fluid dynamicists, crystal growers, process engineers and materials scientists. A systematic classification of microgravity research topics of interest is consequently difficult: classification according to the traditional fields of chemistry, physics, thermodynamics etc. is one possibility; another would be to classify with regard to products, such as single crystals, composites, pharmaceuticals, etc. The production of technologically and commercially relevant materials has frequently been emphasised in the past, particularly after the initial Apollo and Skylab flights. However, interpretation of the results and data obtained has often proved impossible because boundary conditions were complex and often undefined.

Although the ultimate goal of materials research under microgravity is the production of new or improved materials on earth or in orbiting industrial production plants, the first step must be to establish the scientific and technological basis for the different processes. Accordingly, basic phenomena need to be investigated in order to explore eventual applications. Thus, as in any other experimental field, microgravity research can develop only through the flight of well-prepared experiments in combination with the relevant ground testing and theoretical modelling. This in turn means that a certain minimum of 'mission opportunities' with appropriate user facilities need to be available to researchers to ensure the requisite progress.

Experiment opportunities

The decisive characteristics of a given flight opportunity are the duration and quality of the microgravity conditions that it provides. There are several means of 'producing' a microgravity environment (10^{-2}–10^{-6} g):

Microgravity source	Duration
Drop-tower experiments	~ 4.0 s
Aircraft flights	10 – 50 s
Sounding-rocket flights	300 – 600 s
In-orbit facilities:	
– self-contained packages	3 – 4 d
– Shuttle carry-on experiments (e.g. SPAS)	4 – 7 d
– Spacelab (module/pallet)	7 – 14 d
– free-flying platforms	weeks/months

Preparatory to the first Spacelab mission (now planned for the end of 1983) European experimenters have had very limited opportunities for gaining experience with flight experiments and for conducting supporting investigations for their selected experiments. Only German and Swedish experimenters have been given the opportunity to experiment with sounding rockets through a project known as Texus (Technologische Experimente unter Schwerelosigkeit) supported by the German Ministry for Research and Technology and the Swedish Space Corporation. To date five payloads carrying materials-science and fluid-physics experiments have been launched (Fig. 1).

Topics for microgravity experimentation and the relevance of sounding rockets

As already mentioned, classifying and defining the topics of interest for microgravity experimentation is difficult: one possibility is presented in Table 1.

The first subdivision takes in homogeneous fluid systems, i.e. properties of fluids, fluid-flow phenomena, solidification phenomena and finally processing of materials by solidification of homogeneous fluids. Solidification is listed last since an understanding of it is based on an understanding of fluid behaviour under microgravity conditions.

A similar sequence would seem to be logical for the study of heterogeneous fluid systems, listed in the second subdivision of Table 1. The preparation of mixtures and their stability must be investigated and mastered prior to the study of solidification and of the preparation of composite materials.

A third subdivision is devoted to processing technology. The main topics here are containerless processing, shaping of fluids, various crystal-growth, moulding and casting techniques, together with electrochemical processes, electrophoresis and ultra-high-vacuum applications.

A detailed analysis of the above topics based on the results of past Texus and SPAR (NASA) rocket flights shows that the overwhelming majority of them are appropriate for sounding-rocket experimentation, as indicated by the annotation in Table 1 (+, ✳ and ×).

Figure 1 — Launch of a Texus payload from Esrange, Kiruna, Sweden

Figure 2 — Larger regions of Ag formed by coalescence surrounded by Al_2O_3 spheres in a Al_2O_3/Ag mixture solidified under microgravity (Texus-1 flight)

Table 1 – Research topics of interest for microgravity experimentation

1 Homogeneous fluid systems (liquids & gases)

Properties of fluids
- • Heat transfer by diffusion
- • Mass transfer by diffusion
- × Chemical diffusion coefficients
- × Thermo-migration coefficients
- × Electro-migration coefficients
- • Properties of highly reactive materials
- + Boiling
- • Critical-point phenomena
- • Segregation phenomena
- × Precision determination of parameters

Fluid-flow phenomena
- + Influence of residual gravity
- + Fluid flow due to surface-tension (interface) gradients:
  - – concentration gradients
  - – temperature gradients
- • Fluid flow due to volume changes:
  - – thermal expansion
  - – phase transitions
- + Fluid flow due to other factors:
  - – instabilities of liquid meniscus
  - – surface charges
  - – electric fields
  - – magnetic fields
  - – thermo-acoustic fields
  - – Coriolis forces

Solidification of homogeneous fluids
- + Nucleation:
  - – homogeneous nucleation
  - – heterogeneous nucleation
  - – undercooling: glass formation
  - – spinoidal decomposition
- • Directional solidification:
  - – single phases
  - – eutectic reactions
  - – peritectic reactions
  - – monotectic reactions
  - – alloys, multicomponent systems
- • Factors influencing quality:
  - – interface stability
  - – defect formation
  - – macro-segregation
  - – micro-segregation
  - – size
  - – container: contamination, nucleation, defect formation

Materials processing
- • Single crystals (semiconductors, metals, alloys)
- + Glasses
- • Eutectics
- + Monotectics
- + Peritectics
- + Immiscibles

2 Heterogeneous fluid systems

Precision determination of physical and physico-chemical parameters

Preparation of heterogeneous mixtures
- + Nucleation of solid, liquid, gaseous inclusions
- + Spinoidal decomposition
- + Powder mixtures
- + Mixing in the liquid state (mechanical, acoustic etc.)

Properties of heterogeneous mixtures
- + Coalescence
- + Capillarity effects
- + Fluid flow, convection
- • Ostwald-ripening
- + Stability of liquid lamellae (foams)
- + Sedimentation, buoyancy
- + Marangoni-flow
- • Interaction with solid/liquid interfaces
- + Boiling, cavitation

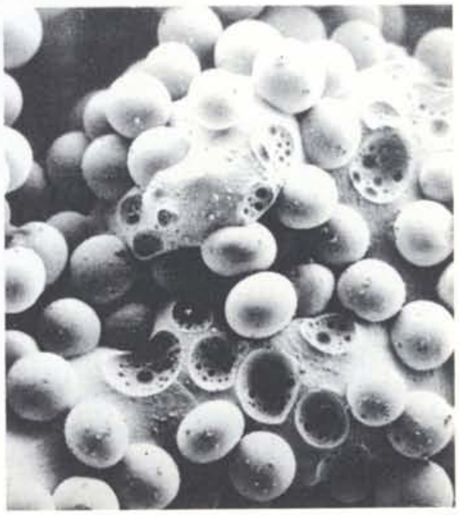
Solidification
- • Interaction of inclusions with advancing solid/liquid interfaces
- • Critical solidification rate for particle incorporation
- + Fluid flow induced due to solidification
- + Secondary segregation effects

Preparation of composites
- + Particle-reinforced composites
- + Fibre-reinforced composites
- + High-porosity materials
- + Foams
- + Dispersion, immiscibles

3 Processing technology

- + Containerless processing:
  - – acoustic positioning
  - – electrostatic positioning
  - – electromagnetic positioning
  - – positioning by means of gas jets
  - – positioning by wetting and adhesion
- + Shaping of fluids:
  - – electrostatic forces
  - – acoustic pressure
  - – centrifugal forces
  - – wetting
  - – gas jets
- × Float-zone technology, purification
- + Skin technology
- + Moulding and casting
- + Joining techniques
- • Crystal growth:
  - – melt growth: bulk, ribbon, whisker drawing
  - – solution growth
  - – hydrothermal growth
  - – travelling heater method
- + Electrochemical processes
- × Electrophoresis
- × Ultra-high-vacuum applications

+ Quality and duration of microgravity provided by sounding rockets (up to 10 minutes at 10^{-4} g) sufficient for most investigations
• Only precursory, qualitative or very simple experiments possible
× Meaningful experiments not possible.



A typical example of sounding-rocket experimentation would be model experiments to determine the stability of multicomponent mixtures (composites) during wetting, thermal soaking and solidification under microgravity conditions. Figure 2 shows a solidified Al_2O_3/Ag mixture flight sample from Texus-1. Larger droplets of Ag formed by coalescence can be seen surrounded by Al_2O_3 spheres.

The payload concept and typical experiment hardware

A material-sciences sounding-rocket campaign like Texus has three distinct

Figure 3 — Typical sounding-rocket mission profile

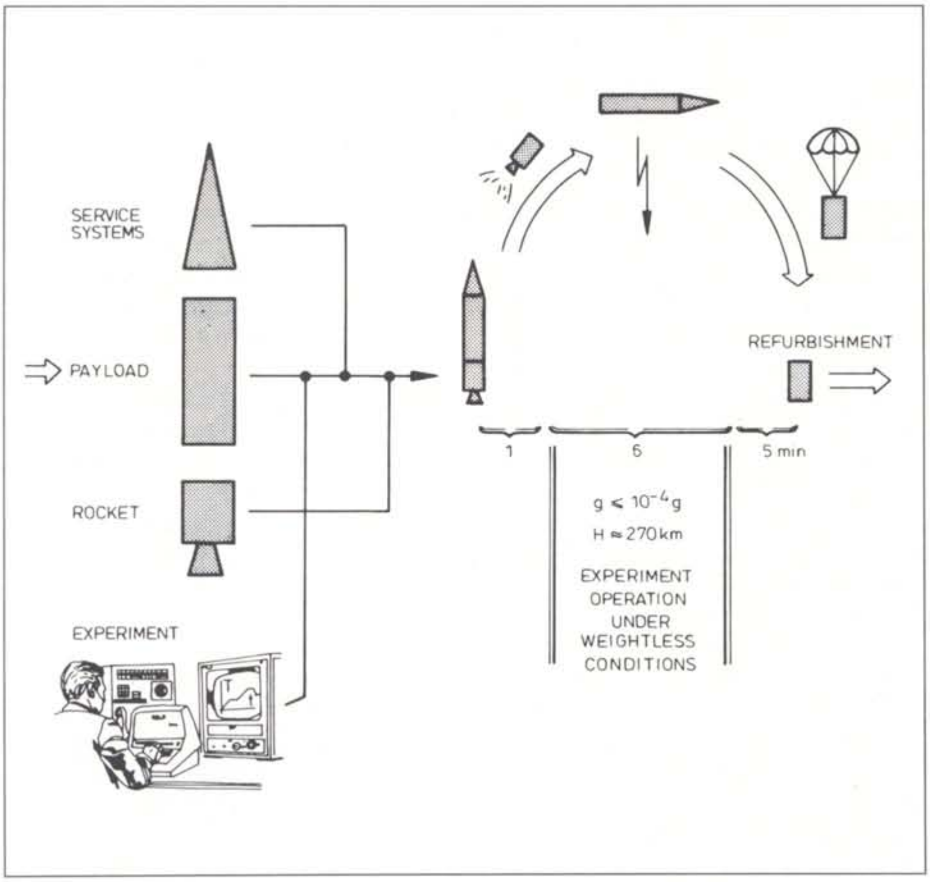
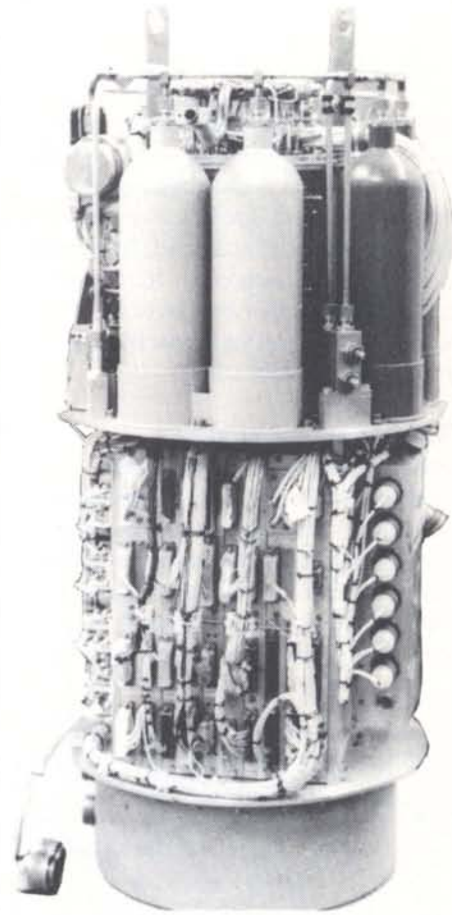


Figure 4 — Texus four-chamber isothermal furnace integrated for flight



phases (Fig. 3):
- The pre-launch phase, involving, apart from the obvious countdown activities and monitoring of the payload until take-off, the activation and checkout of the experiments, and, if need be, the pre-heating of samples that are below melting point.
- The actual flight, consisting of ascent phase (70 s), microgravity phase (360 s), and re-entry of the parachuted payload. During this flight phase, the experiment's behaviour (function, data, temperatures) can be monitored and recorded in real time.
- The post-recovery phase, in which the payload is returned to the launch site for the experiments (samples, films, etc.) to be removed. It is subsequently returned to the experimenter's base for refurbishment.

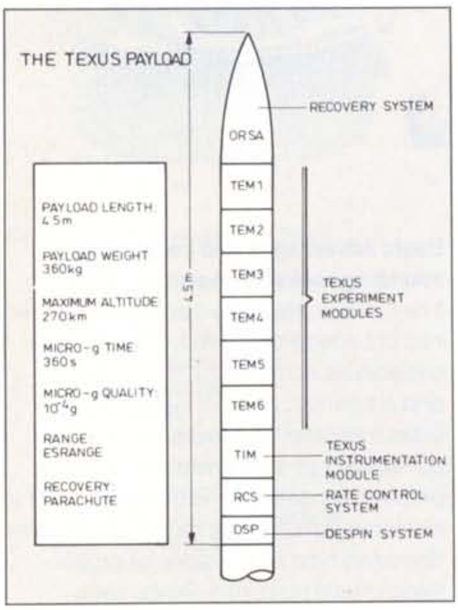
To achieve a high degree of flexibility and low cost and provide good maintenance possibilities for the re-use of the modules, all experiment modules are assembled as autonomous units (Fig. 4), which are mated later with the common service modules, telemetry system, recovery system and attitude control system to form the complete payload for launch. So far, 12 autonomous experiment modules have been developed, built and tested in Europe. Each has its own power, data-interface, and experiment-control subsystems and its own ground-support system for integration and test.

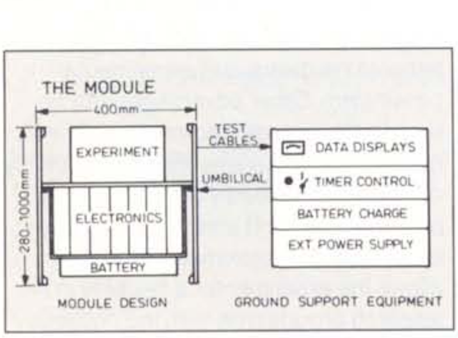
All experiment modules are re-usable and interchangeable. A typical sounding-rocket payload consists of five or six different modules, allowing 10–20 different experiments to be flown, depending on the priorities assigned (Fig. 5).

Basic advantages and constraints of sounding-rocket research

The German/Swedish Texus programme has provided Europe with considerable capabilities both from a technological and a scientific point of view. Rocket experimentation in most cases can be considered as a means of conducting preparatory definition experiments prior to experimentation in the more sophisticated Spacelab-type laboratories or on free-flying orbital platforms. Precursor experiments with rockets thus help in specifying experiment requirements in terms of hardware and experimental parameters. Other advantages can be seen in the low payload-cost, safety and qualification requirements. The frequency of flights can be easily adjusted to meet prevailing demand and the preparation cycle, lasting approximately one year, allows the experimenter a flexibility in his research programme, with the necessary

Figure 5 — The modular payload concept for the Texus flights





scope for scientific iteration.

Constraints on sounding-rocket experimentation are associated with the need to control accelerations and vibrations induced during the launch and initial spinning of the payload. The limited period of microgravity of 5—10 minutes also excludes certain classes of experiment that call for longer thermal and chemical steady states.

ESA's current and proposed involvement in sounding rockets

In the light of its fundamental objectives of providing for and promoting cooperation between European countries in the fields of space research, space technology and space applications, ESA foresees the application of sounding-rocket flights for materials-science research in the coming years as an element of its proposed Microgravity Research Programme.

At the present time, ESA is already involved in the use of sounding-rocket flights for the technological testing of materials-science sample manipulation and processing instrumentation. This instrumentation is being developed within ESA's Technological Research Programme and is destined for use in furnaces on later orbital Spacelab and Shuttle-related missions. The instrumentation in this category includes positioners, mixers and monitoring instruments. The positioners are used for the containerless processing of materials-science samples (thus obviating contamination of the sample by the furnace walls). Mixing instruments are used for the mixing of, for instance, immiscible alloys, and fibre/alloy or powder/alloy mixtures prior to solidification in microgravity conditions. Monitoring instrumentation includes optical and infrared instruments for real-time monitoring of physical conditions in terms of temperature, temperature distribution, and the shape and position of molten and solidifying samples.

Some of the development activities referred to have been in progress for some time, while others are only now being initiated. The development work that has been in progress for some years covers two main areas:

- electrostatic positioning, and
- acousting mixing.

The instrumentation resulting from this work has already been through the feasibility and conceptual-design phases and is now at the demonstration-model stage, making it a prime candidate for testing on a sounding-rocket flight. The decision to test-fly the acoustic mixer within the Texus programme has already been taken and the necessary agreement between ESA and the German authorities established.

The mixer will be flown in combination with an immiscible-alloy (Pb/Zn) experiment on either the Texus-5 or Texus-6 flight, in the spring of 1982. The experimental configuration of the mixer is shown in Figure 6. The mixer is an ultrasonic transducer operating at 40 kHz and working through appropriate transformers into the melt to give a maximum micro-mechanical amplitude of about 15 μm at the mixing-tool face.

The operational success of acoustic mixing is expected to be demonstrated by (a) the appearance of large particle sizes in the area of the melt traversed by the solidification front while the mixer is switched off, and (b) by the ability of the mixer to reduce the particle size once it is switched on again.

Although the basic mixing action can be demonstrated on earth, this is not true of the basic operation of a positioning system such as the electrostatic positioner (Fig. 7). The instrument employs a tetrahedral electrode arrangement with the sample at the centre. The sample's position is sensed capacitatively at each electrode and this forms part of a feedback loop, the control end of which applies voltages in the order of 5 kV to the appropriate electrode. The polarisation of the sample by the high voltage applied to the electrode causes attractive forces between the sample and that electrode, allowing re-positioning of the sample at the centre. Since the applied forces at these voltages are only of the same order as the microgravity forces, full testing of this type of positioner is not possible on the ground. Considerable efforts are therefore being made to devise testing methods employing either aircraft or sounding-rocket flights. Because of the extremely short duration of microgravity conditions on aircraft flights, however, it is likely that full operational testing of the positioner is best accomplished on a rocket flight. This also applies in the case of acoustic positioning. Development work has been initiated by ESA on acoustic positioning, based on a less-

Figure 6 – Schematic of the acoustic mixer to be test-flown on a Texus launch in 1982

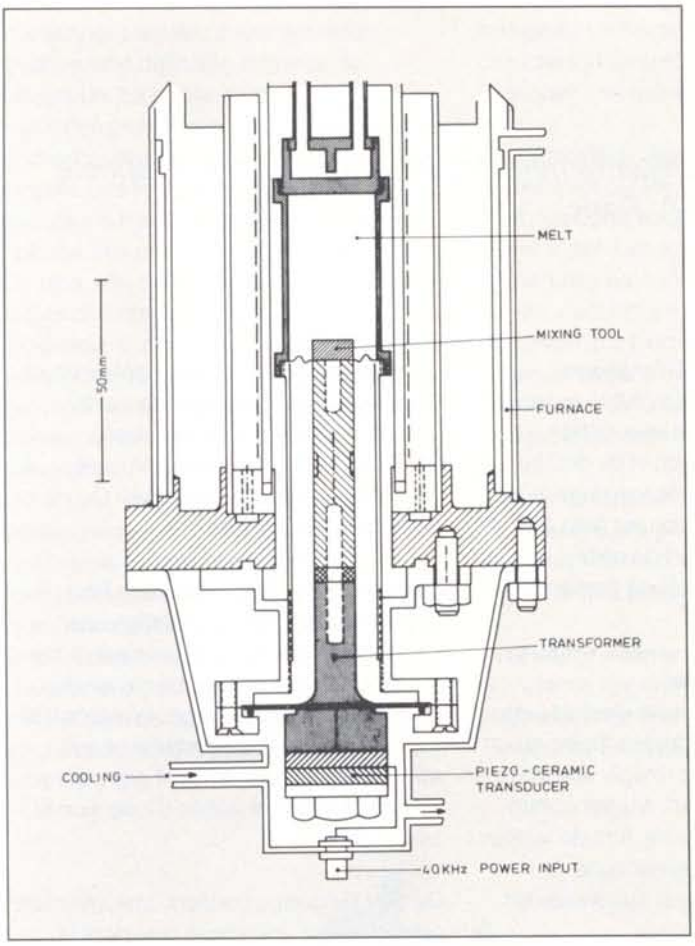
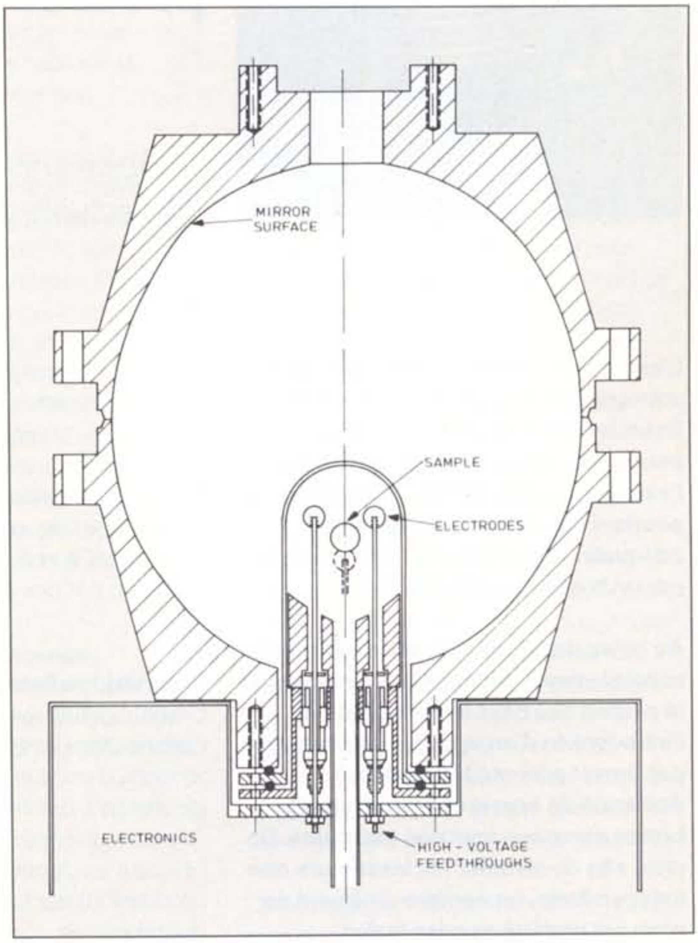


Figure 7 – Schematic of a mono-ellipsoidal mirror furnace with electrostatic positioner



complex system than that previously tested, with somewhat ambiguous results, on Texus-2.

Clearly then sounding-rocket flights offer excellent opportunities for the microgravity testing of advanced manipulation, processing and monitoring instruments developed within the Agency's Technological Research Programme and destined for use in future materials-science microgravity experiments in space.

Outlook

The first Spacelab payload is presently the only flight opportunity provided by ESA to European experimenters for conducting materials-science experiments. Progress and involvement in this new area of experimental physics can only be ensured if a minimum programme is established which gives European experimenters the opportunity to acquire experimental results.

The experience gained to date through sounding-rocket experimentation and the possibilities offered thereby make the sounding rocket a valuable 'work horse' with a 'calculable' risk, able to play a similar role in the furtherance of materials-science microgravity research to that which it has played in the development of the more classical space sciences.

Les inventions de l'Agence et leur protection

R. Oosterlinck, Département Affaires juridiques et Propriété intellectuelle, ESA, Paris

L'introduction de techniques nouvelles, souvent obtenues au prix d'un effort financier considérable, sera de plus en plus à la base de la croissance et de l'expansion industrielles, à condition pourtant que ces techniques soient adéquatement protégées, par exemple, par un brevet d'invention [1].

Au cours des dernières décennies, des considérations économiques ont conduit la plupart des pays industrialisés à l'introduction d'un système de protection par brevet plus moderne, dont la demande de brevet international et le brevet européen sont des exemples. De plus, afin de stimuler les inventeurs non indépendants, un nombre croissant de pays ont protégé par des textes appropriés les inventions de leurs ressortissants.

Cet article a pour objet d'expliquer d'abord brièvement ce qu'est la propriété intellectuelle en général et la notion d'invention en particulier, et de décrire ensuite la procédure à suivre entre le moment où une invention est faite à l'Agence et la protection de cette invention par des dépôts de demandes de brevet.

Propriété intellectuelle

On peut définir la propriété intellectuelle comme étant l'ensemble des règles qui tendent, d'une part, à protéger les droits de création, d'autre part, à lutter contre une concurrence déloyale. Afin de faciliter l'étude d'un domaine aussi vaste, la propriété intellectuelle est subdivisée en quatre parties:

- les droits de propriété industrielle
- les droits d'auteur
- les obtentions végétales
- le savoir-faire.

De ces quatre parties, la première est de loin la plus importante car elle comprend: les brevets d'invention et titres analogues, les modèles et dessins industriels, les marques (de fabrique, de commerce ou de service), le nom commercial, l'enseigne, les appellations d'origine et les indications de provenance. Seul le cas des brevets d'invention est pris en considération ici.

Notion d'invention

Un brevet d'invention n'est autre qu'un titre délivré par l'Etat, qui confère à son titulaire un droit exclusif d'exploitation de l'invention, objet du brevet. Autant il est facile de définir le brevet d'invention, autant il est difficile de définir l'invention.

On chercherait en vain une définition de l'invention dans les textes législatifs traitant de la propriété industrielle. D'ailleurs les manuels de droit sont généralement muets à ce sujet. Qu'est-ce donc qu'une invention?

Selon certains dictionnaires, 'le Petit Robert' par exemple, on désigne par invention l'action d'inventer, c'est-à-dire créer ou découvrir quelque chose de nouveau, et, par extension, le résultat de cette action. Le dictionnaire ne nous apprend malheureusement pas pourquoi telle création est qualifiée d'invention et telle autre pas.

Dans le language courant, une invention est avant tout une chose rare dont la nouveauté va de soi. La preuve en est qu'en demandant autour de soi ce qu'est une invention on obtient généralement une réponse telle que: l'imprimerie, la machine à vapeur, le téléphone etc.

On utilise en fait le terme 'invention' pour qualifier des réalisations techniques importantes qui, dans beaucoup de cas, sont des étapes de l'histoire technologique. En plus, ces réalisations ne sont pas des objets spécifiques issus d'un concept 'générique', mais elles sont des concepts 'génériques' en soi.

Si on compare maintenant ce point de vue limitatif aux quelque 500 000 demandes de brevets déposées par an dans le monde entier, on doit admettre que la définition doit s'étendre au-delà de celle du type générique sans pour autant englober toute création ou découverte. C'est pour cette raison que les lois

[1] Voir également l'article de J. de Reuse, *Brevets et savoir-faire technique dans une organisation de technologie de pointe*, publié dans ESA Bulletin, No. 17, février 1979, pp 30-35

◄ *Dispositif d'orientation de charge utile mise au point à l'ESTEC par M.D. Bentall*

Bâtiment de l'Office européen des Brevets – Département de La Haye

contiennent, au lieu d'une définition positive, une définition négative de l'invention. La convention sur le brevet européen par exemple énumère de façon non exhaustive ce qui n'est pas considéré comme une invention. Parmi ces exclusions figure notamment le cas épineux des programmes d'ordinateurs. De plus, afin de limiter l'application des règles de la propriété industrielle, le législateur a introduit un certain nombre de conditions supplémentaires pour qu'une invention puisse être protégée par brevet: ce sont les conditions de brevetabilité.

Malheureusement, ni les exclusions, ni les conditions de brevetabilité ne sont identiques dans tous les pays: il en résulte que dans certains pays un brevet est plus facile à obtenir que dans d'autres. A titre d'exemple, la loi française du 13 juillet 1978 pose trois conditions de brevetabilité énumérées dans le second alinéa de l'article 6: 'L'invention doit avoir un caractère industriel, être nouvelle et impliquer une activité inventive'.

Que l'invention doive avoir un caractère *industriel* et qu'elle doive être *nouvelle* sont des conditions que l'on retrouve en général dans les textes juridiques de la plupart des pays industrialisés. Par contre, *l'activité inventive* est une condition qui, bien qu'exigée dans plusieurs pays, diffère considérablement par son contenu ainsi que par son interprétation selon les pays.

Ces exclusions ainsi que les conditions de brevetabilité ont pour but principal de rendre la notion d'invention aussi objective que possible.

Procédure interne à l'Agence

A l'Agence la propriété intellectuelle est régie par différents articles du Statut du Personnel. En application de ces articles, les membres du personnel sont obligés de déclarer au Directeur général toute invention réalisée au cours de la période pendant laquelle ils sont employés à l'Agence. Ces inventions sont soumises à un Groupe Brevets constitué de spécialistes scientifiques et juridiques qui examinent l'intérêt de l'invention pour l'Agence ainsi que le mérite individuel de l'inventeur. Cette procédure comporte deux étapes:

- la déclaration de l'invention
- l'examen par le Groupe Brevets.

La déclaration de l'invention

Régulièrement les ingénieurs et techniciens de l'Agence sont confrontés à des problèmes techniques dont la solution ne peut être directement trouvée dans l'état actuel de la technique. Après discussions, calculs et éventuellement expériences ou essais en laboratoire, une solution est trouvée. A ce stade la question se pose de savoir si cette solution doit être considérée comme une invention. Dans l'affirmative, elle doit être communiquée au Directeur général.

Cette obligation de déclarer toute invention a été introduite pour préserver les intérêts de l'Agence et des Etats membres en matière de propriété intellectuelle et, par conséquent, d'éviter que certains résultats techniques tombent dans le domaine public ou encore soient brevetés par un membre du personnel sans accord préalable du Directeur général ou enfin qu'ils soient brevetés par des tiers.

photo w. kipee

Les solutions ainsi trouvées peuvent être classées dans deux catégories:

1. Suite à un problème *pratique* posé lors de l'exécution des programmes de l'Agence, une solution *originale* dont la *faisabilité* a été vérifiée ou n'est pas contestée, est proposée par un membre du personnel.
2. Un membre du personnel, au cours de ses activités à l'Agence, élabore une proposition originale et théorique qui pourrait avoir un intérêt pratique dans un avenir plus ou moins proche.

Dans le premier cas il s'agit donc d'une proposition qui peut immédiatement être appliquée. Le fait que cette solution découle directement des programmes de l'Agence ne veut pourtant pas dire que ses applications appartiennent ou soient limitées au domaine spatial. Par exemple, le procédé de soudage aluminium-acier inoxydable[2] inventé par un membre du personnel de l'Agence a été proposé pour résoudre les difficultés rencontrées lors du raccordement des circuits cryogéniques aux chambres à vide utilisées pour tester les satellites. Les applications de ce procédé qui résulte directement de l'exécution des programmes de l'Agence ne sont naturellement pas seulement limitées au domaine spatial. Il est évident que dans la grande majorité, ce type de solution doit être considéré comme étant une invention; c'est pourquoi, il est vivement conseillé aux membres du personnel de présenter un mémoire descriptif au Directeur général, accompagné le cas échéant d'une demande de reconnaissance de mérite individuel.

Par contre, dans le second cas, pour lequel ni l'intérêt, ni la faisabilité ne sont démontrés, il est plus difficile de se prononcer d'une façon aussi abstraite que dans le premier cas, en faveur de l'introduction d'un mémoire. Bien que chacun soit libre de présenter au Directeur général un mémoire descriptif ainsi qu'une demande de reconnaissance de mérite individuel, il est cependant recommandé de contacter le Service de la Propriété intellectuelle[3] qui pourra étudier cas par cas et conseiller sur l'opportunité de présenter un mémoire.

Une fois la décision prise d'introduire un mémoire, la seconde question qui se pose est la suivante: 'Quel doit en être le contenu?'. Ceci est en effet très important puisque ce document sera à la base de la décision du Groupe Brevets. C'est pourquoi il devrait au moins comprendre une introduction permettant de situer l'invention d'un point de vue technique, une synthèse de l'état de la technique et une description de l'invention. Quant aux circonstances dans lesquelles l'invention a été faite, elles seront relatées dans une requête de mérite individuel.

En pratique, la grande majorité des inventeurs font appel au Service de la Propriété intellectuelle pour leur apporter une aide active dans la rédaction du mémoire et de la requête. Cette intervention du Service de la Propriété intellectuelle dès le début de la procédure a plusieurs avantages. D'abord elle permet une standardisation des mémoires présentés, ce qui facilitera d'une part le travail du Groupe Brevets et d'autre part la rédaction de la demande de brevet au cas où le Groupe Brevets recommande un dépôt. Ensuite, la procédure interne est ainsi accélérée puisque la pratique a démontré qu'entre le moment où un inventeur décide de présenter son invention et celui où le secrétariat du Groupe Brevets reçoit le mémoire, il s'écoule entre un et trois mois.

Examen par le Groupe Brevets

Le Directeur général transmet les documents reçus de l'inventeur au Service de la Propriété intellectuelle qui assure le secrétariat du Groupe Brevets. Dès la réception de ces documents, le secrétariat constitue un dossier complet qui comprend: les documents reçus de l'inventeur, le résultat d'une recherche documentaire effectuée principalement dans la documentation IRS[4] et un avis juridique établi par le secrétariat suivi d'une recommandation. Ce dossier est ensuite inscrit à l'ordre du jour de la réunion du Groupe Brevets et envoyé aux membres de ce Groupe ainsi qu'à l'inventeur.

Le Groupe Brevets se réunit environ six fois par an en réunion ordinaire. En cas d'extrême urgence des réunions extraordinaires sont organisées. Après présentation de l'invention par son auteur, une discussion s'engage entre les membres du Groupe et l'inventeur afin d'établir l'utilité et la faisabilité de l'invention et, le cas échéant, le mérite individuel. Un bref débat entre les membres du Groupe tend ensuite à évaluer l'intérêt de l'invention pour l'Agence.

A la lumière de ces discussions le Président du Groupe propose:

- soit le dépôt d'une demande de brevet et, le cas échéant, la reconnaissance du mérite individuel,
- soit la publication de l'invention dans une revue,
- soit une recommandation au Directeur général pour que l'Agence renonce à ses droits de propriété intellectuelle en faveur de l'inventeur.

La décision est ensuite prise à la majorité simple. Dans le cas où les membres du Groupe prennent une décision en faveur du dépôt d'une demande de brevet, le secrétariat recommande un pays dans

---

[2] Demande de brevet français 80.08752 déposée le 18 avril 1980, *Procédé pour souder un objet en aluminium à un objet en acier inoxydable*

[3] Ce service, rattaché à la Direction de l'Administration (au Siège), relève du Conseiller juridique

[4] IRS (Information Retrieval Service ou Service de Ressaisie de l'Information de l'ESA). Les recherches sont effectuées sur une trentaine de fichiers comprenant entre autres NASA, NTIS, CHEMABS, PASCAL.

Exemple de brevet déposé au Japon par l'Agence concernant l'invention de M. Péra: 'Montage anti-ambiguïté pour système de transmission binaire à manipulation de phase'.

lequel ce dépôt devra être effectué. Le choix d'un pays n'est pas arbitraire, mais tient compte des considérations suivantes:

- l'urgence du dépôt,
- la disponibilité de tous les éléments de l'invention,
- la possibilité d'avoir dans l'année qui suit le dépôt un avis de recherche documentaire et
- la langue dans laquelle les documents sont disponibles.

A l'Agence, les 'premiers' dépôts se font par ordre décroissant en France, en Belgique, en Grande Bretagne et au Luxembourg.

Procédure externe à l'Agence

Par procédure externe à l'Agence, il faut entendre toutes les démarches qui suivent la décision du Groupe Brevets de procéder à un dépôt de demande de brevet. Les différentes étapes parcourues lors d'un dépôt de demande de brevet sont étroitement liées à l'étendue de la protection conférée par un brevet. En effet, cette protection est à la fois limitée dans l'espace, dans le temps et par le contenu du brevet.

Limite territoriale

La protection accordée au détenteur d'un brevet national n'a effet que dans le pays où il a été délivré; de même, le brevet européen n'a effet que dans les pays désignés par le déposant. Un inventeur doit donc déposer des demandes de brevet dans chacun des Etats sur le territoire duquel il désire la protection de son invention. Le dépôt d'une demande étant onéreux, les industriels du siécle dernier ont vite compris qu'une entente entre Etats devait intervenir, soit en faveur d'un brevet international, soit en faveur d'une procédure simplifiée facilitant les différents dépôts nationaux.

L'idée d'un brevet international – le brevet européen étant considéré comme un brevet régional – fut assez vite abandonnée; par contre, la Conférence Internationale de 1880 aboutissant à la création de l'Union de Paris ainsi que le

特　許　証

特許第１０３６４７２号

昭和４８年　特　許　願第０１１５１８号
昭和５５年特許出願公告第０２９６２８号

発明の名称　　位相変位開閉式２進伝送系の受信端子における位相の不確定性除外回路

特許権者　　フランス国　ヌーイーユーシユルーセーヌ　アブニュー　シヤルルードーゴーユ
１１４番地
国籍　　フランス国
オルガニザシオン　ユーロペーヌ　ド　ルシエルシユ　スハシイアル

発　明　者　　ルウイジ　ペラ

この発明は、特許するものと確定し、特許原簿に登録されたことを証する。

昭和５６年　３月２４日

特　許　庁　長　官　　島　田　春　樹

Traité de coopération en manière de brevets adopté et signé à Washington le 19 juin 1970, ont facilité, dans une certaine mesure, les différents dépôts nationaux.

En ce qui concerne les dépôts de demandes de brevet, l'Article 4 de la Convention de Paris est de loin le plus important. Aux termes de cet article, celui qui aura régulièrement fait le dépôt d'une demande de brevet d'invention dans l'un des pays de l'Union, jouira, pour effectuer le dépôt dans les autres pays de l'Union, d'un droit de priorité d'une durée de 12 mois. Autrement dit, aucun document publié après la date de dépôt de la première demande ne pourra être opposé aux dépôts subséquents.

En application de cet article, l'inventeur peut donc dans l'immédiat se contenter de déposer une seule demande de brevet dans un premier pays (premier dépôt). Puis, pendant presqu'un an il aura le temps d'étudier ou de faire étudier la nouveauté et l'intérêt de son invention et, éventuellement, de rechercher un acquéreur ou des capitaux pour la mise en oeuvre de l'invention, avant d'avoir à décider des dépôts de demandes de brevet dans d'autres pays.

Le Traité de Washington dit 'PCT' est un nouveau pas vers une procédure internationale unique: cette procédure est malheureusement d'une grande complexité. Les différentes étapes peuvent être résumées comme suit:

L'inventeur sollicite la protection de son invention par le dépôt d'une demande internationale auprès d'un office récepteur (par exemple, un office national de propriété industrielle), en désignant dans sa requête les pays pour lesquels il réclame une protection. Cette demande est ensuite examinée par une administration chargée de la recherche internationale (par exemple, l'Office européen des Brevets) qui délivre un rapport de recherche documentaire. Ce rapport est publié et envoyé aux offices nationaux des pays désignés. Ainsi prend fin la procédure internationale et la procédure nationale reprend son cours normal dans chaque pays désigné jusqu'à la délivrance d'un brevet national. La demande internationale a trois avantages: elle permet d'abord de prendre date par un dépôt unique, ensuite d'obtenir, dans des délais déterminés, un rapport documentaire de très bonne qualité et enfin de prolonger la période de réflexion de 12 mois à 20 mois.

Quant au brevet européen, il a été instauré par la Convention de Munich, signée le 5 octobre 1973. Cette Convention permet par un *dépôt* et une *procédure* uniques de protéger une invention dans plusieurs pays membres désignés par le déposant. Le brevet, une fois accordé dans les pays désignés, a les mêmes effets que les brevets nationaux respectifs.

A l'Agence, dans l'année qui suit le premier dépôt d'une demande de brevet, le Groupe Brevets réexamine l'invention dont le dossier a, entre-temps, été complété par un avis documentaire émis par l'Office européen des Brevets et, éventuellement, par d'autres documents illustrant l'intérêt scientifique et économique de l'invention.

Limite dans le temps

La durée de vie d'un brevet est différente selon les pays et se situe généralement entre 15 et 20 ans. De plus, dans la plupart des pays, une taxe annuelle doit être acquittée pour le maintenir en vigueur. Dans ces pays, l'Agence maintient ses brevets d'office en vigueur pendant cinq ans. Après quoi, le Groupe Brevets, sur recommandation du Service de la Propriété intellectuelle, décide de l'opportunité de les maintenir en vigueur pour une nouvelle période déterminée.

Contenu du brevet

L'étendue de la protection conférée par le brevet est enfin et surtout limitée par son contenu et, dans les pays qui ont adopté le système à 'revendications', par le seul contenu des revendications. Aujourd'hui la plupart des législations ont adopté l'utilisation des revendications qui est d'ailleurs également recommandée par la Convention de Strasbourg.

Par exemple, l'Article 28 de la loi française du 13 juillet 1978, stipule que: 'l'étendue de la protection conférée par le brevet est déterminée par les revendications. La description et les dessins servent à interpréter les revendications. L'objet des revendications ne peut s'étendre au-delà du contenu de la description complétée, le cas échéant, par des dessins'. Il en découle que les revendications sont la partie la plus importante du brevet. Dans la pratique, les revendications comportent deux parties: un préambule énonçant l'objet de l'invention ainsi que ses caractères connus et une partie définissant l'essentiel de l'invention. Ces deux parties sont généralement séparées par une expression du type 'caractérisé en ce que...'.

Illustrons maintenant ce qui précède par un exemple. Le 13 juillet 1978, M. R. Rogard, membre du personnel de l'Agence, déclare au Directeur général son invention se rapportant à un système pour élaborer, détecter et interpréter de façon fiable un signal de détresse composé, entre autres, d'informations telles que l'identité et la position d'un navire en détresse.

Lors de la réunion du Groupe Brevets, le 4 décembre 1978, il est apparu que cette invention pouvait être nouvelle et avoir un intérêt direct pour l'Agence. C'est pourquoi le Groupe Brevets s'est prononcé en faveur d'un dépôt de demande de brevet. Comme nous ne connaissions aucun document pouvant nuire a priori à la nouveauté de l'invention et, qu'en plus, il semblait que la méthode et la mise en oeuvre étaient nouvelles, nous avons décidé de rédiger des revendications très générales.

La première revendication proposée était la suivante: 'système de

Formulaire de demande internationale de brevet déposée par l'Agence au nom de M.R. Rogard

télécommunications de détresse pour transmettre des signaux de détresse à partir d'une station mobile vers une station côtière par l'intermédiaire d'un satellite de communications, *caractérisé en ce que* la station mobile est organisée pour transmettre les signaux de détresse de façon intermittente en une succession de séquences régulièrement espacées, chaque séquence étant composée d'une phase de détection d'alarme suivie d'une phase de transmission de message'. Cette revendication était reprise dans la demande de brevet déposée le 6 février 1979 en Belgique. Le but recherché en effectuant un premier dépôt en Belgique n'était pas en premier lieu d'obtenir le brevet, mais plutôt de prendre date sans engager trop de frais. En effet, la procédure en Belgique est très courte et donc peu coûteuse; les brevets sont délivrés après un simple examen de forme sans examen quant au fond. Le brevet belge était délivré le 28 février 1979. Afin de pouvoir se prononcer sur la nouveauté, une recherche documentaire était alors demandée à l'Office européen des Brevets.

Dans le courant du mois d'avril 1979, nous recevions le rapport de recherche de l'Office européen des Brevets. Ce rapport citait deux documents opposables à la première revendication de notre brevet belge. Après avoir étudié ces documents il est apparu que d'autres systèmes étaient connus et alors qu'ils ne mettaient pas en doute la nouveauté de notre invention, ils correspondaient quand même à un système tel que celui décrit dans la première revendication de notre brevet. Il était donc évident que notre revendication englobait aussi l'état de la technique. Pour un éventuel dépôt subséquent, une nouvelle rédaction de la première revendication était donc nécessaire.

Au cours de l'année de priorité, différents organismes ont contacté l'Agence pour avoir des renseignements complémentaires sur l'invention de M. R. Rogard. Ces contacts ont montré

PCT ORGANISATION MONDIALE DE LA PROPRIETE INTELLECTUELLE
Bureau international

DEMANDE INTERNATIONALE PUBLIEE EN VERTU DU TRAITE DE COOPERATION EN MATIERE DE BREVETS (PCT)

(51) Classification internationale des brevets 3: H04B 1/034, 7/185	A1	**(11) Numéro de publication int.:** WO 80/01631 **(43) Date de publication int.:** 7 août 1980 (07.08.80)

(21) Numéro de la demande internationale: PCT/EP80/00003

(22) Date de dépôt international: 25 janvier 1980 (25.01.80)

(31) Numéro de la demande prioritaire: 0/193.301

(32) Date de priorité: 6 février 1979 (06.02.79)

(33) Pays de priorité: BE

(71) Déposant *(pour tous les Etats désignés sauf US):* ORGANISATION EUROPEENNE DE RECHERCHES SPATIALES [-/FR]; Rue Mario-Nikis 8-10, F-75738 Paris Cedex 15 (FR).

(72) Inventeur; et
(75) Inventeur/Déposant *(US seulement):* ROGARD, Roger [FR/NL]; Verdistraat 16, 2162 AV - Lisse (NL).

(74) Mandataires: VANDERPERRE, Robert etc.; Bureau Vander Haeghen, 63, Avenue de la Toison d'Or, 1060 Bruxelles (BE).

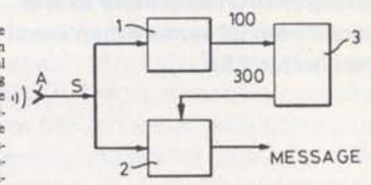
(81) Etats désignés: DE (brevet européen), DK, FR (brevet européen), GB (brevet européen), JP, SE (brevet européen), US.

Publiée
Avec rapport de recherche internationale

(54) Title: PROCESS AND DEVICE FOR DETECTING AND INTERPRETING A DISTRESS SIGNAL

(54) Titre: PROCEDE ET DISPOSITIF POUR DETECTER ET INTERPRETER UN SIGNAL DE DETRESSE

(57) Abstract



The distress signals are transmitted repeatedly in successive sequences each comprised of a detection interval during which an alarm signal is transmitted and of a message transmission interval during which the distress message itself is transmitted indicating particularly the identity of the ship in distress, its position and the type of distress. During the detection interval, the transmitted signal is comprised of a carrier phase modulated by a sub-carrier, the frequency of the latter being a multiple of the information transmission speed. During the message transmission interval, the information is superposed to the sub-carrier by phase binary modulation. The presence of an alarm signal during each detection interval is detected in an alarm receiver (1) monitoring the receiving frequency band simultaneously in several channels of different narrow band widths so as to generate a control signal (300) which indicates the presence of a distress signal in anyone of the channels. In response to this control signal, the message signal received during the subsequent message transmission interval is controlled acurately, and demodulated and interpreted coherently in a message receiver so as to restore the distress message.

(57) Abrégé

Les signaux de détresse (S) sont transmis de façon répétée en séquences successives composées chacune d'un intervalle de détection (Td) pendant lequel est transmis un signal d'alarme et d'un intervalle de transmission de message (Tm) pendant lequel est transmis le message de détresse proprement dit. Le signal d'alarme est constitué d'une porteuse modulée en phase par une sous-porteuse, la fréquence de celle-ci étant un multiple de la vitesse de transmission de l'information, tandis que le message de détresse se trouve superposé à la sous-porteuse par modulation binaire de phase. La présence d'un signal d'alarme pendant chaque intervalle de détection (Td) est détectée dans un récepteur d'alarme (1) surveillant la bande de fréquence de réception simultanément dans plusieurs canaux de largeurs de bandes étroites distinctes afin de produire un signal de commande (300) qui indique la présence d'un signal de détresse (S) dans un canal quelconque. En réponse à ce signal de commande, le signal de message reçu pendant l'intervalle de transmission de message (Tm) subséquent est contrôlé de façon précise, puis démodulé et interprété de façon cohérente dans un récepteur de message (2) afin de restituer le message de détresse.

avec certitude que cette invention avait de l'avenir. C'est pourquoi les membres du Groupe Brevets décidaient de protéger l'invention dans un grand nombre de pays. Le 25 janvier 1980, une demande de brevet international était déposée en désignant les pays suivants: Etats-Unis, Japon, Danemark, République fédérale d'Allemagne, France, Grande Bretagne, Suède et Norvège.

Avec la publication du rapport de recherche internationale qui ne citait aucun nouveau document, se termina la procédure internationale, et les procédures nationales reprennent maintenant leur cours normal. Lors de ces procédures nationales, la demande subit un examen approfondi dont le but principal est d'apprécier la brevetabilité de l'invention. Bien que les brevets nationaux ne soient pas encore accordés et délivrés, l'invention de M. Rogard est maintenant valablement protégée dans tous les pays désignés.

ESRIN – The ESA Establishment in Italy

T. Howell, Head of ESRIN, Frascati, Italy

Though much smaller than the three major ESA establishments of Headquarters, ESTEC and ESOC, ESRIN undertakes several specialist tasks of relevance not only to ESA but also to the broader aerospace community in Europe and around the world. The two main programmes at ESRIN involve close contact with 'end-users' – in one case information searchers, in the other users of earth-resources data – leading to a working environment more akin to that of a commercial venture than found elsewhere within ESA.

Introduction and history

The original concept of an establishment in Italy was born in 1962, two years before the formal creation of the European Space Research Organisation (ESRO). At that time, however, in conformity with the more purely scientific goals of ESRO the on-site activity was that of an institute to 'undertake laboratory and theoretical research in the basic physics and chemistry necessary to the understanding of past, and the planning of future experiments in space'. To this end, an establishment was set up capable of implementing scaled-down laboratory experiments in plasma physics, and thereby simulating phenomena of interest in space physics and chemistry, such as the behaviour of waves and radiation in plasmas, boundary layers, collision-free shocks, turbulence, acceleration of charged particles, etc.

This activity continued at ESRIN until the end of 1971, by which time a decision had been taken by the ESRO Member States to reorient the goals of the Organisation to take account of the growing interest in the applications of space technology. It was thereby decided to forgo some of the more 'purely scientific' activities that had hitherto been undertaken within the Organisation, including the plasma-physics activities at ESRIN. It was further agreed, however, that an activity would be maintained at the Italian site, and it was decided to relocate the ESRO Space Documentation Service – now the ESA Information Retrieval Service (IRS) – to Frascati from Paris.

An aerial view of the establishment, some 20 km south of Rome, is shown in Figure 1; a total of about 100 staff are currently employed on-site, some 70 ESA staff and 30 contractual support staff, the latter group being essentially concerned with the running and maintenance of the ESRIN computer system and its software support.

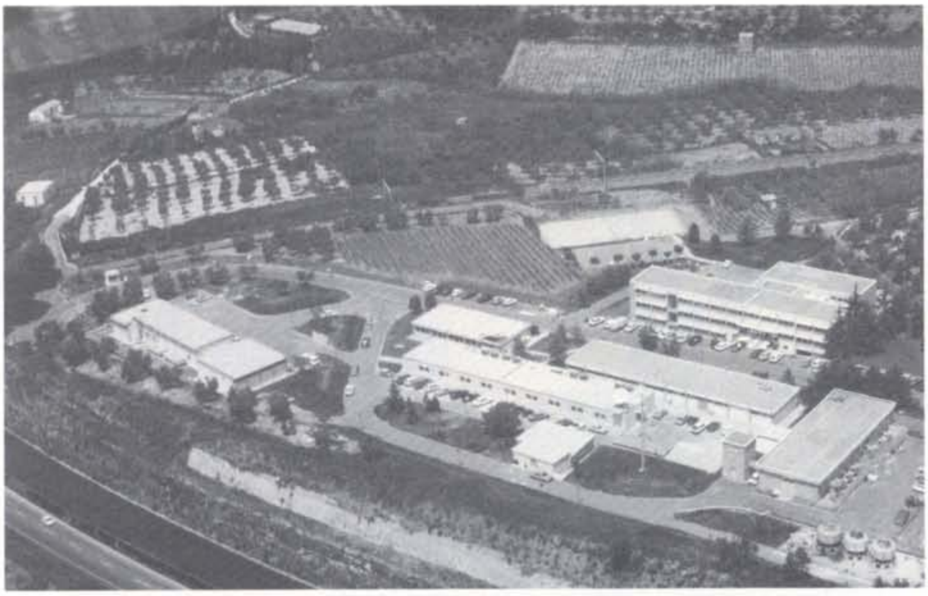
The two main programme activities, IRS and the Earthnet Programme Office for the distribution of earth resources satellite data, are described in more detail in the following paragraphs.

Information Retrieval Service

The aim of the Space Documentation Service – since renamed the Information Retrieval Service – was to provide on-line computer-based bibliographic information to users in the aerospace field, and it was initially set-up in 1964 to implement a NASA/ESRO Agreement on the interchange of aerospace information. This Agreement, which is still in force, foresees the collection and processing by ESA of European aerospace documentation for subsequent inclusion in the NASA information retrieval services (which include the STAR and IAA journals, plus an on-line bibliographic file), and distribution of this information in Europe, with direct on-line access to the NASA database, and the provision of current-awareness services, microfiche or hard-copy reproductions, bibliographies, etc.

The Information Retrieval Service (IRS) has now developed into easily the largest European on-line information centre, and ranks number three in the world. It has 30 bibliographic files on line (among them

Figure 1 — Aerial view of ESRIN



Chemical Abstracts, INSPEC, NTIS, PASCAL, and NASA), and four databanks (Electronic Components, Space Qualified Components, etc.), giving a total of nearly 20 million records.

Through its own data-communication network (ESANET) and the related nodes in many Member States, the system is already accessed by about 2000 users in Europe and Morocco. Following ESANET's recent connection to other commercial data networks, non-European customers have also been given access to the system.

The activities carried out under the umbrella of ESRIN/IRS may be broadly categorised then as:

- the ESA-QUEST on-line information service
- the ESANET scientific and technical information network
- the ESA databanks
- the activities in support of the NASA/ESA Information Exchange Agreement
- various ESA development projects.

ESA-QUEST on-line information service
The ESA-QUEST on-line service is a major provider of information in most fields of science and technology, in the form of on-line access to bibliographic references and factual data, on-line ordering of original documents, direct provision of NASA-sponsored literature, etc. The associated IRS-developed software, called ESA-QUEST, controls and supports three processes:

1. Data storage and retrieval; the information is stored in a classical 'inverted file' system, containing the keywords and terms to be used to retrieve specific items.
2. Command languages; two main languages are in use, the basic ESA-QUEST for on-line conversation, and the QUEST implementation of the EURONET Common Command Language. A third instruction set is provided for on-line data entry.
3. Telecommunications; to support a number of terminal facilities and protocols. Teletype-compatible dial-up terminals with speeds from 110 to 1200 bit/s and higher speed 2400 bit/s video terminals are supported, as well as IRS-developed remote terminal concentrators. There are connections to a number of telecommunications networks in addition to ESA's own ESANET network; examples are TYMNET, TRANSPAC and EURONET.

Currently there are 30 files loaded (a list is given in Table 1), including the NASA file (IRS is the only source of this file other than NASA itself), covering the areas of multidisciplinary science and technology, chemical and biological sciences, earth sciences, engineering and metallurgy.

Central services provided by IRS include the preparation of restrospective bibliographies and current-awareness files, and reproduction of NASA, AIAA and ESA documents in either microfiche or hard-copy form.

The information retrieval system is based on medium-sized computers, the computer room at ESRIN housing two central-processor units connected to a major disk-memory installation, presently capable of holding 20 Gbit of information (Fig. 2). The usual mode of operation is to use one processor to support the on-line service, and one for off-line batch work, software development, and preparation for loading of updated file information.

ESANET scientific and technical information network
Recognition of the fact that the reliability of a private network can be no better than the reliability and quality of the international lines leased from the European PTTs prompted IRS to initiate the development of its own communications network, ESANET. Initially implemented with no more in mind than the support of a few dedicated leased-line remote terminals at ESA establishments, it pioneered the support of up to two dozen sophisticated terminals now distributed throughout most ESA Member States. The RTC (Remote Terminal Concentrator), based on a PDP-11 minicomputer, was field-tested during 1975 and as a result of the grafting of the RTCs onto ESANET to provide easy access to cheap dial-up terminals, the mushrooming growth in the

Figure 2 — The ESRIN computer room

Table 1 – Bibliographic databases currently accessible with ESA-QUEST

File title	Basic subject matter	Start date of information
ABI/Inform	Management disciplines	1971
Acompline	Urban sciences	1973
AGRIS	Agricultural sciences	1975
Aluminium	Technical literature on aluminium	
Aqualine	Water research, pollution	1974
BIOSIS	Biological science	1973
BNF Metals	Non-ferrous metal technology	1961
CAB	Agricultural sciences	1972/73
CHEMABS	Chemical science	1969
COMPENDEX	Engineering literature	1969
Conference Papers Index	Scientific conference digest	1973
EDF-DOC	Electrical energy	1972
Energyline	Energy	1971
Enviroline	Environmental sciences	1971
France-Actualité	Summary of French press	1978
FSTA	Food science	1969
INIS	Nuclear energy	1975
INSPEC	Electronics and electrical engineering	1971
INSPEC information	Information sciences	
IRRD	Road research documentation	1972
ISMEC	Mechanical engineering	1973
METADEX	Metallurgy	1969
NASA	Aerospace and related sciences	1962
NTIS	Multidisciplinary file for US government reports	1964
OCEANIC	Oceanographic sciences	1964
PASCAL	Scientific multidisciplinary file	1973
PNI	Pharmaceutical information	1974
Pollution	Pollution	1970
RAPRA	Rubber and plastics science	1974
WTI	Summary of scientific translations	1978

number of IRS customers really began in 1976. The subsequent ability to use ESANET to distribute search results for off-line printing at remote stations in Paris, London and Noordwijk, enabled IRS to overcome the otherwise insuperable problem of mail delays. Today's network is shown in Figure 3.

ESANET, at least within the ESA Member States, may now be about to be superseded by new, public developments. Preparations are being made to phase out the network in favour of alternatives which will include EURONET, developed by the European communities, and other public-data-network initiatives from the European PTTs.

ESA databanks

The IRS databank unit is primarily concerned with the creation of source files from which to generate on-line databanks; the unit is thus analogous in this respect to the database suppliers from whom IRS receives its various computer-readable tapes. There are three operational databanks:

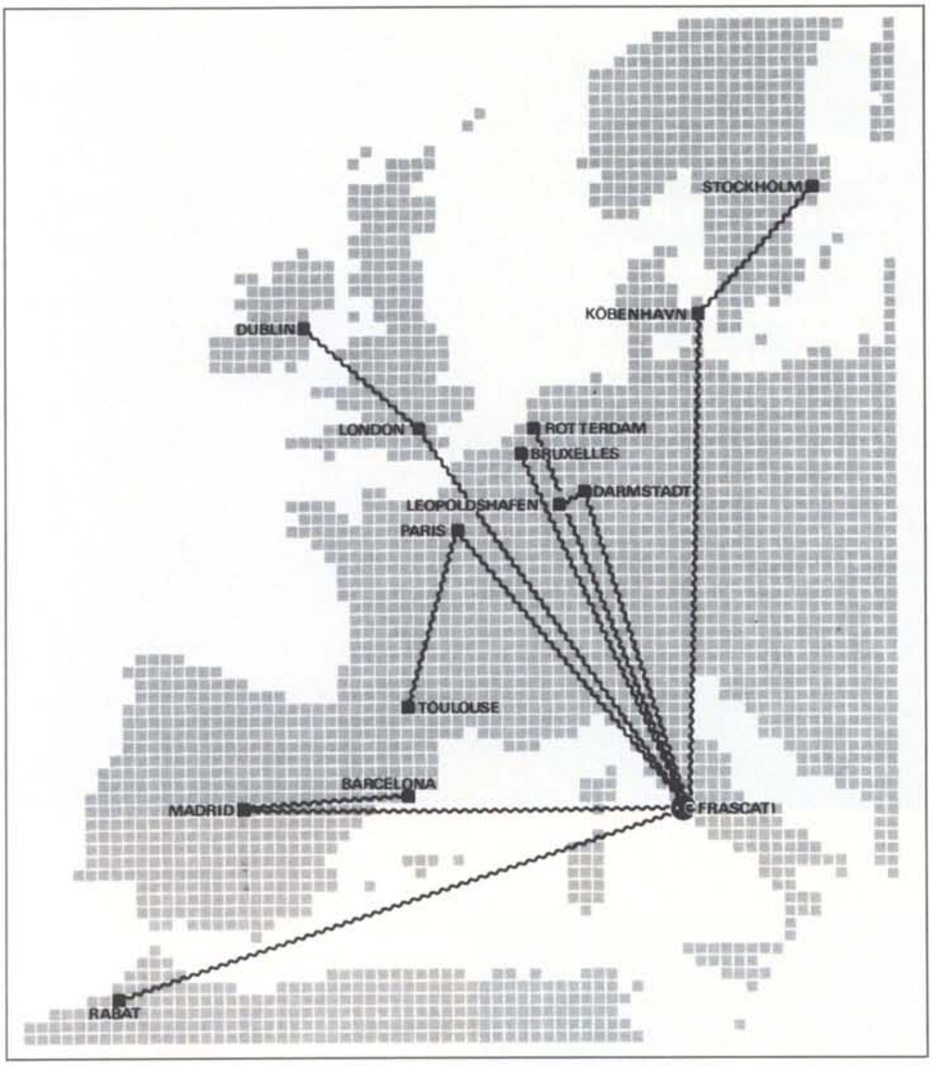
- Elecomps, containing all technical characteristics of and manufacturers or agents for a range of electronic components
- Elspecs, containing specifications and approvals from national agencies for electronic components
- Spacecomps, reviewing electronic components actually used in space projects, giving reliability reports, failure reports and radiation-sensitivity reports.

A fourth file, Sateldata, containing information on satellite subsystems, is currently under development.

The development of a new source-file production procedure is now under way to take full advantage of a new on-line data entry (ODE) screen-oriented input system that has been introduced.

This ODE system enables the user to generate his own database on the IRS

Figure 3 — The IRS network



computer, and is designed to meet the growing needs of on-line information users for the computerisation of information services or activities, such as:

- the creation of personal on-line bibliographic files
- the handling of library inventories
- the handling of mailing/distribution lists for periodicals, newsletters, etc.
- the management of client accounts
- the handling of accounting files

without having to invest in dedicated computer hardware, or to await the development of new software for an existing in-house computer.

NASA/ESA Information Exchange Agreement

IRS serves as a European extension of the NASA Scientific and Technical Information Facility. It maintains contact with all bilateral NASA information-exchange partners in Europe and arranges information-exchange agreements between ESA and European groups working in the aerospace field, to ensure the acquisition of as much as possible of the aerospace literature originating in Europe. Items published openly, e.g. in the periodical literature, are not accepted, while difficult-to-obtain material such as research reports is actively sought.

An item selected for the NASA STAR (Scientific and Technical Aerospace Report) journal is given an English-language abstract (the source document may be in any of eight European languages, including English), descriptors from the NASA Thesaurus are assigned, it is catalogued, and a mother microfiche of the source document is prepared. Simultaneously, the details coded into the input worksheet are keyboarded to computer-readable, terminal-compatible form, and the cumulation of data is rolled out weekly onto a mini tape and despatched with a back-up copy.

Under the terms of the ESA arrangements with NASA, on-line access to the NASA file is granted in return for the submission of European literature falling within the scope of the NASA information service.

Development projects

The development of IRS over the past ten years has called for a great deal of work on system upgrading. Examples have been the introduction of the remote-terminal concentrator; remote off-line printing stations and the current work to convert these for disk-to-disk operation; the new high-speed terminal package; the Eurab terminal; ODE (on-line data entry); the LEDA Earthnet imagery databank; the link to EURONET; the EURONET Common Command Language; distributed databases, etc.

The Eurab terminal is a dual-alphabet video display unit, which was developed by IRS and is now being prepared for production. The terminal can handle any two alphabets, but in the first instance was programmed for latin and arabic characters, hence the name Eurab. A number of these terminals have been installed in Morocco, and although they are only pre-production versions, originally designed for data retrieval only, they have been successfully adapted by a combination of hardware/software modifications to serve as efficient data-entry units. The final version will incorporate all the sophistications of both a data-entry and data-retrieval terminal. Figure 4 shows a typical display, here listing some of the terminal's own applications.

The ten terminals currently in use are fully occupied in the production of the 'LEXAR file', which represents another first for IRS in the field of information retrieval. This file is the first attempt to create a machine-readable arabic dictionary of technical terminology. It is planned to link it later to other existing terminology databanks.

Future system upgrading may be expected to include:

- Videotex applications
- integral database handling
- distributed database handling
- simplified retrieval techniques
- data-compression techniques
- new storage devices
- storage and transmission of original document full texts
- quicker updating of databanks.

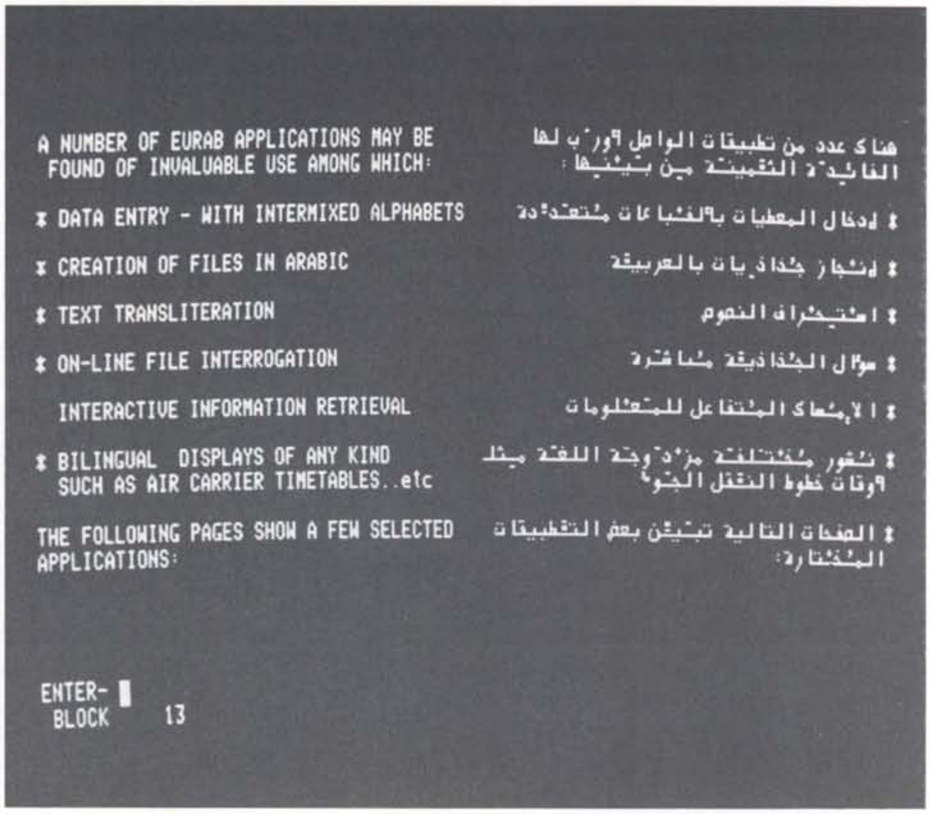


Figure 4 — The Eurab terminal and its applications

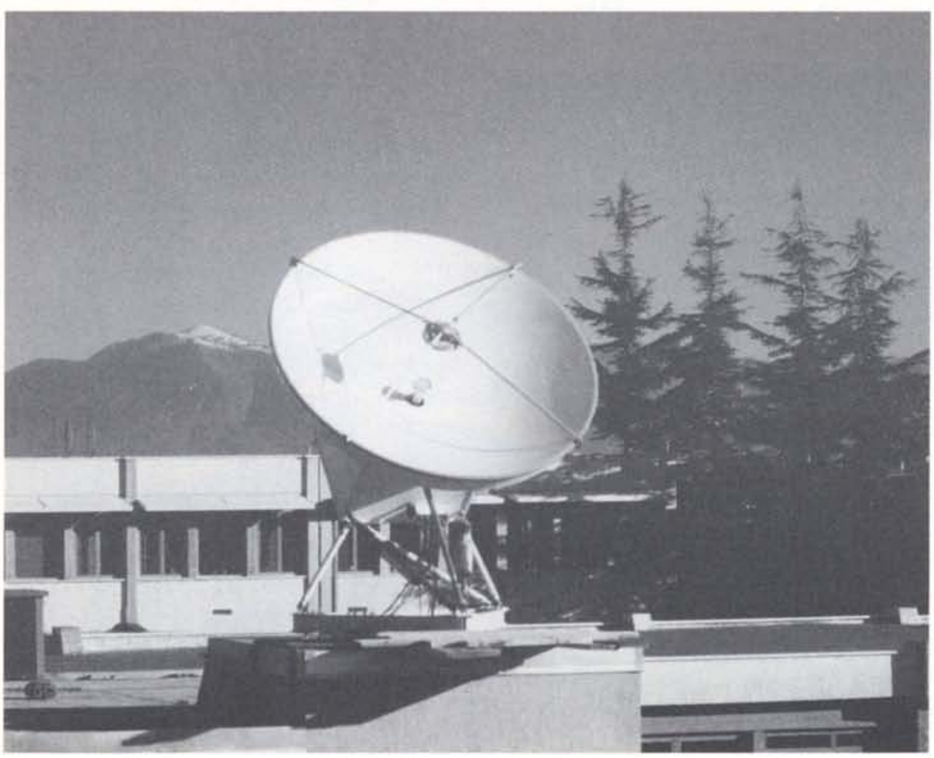


Figure 5 — 3 m Spine antenna on the roof of the ESRIN computer building

One experiment of particular interest currently being undertaken by IRS in conjunction with various other ESA establishments is the Space Informatics Network Experiment (Spine), in which the Agency's OTS communications satellite is being used for high-speed data-communications experiments via small satellite ground stations throughout Europe. The 3 m antenna installation for Spine on the roof of the ESRIN computer building is shown in Figure 5. As far as ESRIN itself is concerned, Spine has permitted a useful association of the file-generation and network-distribution knowledge of the IRS programme with the earth-resources satellite data-dissemination activities of the Earthnet Project Office. The element of Spine supported by ESRIN aims to make use of the satellite link for the exchange of remote-sensing satellite imagery between the central Frascati Earthnet facility, the Earthnet national point of contact at the

Table 2 – The Earthnet spacecraft and their data

Spacecraft	Lifetime	Sensor type	Application
Landsat-1	Launched 22.7.72 retired 6.1.78	Multispectral scanner (MSS)	Land
Landsat-2	Launched 22.1.75 retired 22.1.80 back in operation in May 1980	Multispectral scanner (MSS)	Land
Landsat-3	Launched 5.3.78 expected to operate until mid 1983	Multispectral scanner (MSS) Return beam vidicon (RBV)	Land
Landsat-D/D'	Launches planned for 1982 and following years	Multispectral scanner (MSS) Thematic mapper	Land
Seasat-1	Launched 26.6.78 failed 9.10.78	Active and passive microwave sensors – Altimeter – Scatterometer – Synthetic aperture radar (SAR) – Scanning multi-channel microwave radiometer (SMMR)	Sea and coastal zones (and land for SAR-type data)
HCMM	Launched 26.4.78 retired 14.9.80	Two-channel scanning radiometer (thermal infrared band)	Earth surface temperature measurement
Nimbus-7	Launched 24.10.78 expected to operate until 1983	Coastal zone colour scanner (CZCS) Scanning multichannel microwave radiometer (SMMR)	Troposphere and stratosphere observation, ocean monitoring. Land and sea temperature profiles, sea surface winds, snow cover, soil moisture, etc.

Royal Aircraft Establishment at Farnborough (UK), the Swedish Space Corporation at Solna (Sweden) and the Swedish Earthnet station at Kiruna (northern Sweden).

The distribution of the remote-sensing data, including both 'quick-look' and full-resolution images, has been integrated functionally into a comprehensive database interrogation system, in order to demonstrate the feasibility of offering earth-resources data users a complete on-line service, extending from initial enquiry to actual delivery of the final product.

Earthnet
The Earthnet programme was set up to facilitate the establishment of a well-structured remote-sensing user community in Europe and to build up the necessary remote-sensing expertise within the Agency, in preparation for the future European remote-sensing satellite programme. The decision to locate this unit at ESRIN was taken in 1978. The terms of reference of the programme include the acquisition, archiving, preprocessing and distribution of satellite remote-sensing data. The Earthnet Programme Office is responsible for programme management, network

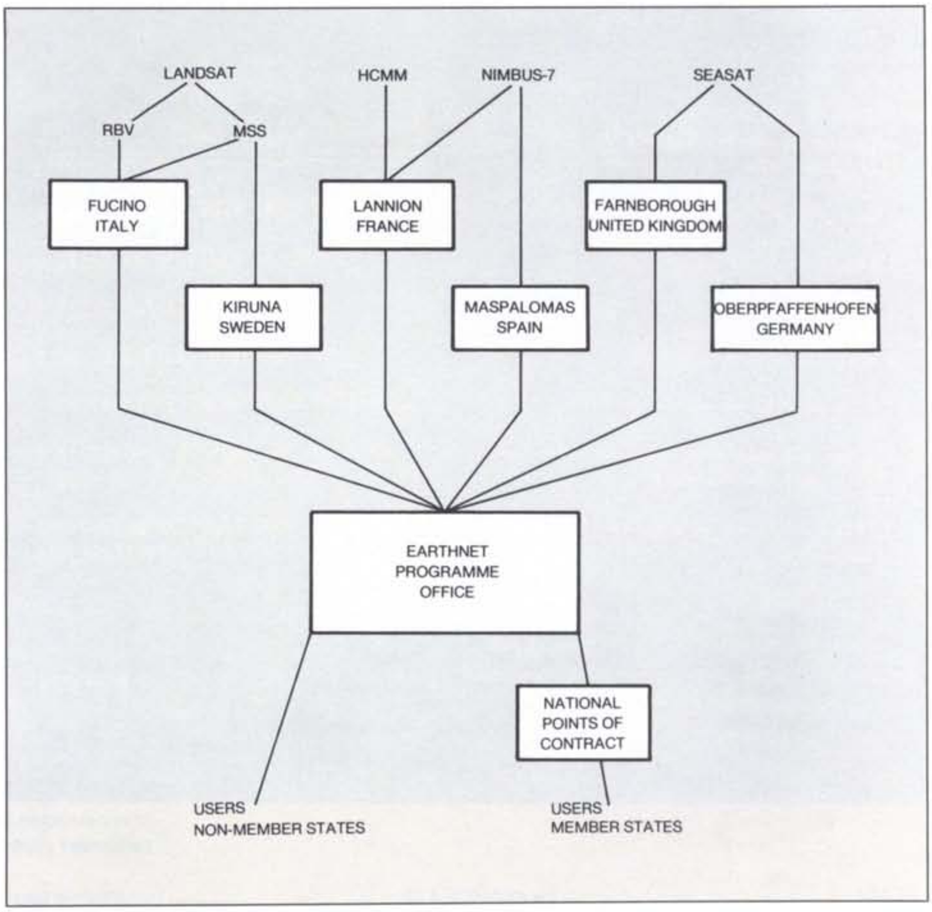


Figure 6 – The current Earthnet network

monitoring, user interfacing, data distribution, and preparations for future activities.

Present Earthnet activities are centred around the acquisition and preprocessing of data from the American Landsat-1, 2 and 3, Nimbus-7 and HCMM (Heat Capacity Mapping Mission) satellites, the roles of which are summarised in Table 2. Future activites will include the handling of data from the Landsat-D/D' satellites and from a number of ad-hoc campaigns, such as the Convair-580 aircraft SAR campaign this year, and from the microwave experiments on the Space Shuttle and on Spacelab.

Work is currently underway in preparation for the first European remote-sensing satellite, and particularly for those aspects associated with the acquisition, preprocessing and distribution of the data from this satellite.

The data collection is to be based on a network of stations (Fig. 6) which first became operational in 1978; it currently includes four receiving stations and two synthetic-aperture radar (SAR) processing centres. The stations are located at Fucino in Italy and Kiruna in Sweden (Landsat data), Lannion in France (HCMM and Nimbus-7 data), and Maspalomas on the Canary Islands (Nimbus-7 data). The coverages of these stations are shown in Figure 7 (the Oakhanger station in the UK has been used to acquire data from Seasat-1).

The two SAR processing centres are at Farnborough (RAE) in the UK and at Oberpfaffenhofen (DFVLR) in Germany.

The remote-sensing data already being distributed from ESRIN includes multispectral images in the visible and infrared, as well as microwave data obtained from active and passive sensors. Users can take advantage of different powers of resolution, ranging from the 10m × 12 m for Seasat SAR to the 40 m × 40 m of Landsat, and the 50 m × 50 m of the multichannel microwave radiometers of Seasat and Nimbus-7.

The standard products include digital data in the form of raw data or system-corrected information on computer-compatible tapes, and data in photographic form – black and white films and prints, colour composites, optical enlargements on various scales.

Only the 'standard products' mentioned above are distributed directly from the central facility at ESRIN. The national points of contact in the Member States are responsible for the redistribution and provision of special products, services such as the interactive use of computer systems, data analysis and interpretation, and discipline-oriented applications packages.

A further service provided by the Earthnet Programme Office at Frascati is the so-called 'browse facility' (Fig. 8), which is intended to help users to inspect the archives and formulate their orders. Complete, up-to-date files of incoming data are maintained in 'quick-look' form, to aid users in assessing specific coverages, and cloud-free imagery, as well as the best available recordings. The facility also includes micro-image catalogues of Earthnet Landsat acquisitions, as well as a microfiche collection, from the US EROS Data Center, of Landsat recordings made around the world.

As far as the next few years are concerned Earthnet's key objectives will be:

- to increase the number of remote-sensing missions handled

Figure 7 – Coverage zones of the Earthnet ground stations

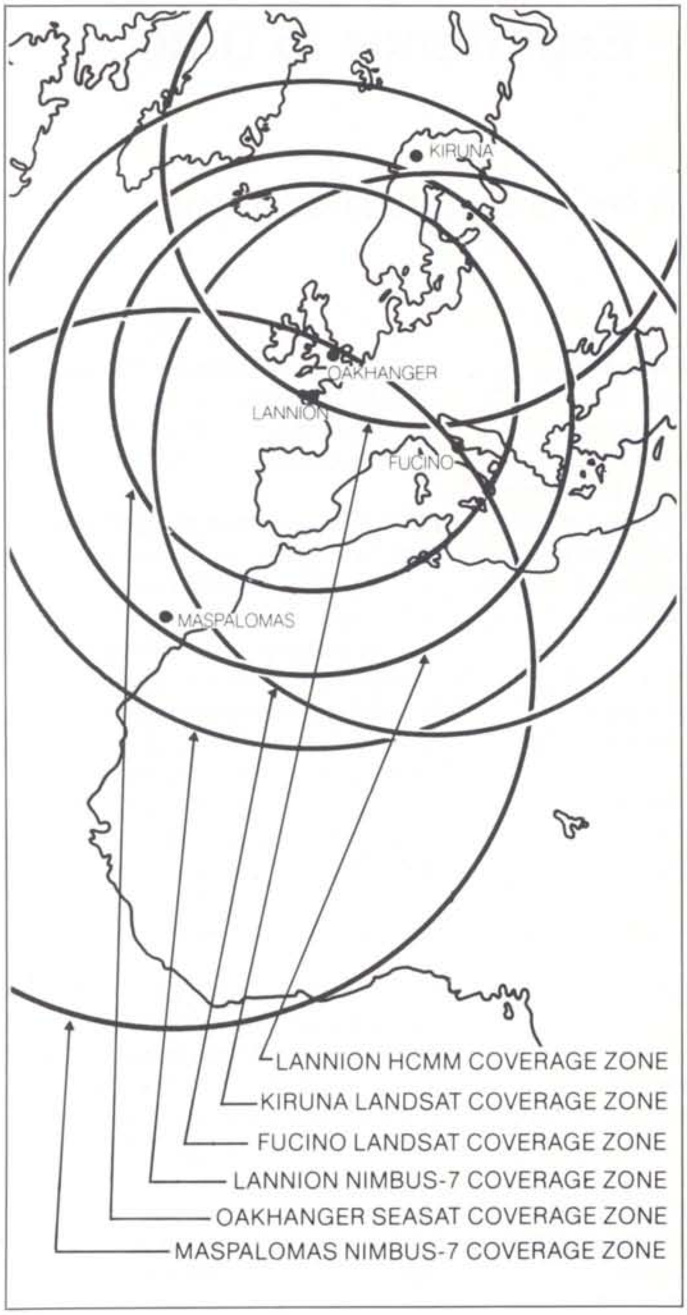


Figure 8a,b – The Earthnet Programme Office's browse facility

- to maintain a high quality of standard product
- to introduce new products tailored to users' needs
- and to offer a faster data-distribution system.

Nimbus-7 Coastal-Zone Colour Scanner Data Processing for Earthnet – Experience to Date

L. Fusco, Earthnet Programme Office, Frascati, Italy

The acquisition, preprocessing, archiving and distribution to users of CZCS data from the Nimbus-7 spacecraft is one of the tasks of the Earthnet Programme Office*. CZCS data are used by the European scientific community to demonstrate the usefulness of space-acquired data for coastal-waters monitoring.

*See article on page 28 of this issue for further information.

The Nimbus-7 spacecraft system

Nimbus-7 was launched in October 1978 to conduct a variety of experiments in oceanography, meteorology and pollution control. Integrated subsystems on the spacecraft provide the power, attitude control and information flow to support the scientific experiment payload, which makes use of the following instruments:

CZCS	coastal-zone colour scanner
ERB	earth radiation budget
LIMS	limb infrared monitor for the stratosphere
SAM-II	stratospheric aerosol measurement (II)
SAMS	stratospheric and mesospheric sounder
SBUV	solar and backscatter ultraviolet spectrometer
TOMS	total ozone mapping spectrometer
SMMR	scanning multichannel microwave radiometer
THIR	temperature humidity infrared radiometer.

The Nimbus-7 communication and data-handling system includes three different routings for the sensed data:

- a versatile information processor (4 kbit/s)
- a digital information processor (25 kbit/s)
- the CZCS information processor (800 kbit/s).

The 800 kbit/s CZCS data processor multiplexes the data acquired from the six CZCS radiometric channels, removes non-sensible data and adds calibration and synchronisation data.

Figure 1 shows the Nimbus-7 spacecraft in orbital configuration, with its solar panels unfolded. The spacecraft's performance is summarised in Table 1.

CZCS instrument and its objectives

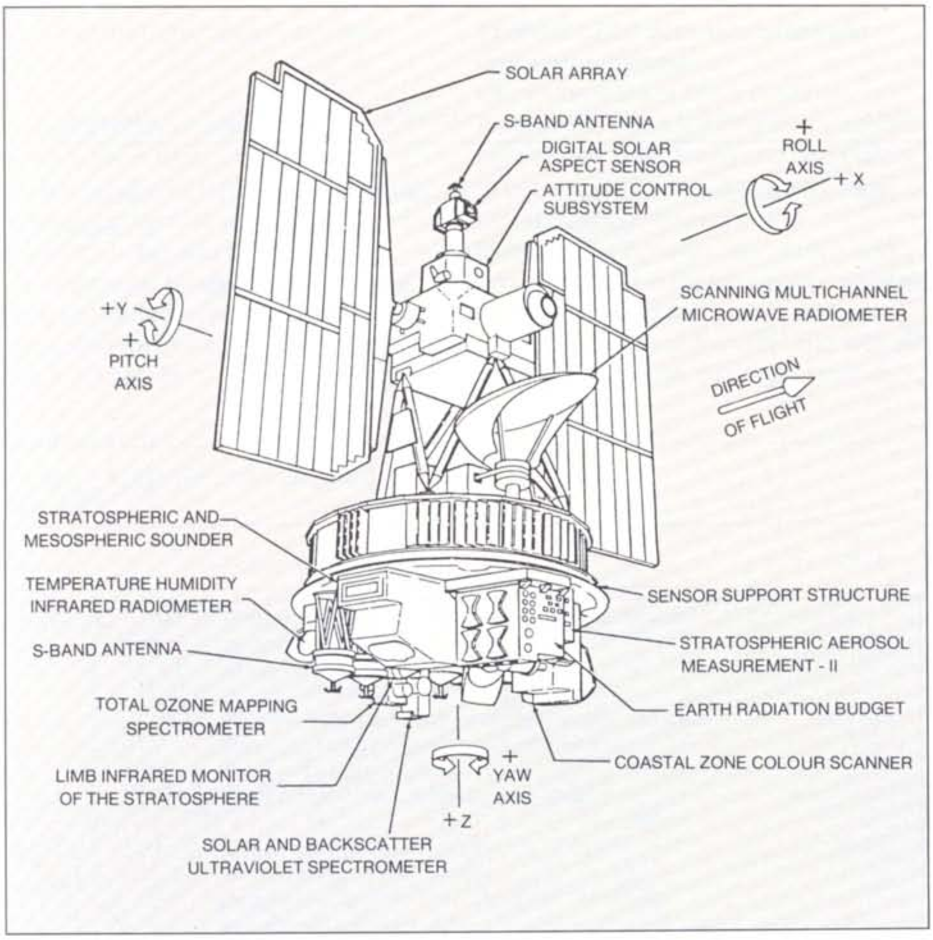
The coastal-zone colour scanner is the only space instrument to date to be devoted solely to ocean and coastal-zone water monitoring. Each instrument parameter has therefore been optimised for use over water, to the exclusion of any other land and meteorological sensing. Since water is a poor reflecting surface, high signal-to-noise ratios are used in the spectral channels sensing reflected solar radiance. Consequently, some of the channels saturate when the fields of view encompass land areas and clouds.

The CZCS experiment is designed to measure water colour and temperature. It is well known that water colour is affected by many organic and inorganic coloured scatterers and absorbers. Chlorophyll, for example, absorbs strongly in the blue and normally changes the water colour to green. Inorganic elements usually have different colours from organic materials, typically in the red/brown part of the spectrum.

The major objectives for the CZCS can be summarised as:

- optimum qualification and quantification of suspended materials. By providing the first opportunity to carry out rapid measurements over large water areas, the CZCS will increase our scientific knowledge of water phenomena. Analysis of the

Figure 1 – The Nimbus-7 spacecraft



data collected over the existing fish-producing areas will be used to investigate other potentially productive areas.

– definition of the requirements for future ocean-monitoring instruments. The CZCS experiment will help to define the requirements for future operational oceanographic satellites, such as Europe's ERS-1. Oceanographic institutions are already experimenting with real-time acquisition and production of sea-parameter maps for the planning of their future activities.

The performance of the CZCS instrument is summarised in Table 2. Considerable flexibility has been built into the instrument: individual gains can be set for channels 1–4 to allow the best possible dynamic range over water targets, and the scan mirror can be tilted to avoid sun glint. To improve the instrument's response still further, thresholding of the top 30% of the signal is possible for channels 1–4.

All channels were calibrated prior to launch. Channels 1–5 can be calibrated

Table 1 – Nimbus-7 performance parameters

Orbital altitude	955 km
Orbital inclination	99°
Orbital period	104 min, passing equator at 1200 h mean solar time
Westward displacement of consecutive subsatellite tracks at the equator	26.04° ≃ 2890 km
Number of orbits per day	14
Westward displacement of subsatellite tracks on consecutive days at the equator	4.56° ≃ 506 km
Repeat cycle	83 orbits ≃ 6 d
Westward displacement of subsatellite tracks of the repeat cycle at the equator	1.3° ≃ 144 km

Table 2a – CZCS performance parameters

Angular resolution	0.865 m rad (.0496)
Interchannel registration at nadir	0.15 m rad
Resolution	0.825 km × 0.825 km at nadir (sea level)
Scan angle	1.374 rad (78.68°)
Swath width	1566 km
Consecutive swath overlap	0.209 km (25%)
Information bandwidth	800 kHz (for 6 channels)
Scan mirror – tilt around pitch	± 20° with steps of 2°
Telescope	Cassegrain
Data count resolution	8 bits (for all channels)

Figure 2 — The EURASEP test sites

Table 2b – CZCS performance parameters

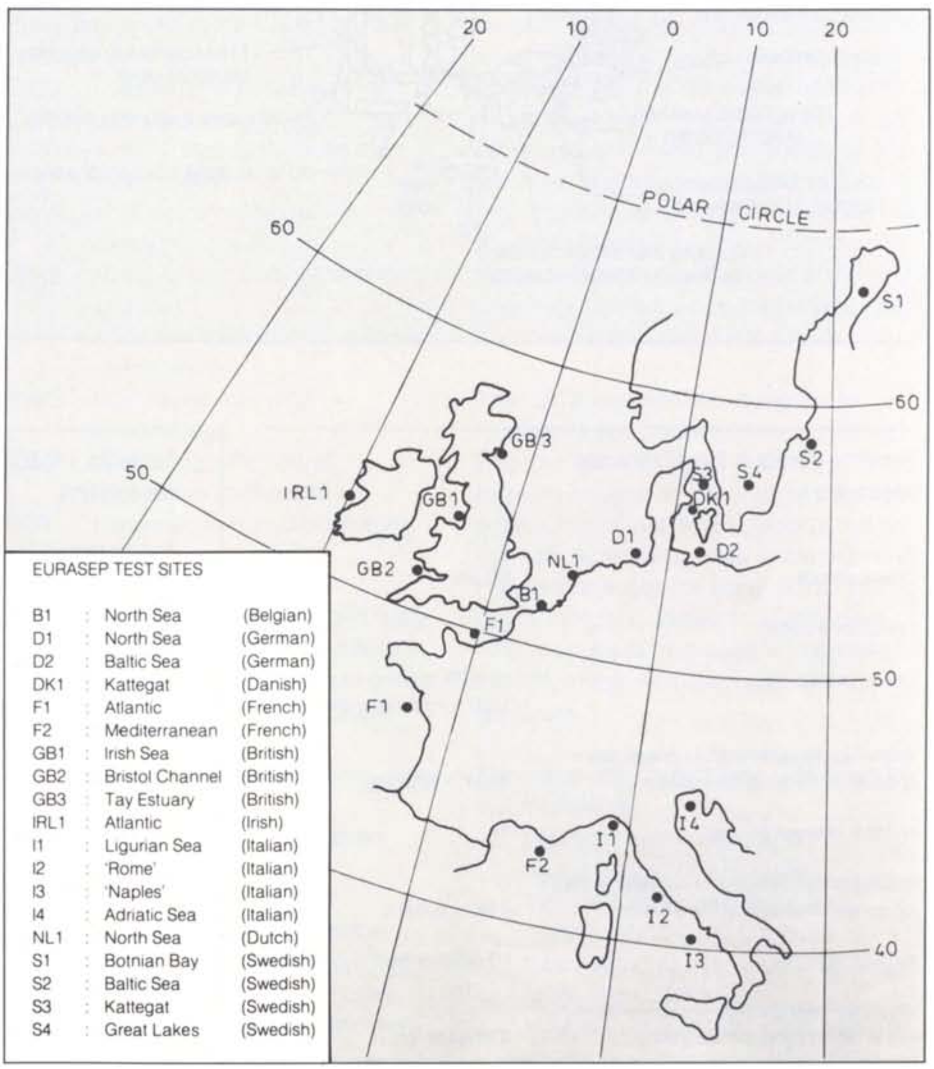
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6
Scientific observation	chlorophyll	chlorophyll	yellow substances	chlorophyll	surface vegetation	surface temperature
Spectral bandwidth (μm)	0.433 – 0.453	0.510 – 0.530	0.540 – 0.560	0.660 – 0.680	0.700 – 0.800	10.5 – 12.5
Saturation radiance for gain 0 (mW/cm^2.Sr.μm)	11.46	7.64	6.21	2.88	23.9	
Saturation radiance for gain 3	5.41	3.50	2.86	1.34	23.9	
Channel 6 noise equivalent temperature difference						0.22 K at 270 K
Channel 6 usable range						270 – 320 K

in-flight using a light source and channel 6 with a blackbody source at monitored temperature.

The CZCS data can be recorded on board and played back later to a NASA acquisition station, or transmitted to ground in real time at 800 kbit/s.

CZCS user community
As part of the Nimbus-7 programme and NASA's centralised processing organisation, a group of expert users has been set up to support development of algorithms to aid the operational acquisition planning, and to demonstrate the usefulness of the data products. The tasks of this CZCS Nimbus Experiment Team (CZCS-NET) include development trade-offs, sensor calibration, sensor-performance verification, definition of priorities in data acquisition, data formats, testing of algorithms for the extraction of geophysical parameters by comparison with truth measurements, etc.

The European contribution to CZCS-NET is provided by EURASEP (European Association of Scientists for Experiments on Pollution), a project organised by the Joint Research Centre of the Commission of the European Communities, with the aim of establishing a technique for monitoring the quality of the coastal



waters of the Commission's member countries.

European offshore waters vary significantly in terms of climate, tidal actions, upwelling, latitudes, bathymetry, types and quantities of suspended and dissolved matter and coastal characteristics. Nineteen test sites have been selected to represent as many of these different characteristics as possible (Fig. 2 & Table 3).

Earthnet CZCS data-acquisition and processing stations

One of the tasks of ESA's Earthnet Programme Office (EPO) is the reception, preprocessing, archiving and distribution to users of CZCS data. It therefore runs two acquisition stations, one at Maspalomas in the Canary Islands and one at Lannion in Brittany, at which data are also archived and processed up to the generation of 'quick-look' and system-correction products. CZCS data can also be processed at the EPO central facility in Frascati for quality-assurance purposes. Figure 3 shows the coverage of the data archived by the two stations.

The Maspalomas station, opened in September 1980, has an S-band 10 m antenna and associated receiving chain. The CZCS data (800 kbit/s) and the data from the other sensors (25 kbit/s) are bit and format synchronised and fed in to a PDP-11/34 minicomputer, for preformatting and subsequent recording on computer-compatible tapes (CCTs).

The Lannion CZCS station, opened in April 1979 (from orbit 2200), uses two antennas and acquisition chains up to the analogue recording of the CZCS signal.

CZCS data processing

The Earthnet data-processing package is based on a NASA package run at Goddard Space Flight Center (Fig. 4).

Raw data products

The CZCS data recorded on high-density tapes (HDTs) at Lannion or on CCTs at Maspalomas are processed to

Table 3 – EURASEP national project objectives

Country	Research objectives	Test site no.
Belgium	Primary production, eutrophication and industrial waste dumping in the English Channel Modelling of the North Sea	B1
France	Sediment transport, dynamics of estuaries and tidal zones Pollution of telluric origin, diffusion phenomena Pollution by hydrocarbons Spectral signatures and atmospheric effects	F1, F2
Germany	Geodynamics of coastal regions Chemical and thermal pollution Sediment transport by tides, chlorophyll, distribution Ice registration and sea state Atmospheric turbidity	D1, D2
United Kingdom	Suspended-sediment concentration and temperature Chemical constitution Salinity Currents	GB1, 2, 3
Italy	Sediment transport Pollution of coastal zones Turbidity and fresh/salt-water interface Dynamics of estuary zones Currents Chlorophyll concentration Chemical wastes Coastal-water temperatures	I1, 2, 3, 4
Netherlands	Primary production Salinity distribution Sediment distribution Dumping of wastes Temperature distribution	NL1
Ireland	Salinity distribution Currents Yellow substances	IRL1
Sweden	Chlorophyll concentration Domestic pollution	S1, 2, 3, 4
Denmark	Various	DK1

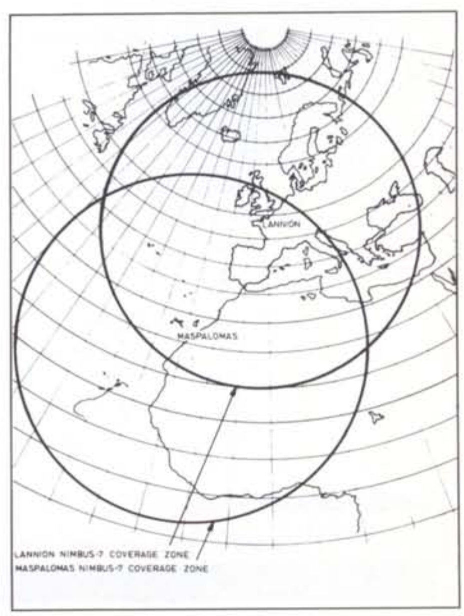
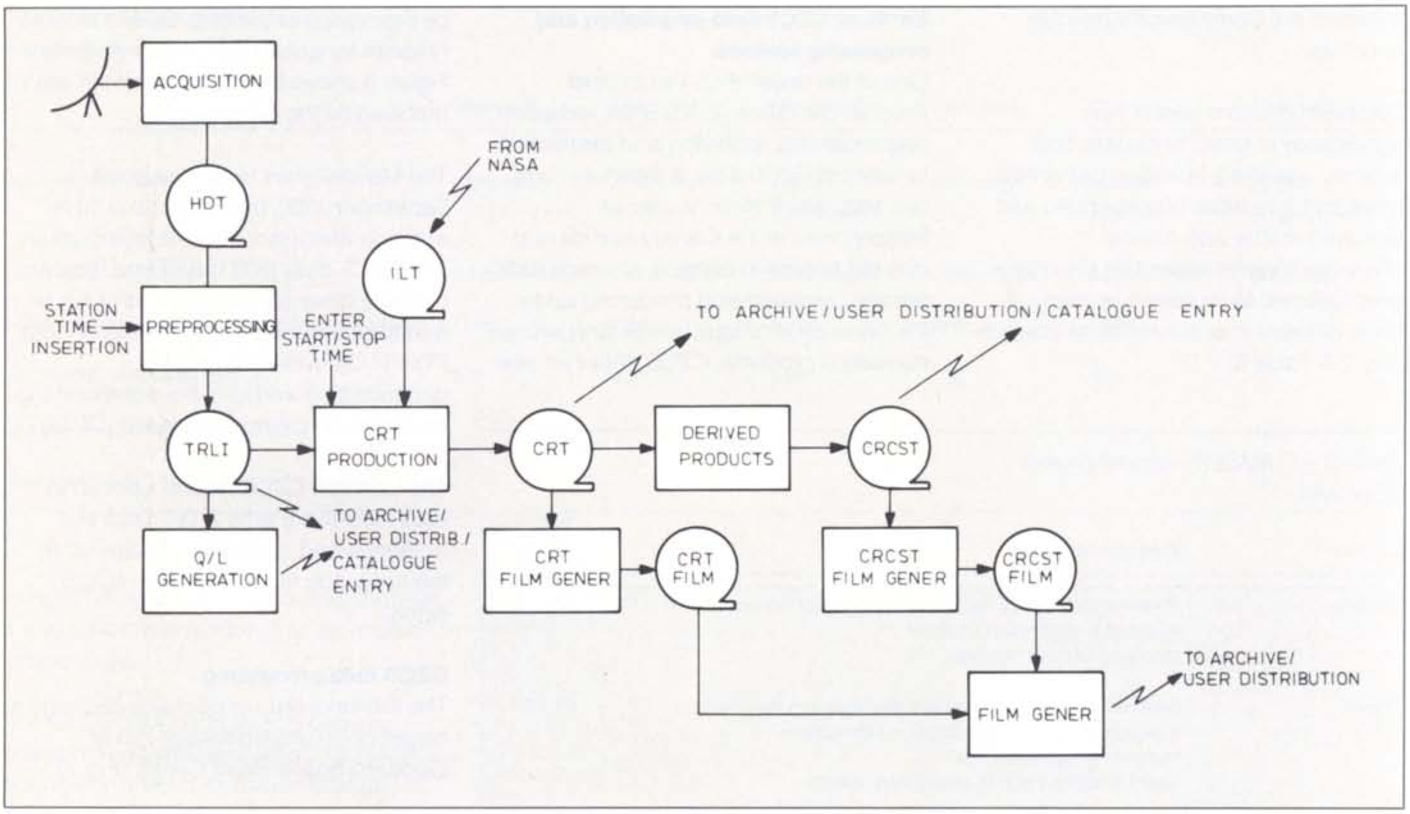
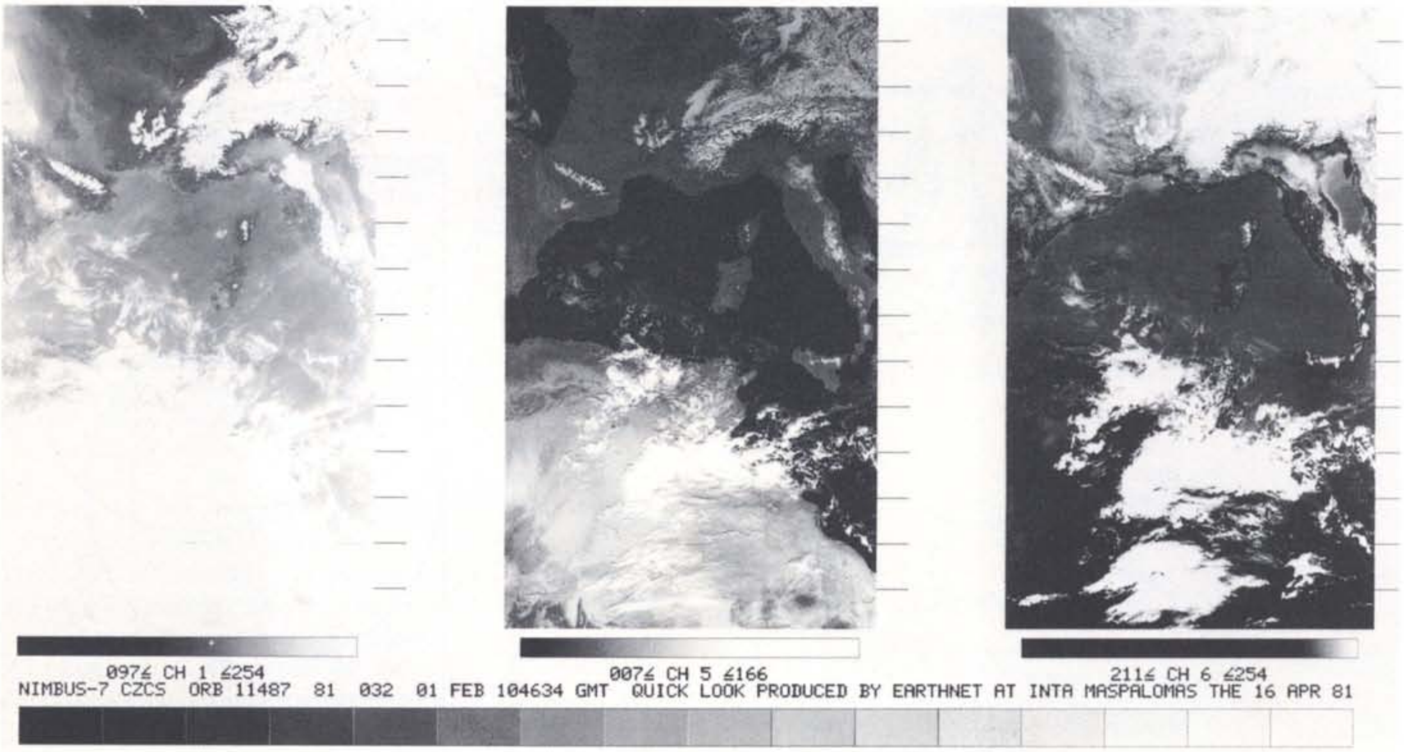


Figure 3 – Coverage zones of the Maspalomas and Lannion Earthnet stations

Figure 4 — CZCS-processing flowchart for the Lannion Earthnet station

Figure 5 — A CZCS 'quick look' image produced at the Maspalomas Earthnet station





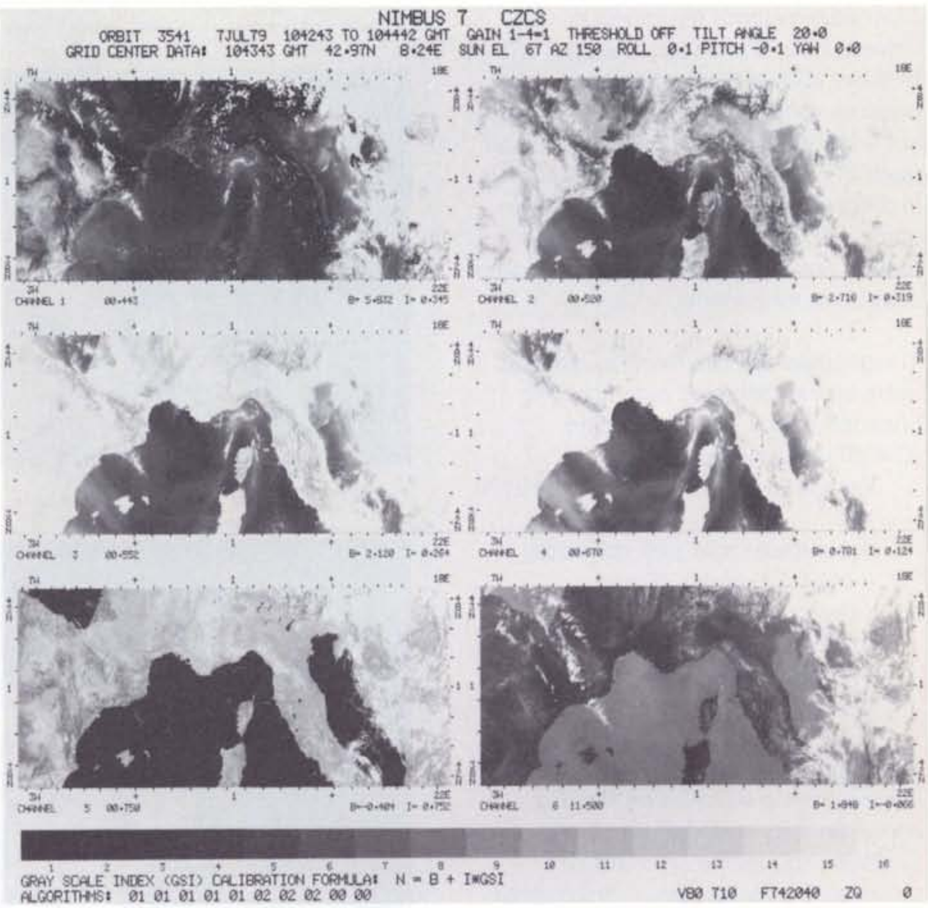


Figure 6 – Typical CRT film product delivered by the Lannion Earthnet station

generate CCTs with re-synchronised lines (TRLIs). These TRLI tapes carry the raw input for further processing and represent the prime archiving for CZCS data.

A quick-look capability is provided at TRLI generation for channels 1, 5 and 6 (Fig. 4). Data are stretched and time-tagged every 30 s, with indications of acquisition start/end times, ascending-node times, dates and orbit numbers.

An example of a CZCS quick-look is shown in Figure 5.

System-corrected products

The steps involved in generating standard system-corrected radiance and temperature products are as follows:

1. The TRLI raw data are read to select the 2 min (970 scan lines) of interest. The appropriate data are then copied from tape to disk in a prescribed format. Relevant image-location information provided by NASA on the ILT-tape is copied onto disk. Operator inputs are requested to specify orbit number and start/end time of data to be processed.

2. The raw-image, housekeeping and image-location data are processed to generate the CRT tape. The housekeeping data are first screened to extract calibration parameters in the visible and infrared channels, gain setting, tilt angle, reference lamp flag; spacecraft and sun-ephemeris attitude parameters are then processed to locate in a given earth coordinate system for each scan line (77 reference pixel positions). Misalignments of mirror rotation with respect to the optical (roll and tilt) axes are taken into account.

3. The CRT tape is formatted. Image data are not corrected, but all necessary correction parameters are provided on tape.

4. The CRT tape is processed to generate the CRT film product. The CRT documentation records are read in and the data are processed to generate film annotation information. CRT image data are enhanced and an intermediate CCT – called CRT film tape – is generated. The enhancement transformation uses the estimated radiance at the centre of the scene due to the Rayleigh scattering for channels 1 – 4. The same correction is applied to the whole image to improve the results over water.

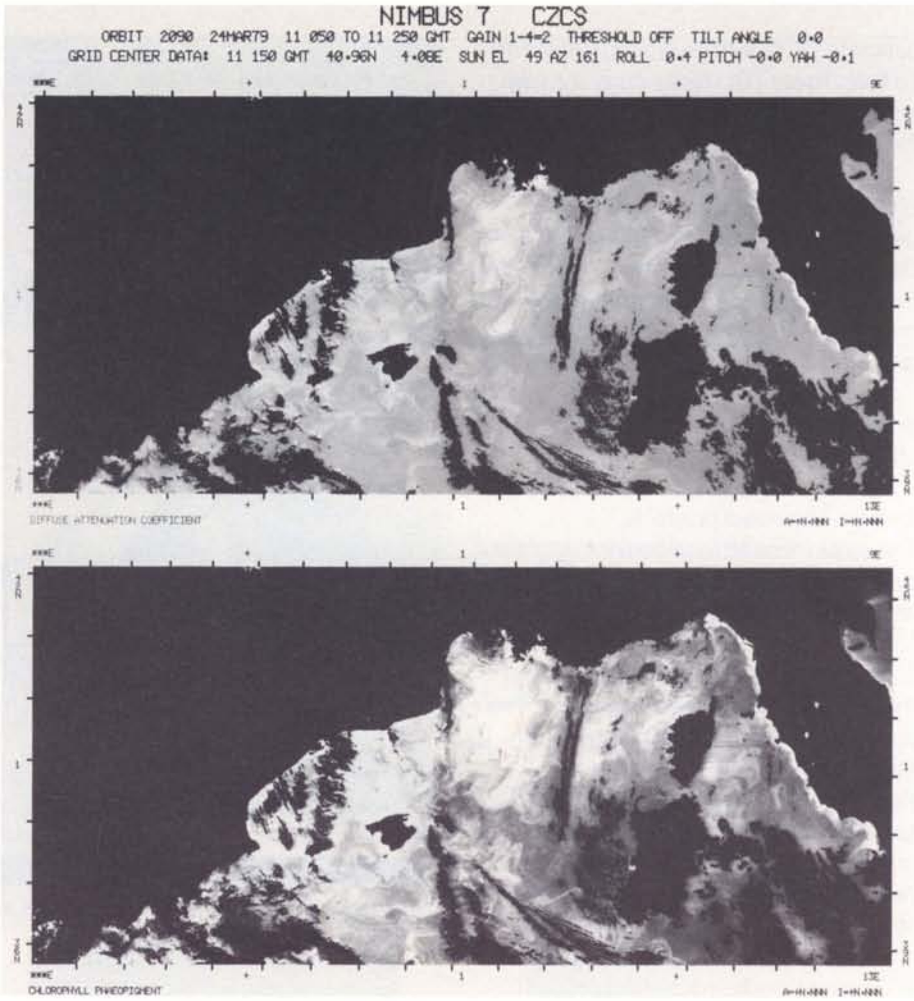
The CRT film tape is used as the data source for the film writer device. The Lannion station uses a VISIR laser film recorder, while Maspalomas uses an Optronic system. To achieve an image aspect ratio of 1 : 1, certain lines must be duplicated (19%) and certain pixels repeated (25%). A typical CRT film product is shown in Figure 6.

5. Finally, the CRT tape is processed to generate user printouts carrying the relevant CRT information.

Geophysical data products

The first objective in deriving geophysical water parameters is to compute radiances at sea level, for which the contribution of the various absorption and scattering sources must be computed. The NASA algorithm (from H. Gordon, University of Miami) uses the radiance in the 0.750 mm band to screen out clouds, land and regions of high sediment and/or chlorophyll, and the radiance in the 0.670 mm band to estimate the effect of sun glint and aerosol scattering on the upwelled radiance observed at the spacecraft. The upwelled radiance in the 0.443, 0.520 and 0.550 mm bands is then corrected at each pixel to derive the subsurface radiances.

Figure 7 – Preliminary examples of NASA-processed geophysical products



Alternative methods for atmospheric correction have been proposed by B. Sturm (EURASEP) and other scientists, because some of the hypotheses inherent in the NASA algorithm do not apply to all types of European waters. A large effort is in progress within the scientific community, lead by the Nimbus Experiment Team, to finalise the proposed algorithms for Earthnet.

The geophysical data made available to users on the calibrated radiances, chlorophyll sediment temperature (CRCST) tape include:

- aerosol radiances, computed at 0.670 mm
- subsurface radiances, computed at 0.443, 0.520 and 0.550 mm
- pigment concentrations and diffuse attenuations computed as functions of the 0.442, 0.520 and 0.550 mm subsurface radiances.

These geophysical parameters are also made available by NASA on film (Fig. 7 shows an early example), and the Earthnet Programme Office will be providing European users with the same type of product in the coming months.

Nimbus-7 CZCS Data Catalogue

All CZCS-acquired and processed data are made available to the Earthnet user community. The Earthnet centralised catalogue system contains the information needed to retrieve and select CZCS image data and products. Entries in the Catalogue are set up at the acquisition and processing station, using tracking information (i.e. geographic parameters), CZCS image and housekeeping data (i.e. data quality), and operator inputs (i.e. visual quality). The CZCS Catalogue is organised so that users may access it either as a geographical database or by specifying an orbit and time of acquisition.

The CZCS Catalogue is currently available at the Earthnet Programme Office in Frascati and it is planned to make it more widely accessible via ESA's Information Retrieval Service (IRS) network.

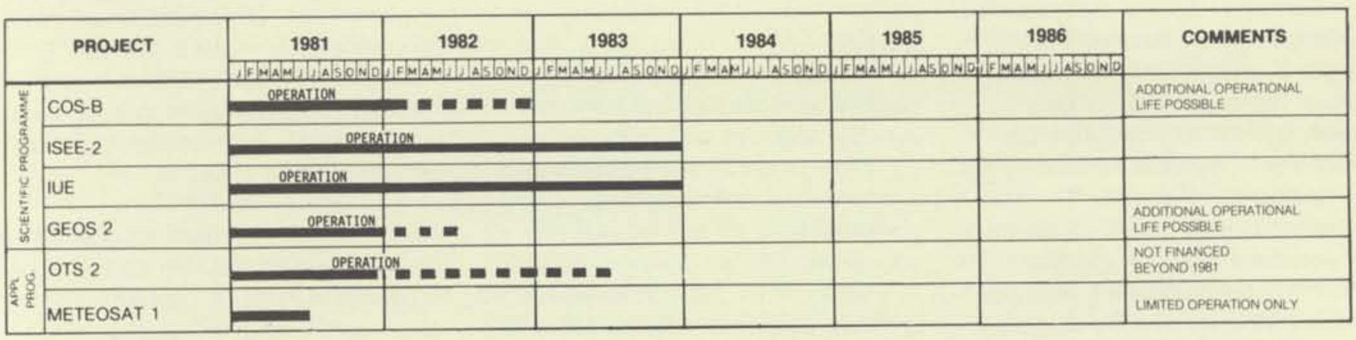
Summary of CZCS operations

The operational CZCS data-processing and user-product services are based on the following scheme:

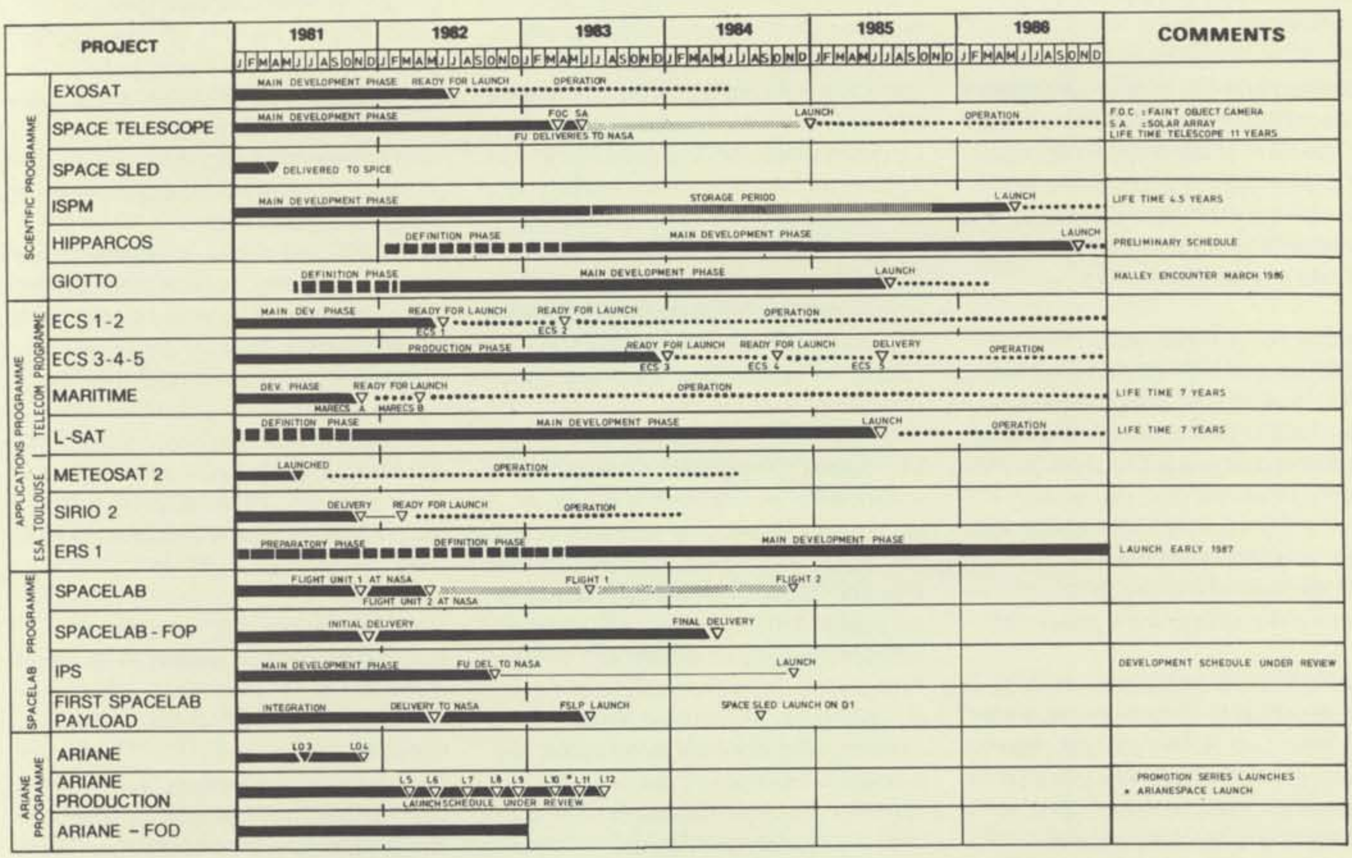
- The CZCS data-acquisition stations (Lannion and Maspalomas) are responsible for acquisition, data formatting (TRLI), data archiving, quick-look generation, and system-corrected products. Derived products will be available from the central facility (EPO, Frascati).
- Quick-looks are distributed weekly to major users and to EPO.
- The Earthnet Catalogue is kept up to date at EPO.
- The Earthnet User Services Branch services all user needs in the areas of data selection/ordering/distribution.
- Data quality control is performed at two different levels:
  (1) during product generation at the archiving station. The operators manually check the printouts produced during processing against reference values. Special visual inspections are made of the film products.
  (2) at EPO, on selected products. The CZCS product-generation package is also installed on the EPO computer, so that specific problems highlighted during operational processing at the two stations can be studied centrally.

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

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



* Reporting status per 1 June 1981/Bar chart valid per 1 July 1981

Situation des projets décrits 1er juin 1981/Planning 1er juillet 1981

OTS

OTS entre dans sa quatrième année d'exploitation en orbite et tous les sous-systèmes de bord continuent de fonctionner de manière excellente. Les Etats membres ont donné leur accord de principe pour que la mission se poursuive pendant encore deux ans et les dispositions financières nécessaires sont en cours de mise au point.

A l'exception d'une panne accidentelle de l'amplificateur à tube à ondes progressives (ATOP) qui a entraîné l'utilisation d'une unité redondante, tous les équipements embarqués continuent de fonctionner de façon satisfaisante. Les températures à bord du satellite ont tendance à s'égaliser, ce qui indique une vitesse de dégradation réduite des surfaces de protection thermique. La quantité d'ergol indiquée est supérieure à 33 kg, de sorte qu'avec une consommation d'environ 10 kg par an, il serait possible d'assurer le maintien à poste pendant une cinquième année en orbite. La puissance de sortie du réseau solaire reste bien au-dessus de la valeur minimale prévue. Le fonctionnement des batteries d'accumulateurs au cours de la période en éclipse qui vient de s'achever récemment dénote des performance irréprochables.

Les équipements des expériences Stella et Spine continuent de fonctionner de façon satisfaisante et ils permettent d'acquérir, dans le domaine de l'exploitation des réseaux de transmission de données, une expérience qui pourra utilement être appliquée aux systèmes futurs.

Les essais de transmission de données numériques à grande vitesse se déroulent régulièrement à partir des grandes stations terriennes d'Eutelsat en utilisant le module A du satellite. On utilise de plus en plus le module B pour un certain nombre d'expériences orientées vers les applications, car le nombre des expérimentateurs de la propagation continue à diminuer comme prévu.

Les transmissions de télévision française à destination de la Tunisie continuent à fonctionner avec succès sur une base régulière et on a également procédé à des démonstrations de divers types, notamment une démonstration de téléconférence qui a eu lieu en mars, à Gênes (Italie), lors de la 'Conférence internationale sur les Télécommunications numériques par satellite'.

Une conférence a eu lieu à Londres, en avril, sous les auspices de l''Institution of Electrical Engineers'; elle était entièrement consacrée aux résultats des mesures et des expériences d'OTS. L'assistance y a été nombreuse et les documents présentés, parmi lesquels plusieurs contributions de l'ESA, ont fait apparaître l'importance du programme expérimental exécuté par la communauté des utilisateurs à l'aide d'OTS.

Exosat

Satellite

Le modèle technologique du satellite est parvenu au terme du programme des essais obligatoires après quoi plusieurs équipements ont dû être démontés pour faciliter les travaux d'intégration préliminaires du modèle de vol. Ces équipements ont été depuis réintégrés et la mise en service des logiciels est terminée. Des essais de compatibilité RF avec l'équipement de télémesure de la station sol doivent avoir lieu en juillet.

La seconde et dernière partie de la Revue critique de Développement (DRR-B), tenue en mars, a permis de définir des mesures destinées à faciliter la liquidation des travaux au cours des prochains mois.

Le modèle mécanique a été utilisé à l'ESTEC pour vérifier les paramètres de performances critiques de l'interface satellite/lanceur qui jouent un rôle crucial au moment de la séparation. D'autres essais sont en préparation pour confirmer d'importants impératifs concernant l'accès au satellite lors de son installation sous la coiffe du lanceur.

Les travaux d'intégration du modèle de vol ont été interrompus chez MBB et la structure a été renvoyée chez MSDS pour des modifications à apporter au circuit de propane de l'équipement de commande par réaction (AOCS). Les travaux ont maintenant repris chez MBB et l'intégration de l'alimentation électrique, du câblage et de l'équipement de traitement des données est terminée. Les problèmes identifiés au niveau des sous-systèmes du satellite concernent l'électronique de l'AOCS (défaillance de composants), le réseau solaire (échec des essais) et des équipements de traitement de données (modification conceptuelle).

Charge utile

Le nouveau fournisseur des feuilles en béryllium est maintenant en mesure de fabriquer, avec une reproductibilité raisonnable, des feuilles de 62 μm d'épaisseur pour les fenêtres d'admission des rayons X des détecteurs 'moyenne énergie'. On a en outre fait appel à une nouvelle méthode consistant à fixer la feuille sur une plus grande partie de la surface du collimateur de façon à limiter rigoureusement le mouvement de la fenêtre.

Trois détecteurs dotés de feuilles de 37 μm ont été livrés et étalonnés dans les installations de Leicester. Quatre autres détecteurs se trouvent à des stades divers du montage et des essais chez les contractants (LND), la réalisation d'un cinquième sera entreprise sous peu, après livraison des feuilles. Huit détecteurs sont nécessaires pour le vol.

Les deux télescopes imageurs destinés au modèle de vol ont été livrés, l'un pour intégration au satellite, l'autre pour des essais d'étalonnage à l'installation de Munich (MPI). Les activités d'étalonnage, qui se sont déroulées depuis le mois de mars jusqu'à ce jour, ont fait apparaître un certain nombre de problèmes au niveau 'système'; des solutions adéquates ont déjà été trouvées pour la plupart d'entre eux. Le principal sujet de préoccupation est lié au flux du compteur proportionnel à gaz pour les coordonnées d'impact, qui se révèle être plus important que prévu aux basses énergies. Cet effet n'avait malheureusement pas été détecté sur les modèles scientifiques ou technologiques disponibles au MSSL et des études sur de nouveaux détecteurs ont été entreprises d'urgence chez le sous-traitant (Sira).

Le compteur proportionnel à scintillation dans le gaz (GSPC) sera livré prochainement; il fera l'objet d'un étalonnage complet et sera changé par la suite.

L'avis d'offre de participation au programme d'observation d'Exosat vient d'être lancé.

Lanceur

Les essais de validation de la configuration des injecteurs pour le lanceur L03 ont été conduits à bon terme et les préparatifs en vue d'un lancement de ce véhicule au mois de juin se déroulent conformément au calendrier.

OTS

OTS is now entering its fourth year of orbital operation with the status of all on-board subsystems continuing to be excellent. Member States have agreed in principle to continuation of the mission for a further two years and funding arrangements are being made to enable this.

With the exception of a random TWTA failure, which has necessitated the use of a redundant unit, all on-board equipment continues to operate well. Spacecraft temperatures are tending to level off, indicating a reduced rate of degradation of thermal surfaces. The indicated propellant level is above 33 kg which, with a usage rate of approximately 10 kg/year, could allow on-station operation well into a fifth year in orbit. The array power output continues to remain well above the minimum predicted value. Battery operations during the recently completed eclipse period indicated flawless performance.

The Stella and Spine experiments continue to operate satisfactorily and both are providing experience in the operation of data-transmission networks which can usefully be applied to future systems.

High-speed digital tests are taking place on a regular basis from the large Eutelsat earth stations through module A of the satellite. Increasing use is being made of module B for a number of applications-oriented experiments, as the number of propagation experiments continues its planned decline.

French television transmissions to Tunisia continue to function successfully on a regular basis and a variety of other demonstrations have also been given including a teleconference demonstration at the International Conference on Digital Satellite Communications in Genoa, Italy in March.

In April, a conference held under the auspices of the Institution of Electrical Engineers in London was entirely devoted to the results of OTS measurements and experiments. The conference was well attended and the papers presented, including a number of ESA contributions, reflected the significant extent of the experimental programme carried out by the user community using OTS.

Exosat

Satellite

The engineering model has completed its mandatory test programme, after which several units had to be removed to assist preliminary flight-model integration work. These units have now been reintegrated and software commissioning completed. RF compatibility testing with the ground-station ranging equipment is due to take place in July.

The second and final part of the Development Results Review (DRR-B) was conducted in March and a number of remedial actions were defined to facilitate proper close-out during the forthcoming months.

The mechanical model has been used at ESTEC to verify critical performance parameters for the satellite-to-launcher interface, which plays a vital role during the separation phase. Further tests are being prepared to check important requirements for access to the satellite during its installation under the launcher's fairing.

The flight-model spacecraft integration work was interrupted at MBB during the reporting period and the structure returned to MSDS for rectification work on the AOCS propane subsystem. Integration work has now restarted at MBB and the power-supply, harness and data-handling equipment have been integrated successfully. There are still a number of problems relating to spacecraft subsystems, including the AOCS electronics (component failure), the solar panels (test failure) and the data-handling units (design change).

Payload

The new producer of beryllium foil is now able to manufacture 62 μm sheets for the X-ray entrance windows of the medium-energy detectors with reasonable repeatability. A method of attaching the foil to a greater area of the collimator has also been introduced to strictly limit window movement.

Three detectors with 37 μm foils have been delivered and calibrated at the Leicester facility. Four others are in various stages of assembly and test at the contractor (LND) and a fifth will be started shortly. Eight detectors are required for flight.

The two flight-model imaging telescopes have been delivered, one for spacecraft integration and one for calibration at the Munich (MPI) facility. The calibration activity, lasting from the beginning of March until now, has uncovered a number of system-level problems, but adequate solutions to the majority of them have already been identified. The greatest cause of concern is the higher than expected flux of the position-sensitive gas proportional counter at lower energies. This effect was not apparent on the scientific or engineering models available to MSSL and urgent investigations are presently proceeding at the subcontractor (Sira) on additional detectors.

The flight-model GSPC will be delivered shortly, will undergo full calibration, and will be integrated at a later date.

The announcement of opportunity for participation in the Exosat observation programme has just been issued.

Launcher

In view of the successful validation tests for the L03 injector configuration and the fact that preparations for a June launch of L03 are reported to be on schedule, the launch slot for Exosat in the middle of 1982 now agreed with the Launcher Authority appears realistic and all efforts are being made to meet this date.
While there is still a need to check the compatibility of vital interfaces between launcher and satellite, it has been agreed that verification tests should proceed on the appropriate levels and to cancel the requirement for the full-scale compatibility test previously envisaged.

Ground segment

Pre-integration at ESOC of the principal ground-station equipment was nearing completion at the end of May.
Preparations for the start of the compatibility tests with this equipment at ESOC have advanced well and MBB have initiated the changes to the CTU (compatibility test unit) needed to make the unit more representative of the flight model.

The software has now reached an advanced stage of development and some subsystem tests have started. The MSSS computers have been reconfigured to meet the Exosat requirements. Preparation of the necessary operating procedures has progressed well, and the first draft of the Flight Operations Plan is now due to be issued at the end of May.

C'est pourquoi le créneau de lancement actuellement arrêté pour Exosat avec les responsables du lancement – vers le milieu de 1982 – semble réaliste et tout est actuellement mis en oeuvre pour faire en sorte que cette date soit respectée.

Bien que la nécessité d'un contrôle de compatibilité des interfaces capitales lanceur/satellite ait été maintenue, il a été décidé que les intéressés procéderaient aux essais de vérification au niveau approprié et qu'on renoncerait à l'impératif d'un essai de compatibilité grandeur réelle précédemment envisagé.

Secteur sol

Fin mai, la préintégration à l'ESOC des principaux équipements de station-sol était presque terminée. Les préparatifs en vue de la mise en route des essais de compatibilité avec ces équipements à l'ESOC ont bien progressé et MBB a entrepris les modifications qui doivent être apportées à l'équipement d'essai de compatibilité pour le rendre plus représentatif du modèle de vol.

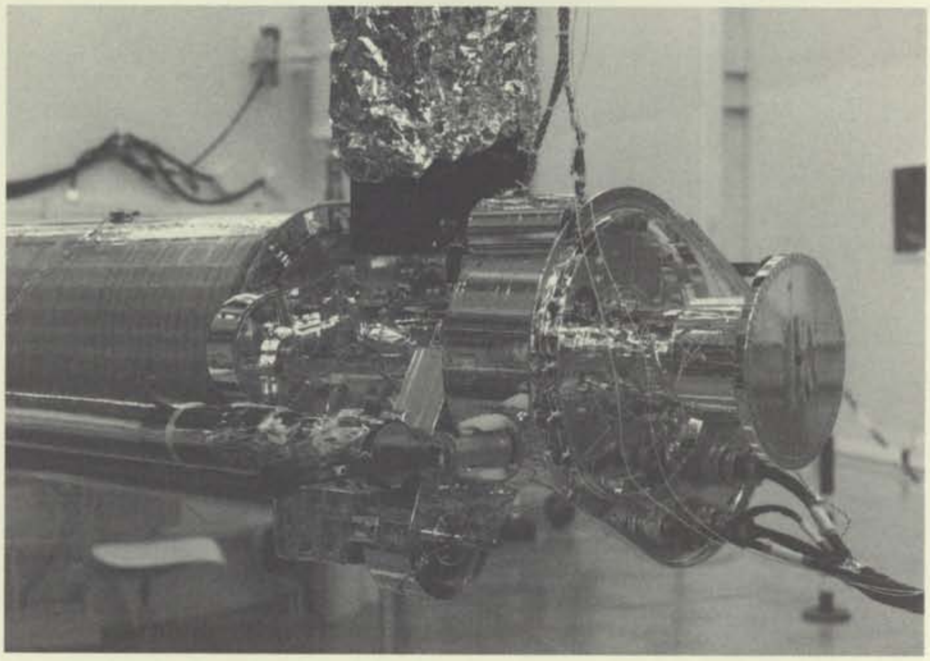
La mise au point du logiciel est parvenue à un stade avancé et quelques essais au niveau sous-système ont commencé. La configuration des moyens calcul du MSSS a été modifiée pour répondre aux impératifs d'Exosat. La préparation des procédures d'exploitation a bien progressé et la première version du Plan des opérations de vol devait paraître à la fin du mois de mai.

Télescope spatial

Réseau solaire

L'intégration du mécanisme secondaire du modèle de développement s'est achevée. Les opérations de déploiement et de rétraction sur tables hydrauliques ont été couronnées de succès. Les essais de système ont commencé. Les essais acoustiques et les essais de bilan thermique ont été effectués avec succès et les essais en vibrations se poursuivent. Les essais au vide thermique sont prévus pour la fin de l'été.

Cependant, un échec a été enregistré au cours des essais de cyclage thermique accéléré d'un échantillon de la couverture testé en vue de sa qualification et qui a subi 30 000 cycles de −100°C à +100°C simulant ses cinq ans de fonctionnement sur orbite terrestre basse. Des recherches approfondies sont en cours pour déterminer la nature exacte et les conséquence de cet échec.



Mécanisme secondaire du réseau solaire du Télescope spatial en cours de préparation aux essais dans l'installation d'équilibrage thermique de l'ESTEC

Space Telescope solar-array secondary deployment mechanism being prepared for testing in the ESTEC heat-balance facility

La NASA continue à étudier les différents modes de déploiement en orbite, de maintenance et de récupération à utiliser lors des missions du Télescope spatial, de sorte qu'une incertitude persiste au sujet de la conception thermique.

Chambre de prise de vues pour astres faibles

L'examen critique de la conception est terminé et a donné des résultats satisfaisants. L'intégration de l'ensemble électronique est presque achevée et les essais complets de compatibilité électromagnétique auront lieu en juin. Un autre fournisseur de dispositifs de mémoire CMOS 4 K pour le stockage des données scientifiques a été identifié et des pastilles ont été achetées en quantité suffisante pour le système de stockage des données scientifiques en vol.

Le matériel du modèle de vol de la chambre de prise de vues pour astres faibles est en cours de livraison et les essais des exemplaires de vol vont commencer.

Ensemble détecteur de photons

La panne de la partie 'intensificateur' du modèle technologique survenue après plusieurs centaines d'heures de bon fonctionnement paraît avoir été provoquée par une décharge corona à haute tension. Cette panne et d'autres problèmes similaires affectant la partie 'chambre photographique' et les connecteurs à haute tension ont conduit à adopter des approches différentes en ce qui concerne la conception et les essais. Ces difficultés ont entraîné d'importants retards de calendrier, mais la conception retenue pour le prototype de vol de l'ensemble détecteur de photons et les remaniements apportés au programme de chambre de prise de vues pour astres faibles permettent cependant de respecter la date à laquelle cette chambre doit être livrée à la NASA, c'est-à-dire avril 1982.

Les essais du système électronique de l'ensemble détecteur de photons, qui utilise un tube analyseur opérant dans les conditions ambiantes, se déroulent de façon satisfaisante.

Activités de la NASA

La date de lancement du Télescope spatial a été reportée jusqu'au début de 1985. La NASA a signé avec les 'Universités associées pour la Recherche en astronomie' un contrat relatif à l'établissement et au fonctionnement de l'Institut scientifique du Télescope spatial à l'Université John Hopkins de Baltimore.

Space Telescope

Solar array

Integration of the development model secondary deployment mechanism has been completed and deployment and retraction tests conducted on water tables have been successful. System testing has started. Acoustic testing and thermal-balance testing have been successfully conducted and vibration testing is in progress. Thermal-vacuum tests are scheduled for the end of the summer.

A failure in a qualification blanket sample has occurred during accelerated thermal-cycling tests (from −100°C to +100°C over 30 000 cycles) to simulate the five years of operation in a near-earth orbit. Detailed investigations are in progress to assess the precise nature and consequences of this failure.

The various Space Telescope mission modes for in-orbit deployment, maintenance and retrieval are still under study by NASA, which implies that an uncertainty still remains with regard to the thermal design.

Faint-Object Camera

The Critical Design Review has been completed satisfactorily. Integration of the electronics-bay assembly is nearly complete and overall EMC testing will be carried out in June. An alternative source of high-quality 4 K CMOS memory devices for the scientific data store has been found and sufficient chips for the flight scientific data store have been procured.

Hardware for the flight-model Faint-Object Camera is being delivered and flight-unit testing is now starting.

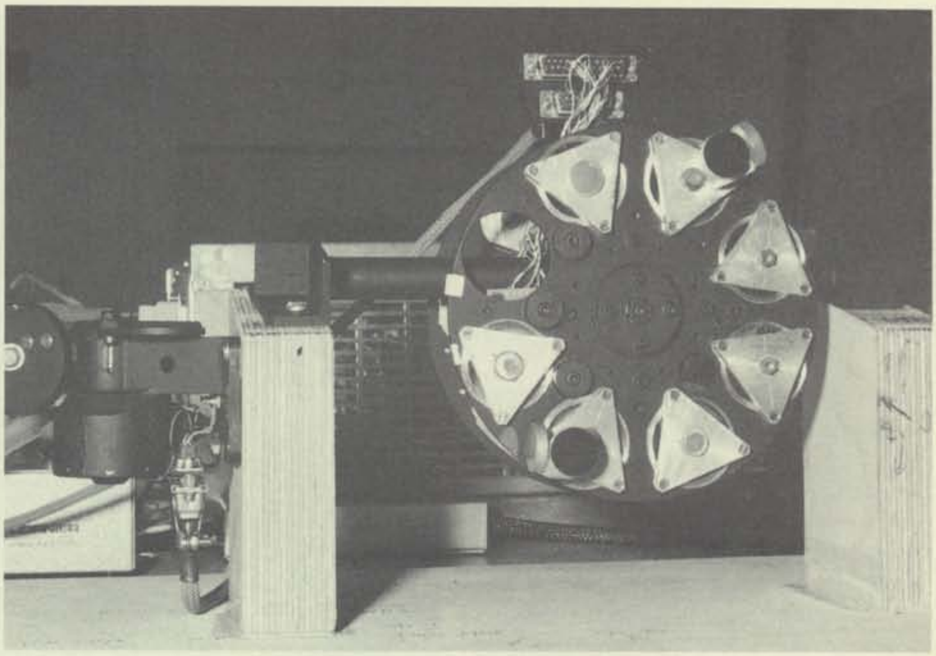
Photon Detector Assembly

The failure in the engineering-model intensifier section which occurred after several hundred hours of successful operation, appears to have been induced by high-voltage coronal discharge. This, together with similar problems in the camera section and high-voltage connectors, has led to different design and test approaches. These difficulties have led to substantial schedule delays, but the introduction of a protoflight model philosophy for the Photon Detector Assembly and re-arrangements in the overall Faint Object Camera programme still allow the NASA need date for delivery of the camera of April 1982 to be met.

The testing of the electronic system of the Photon Detector Assembly using a camera operating under ambient conditions is proceeding satisfactorily.

NASA activities

The launch date for the Space Telescope has been shifted to early 1985. NASA has signed a contract with the Associated Universities for Research in Astronomy for the development and operation of the Space Telescope Science Institute at the Johns Hopkins University in Baltimore.



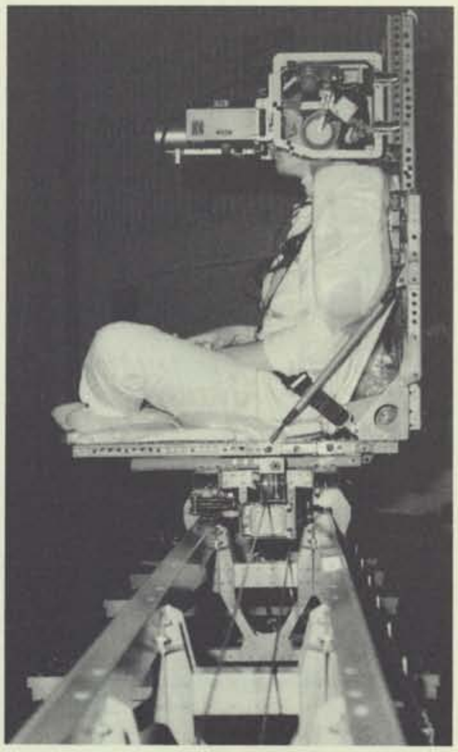
Space Telescope engineering-model filter-wheel mechanism under test at Dornier, Friedrichshafen

Mécanisme du porte-filtres du Télescope spatial au cours des essais chez Dornier à Friedrichshafen.

Sled

The Sled development programme was completed on schedule and within the original cost estimates at the end of March 1981. The Acceptance Review Board recommended the Sled's acceptance by SPICE, subject to the satisfactory outcome of a number of actions, most of which have since been completed.

Some last spare parts and a special hoist rig for installing the Sled inside Spacelab are still in manufacture, and delivery of the final items is expected to take place this summer. The Sled training model, the flight model and their spares and support equipment have been put into storage at ESTEC until needed by SPICE for the Spacelab D-1 mission.



Sled facility with test subject seated at right angles to the direction of travel

Essais du Traîneau spatial avec sujet assis à angle droit par rapport à la direction du mouvement

Traîneau spatial

Le programme de développement du Traîneau spatial s'est achevé dans les délais prévus et dans les limites des estimations de coût initial, à la fin de mars 1981. La Commission compétente en a recommandé la recette par le SPICE sous réserve de l'issue satisfaisante de plusieurs activités, dont la plupart ont été terminées entre temps.

Il reste en fabrication quelques pièces de rechange et un système de levage spécial pour installation du Traîneau dans le Spacelab; la livraison du dernier élément est prévue pour l'été. Le modèle de formation, le modèle de vol et leurs rechanges ainsi que l'équipement de soutien ont été stockés à l'ESTEC en attendant que le SPICE en ait besoin pour la mission D-1 du Spacelab.

La phase d'essai du système à l'ESTEC n'a rencontré aucun obstacle et s'est déroulée exactement selon le calendrier fixé en août 1980. Le Traîneau a répondu à toutes les exigences des utilisateurs, a fonctionné correctement avec l'ensemble complexe de matériels des expériences européennes et s'est avéré sans aucun danger pour les sujets humains soumis aux essais. Les utilisateurs scientifiques ont estimé que les performances du Traîneau spatial sont supérieures à celles de tous les traîneaux basés au sol qu'ils connaissent.

L'équipe de développement a été affectée à d'autres tâches et fournira un soutien au SPICE pour les travaux d'intégration futurs des expériences du Traîneau avec le reste de l'installation en vue de la mission D-1 du Spacelab.

Préparation du sujet aux essais sur Traîneau spatial à l'ESTEC

Test subject being prepared for a Sled test run at ESTEC

ISPM

La NASA ayant annoncé son intention d'annuler le satellite américain, une intense activité s'est déployée, sur le double plan diplomatique et administratif, pour rétablir la mission à deux véhicules spatiaux. Il est actuellement trop tôt pour dire si ces démarches seront couronnées de succès mais la tendance est plutôt à l'optimisme.

Une nouvelle complication est apparue aux Etats-Unis touchant à la méthode de lancement des véhicules spatiaux ISPM. Début 1981, la NASA avait annoncé son intention de passer, pour la mise en orbite interplanétaire, de l'étage supérieur inertiel (IUS) à un étage supérieur Centaur modifié. Ce plan semble s'être heurté à des difficultés d'ordre législatif et on examine actuellement un certain nombre de possibilités de lancements à la fois combinés (en tandem) et séparés pour les deux véhicules spatiaux. On espère que ce problème, comme celui du nombre des véhicules spatiaux, sera réglé dans le courant de l'été.

En dépit des incertitudes qui règnent outre-Atlantique sur le projet, les travaux sur le véhicule spatial de l'ESA se poursuivent à peu près dans les délais, mais des retards dans la livraison de certains composants de haute fiabilité résistant aux radiations obligent à rechercher des solutions de remplacement. Le modèle structurel du véhicule spatial a été livré au contractant principal et un essai de charge statique est en cours. Il démontrera la solidité de la structure du satellite, élément de sécurité essentiel pour permettre un lancement par la Navette. L'équipement électrique de soutien au sol a également été livré et, après quelques problèmes, l'équipement mécanique de soutien au sol est lui aussi presque achevé.

Courant mai, une réunion du Groupe de travail scientifique, réunissant les chercheurs principaux pour toutes les expériences prévues sur les deux satellites, a eu lieu à Heidelberg, en Allemagne.

Un certain nombre de questions scientifiques ont été examinées outre les problèmes concernant la conception de la mission et les interfaces des véhicules spatiaux. Des résolutions ont également été prises au cours de cette réunion pour recommander vivement le maintien de la mission à deux satellites et pour demander à la NASA de reconsidérer sa décision d'annuler l'expérience de prise d'images du soleil qui était prévue sur son satellite.

ECS

Les activités d'assemblage, d'intégration et d'essais (AIT) du premier modèle de vol d'ECS ont commencé comme prévu dans les nouvelles installations de Matra à Toulouse. Les modifications et renforcements qui avaient déjà été apportés à la structure de Marecs l'ont

The Sled system-test phase at ESTEC ran smoothly and in accordance with the schedule dates established in August 1980. The Sled satisfied all user requirements, performed well with the complex European set of experiment hardware, and was proved to be absolutely safe. The user scientists consider the unit's performance to be superior to that of any ground-based human accelerator known to them.

The Sled development team, now reassigned to other tasks, will support SPICE in its future work of integrating the Sled experiments with the facility for the Spacelab D-1 mission.

ISPM

Following the announcement by NASA of their intention to cancel the American spacecraft, there have been considerable efforts, both diplomatic and administrative, with the intention of ensuring restoration of the two-spacecraft mission. It is still too early to say whether these will be successful , but there are signs for optimism.

A further problem has arisen within the USA concerning the method of launching the ISPM spacecraft. Early in 1981 NASA announced its intention to change from the Inertial Upper Stage (IUS) for interplanetary injection to a modified Centaur Upper Stage. This plan appears to have run into legislative difficulties and a number of launch options are now being considered for combined (tandem) and separate (split) launches for the two spacecraft.

It is hoped that both of these issues will be resolved during the summer months.

Despite the various uncertainties concerning the project on the other side of the Atlantic, work on the ESA spacecraft is continuing approximately on schedule, although late delivery of some radiation-hard high-reliability components is leading to a need for some work-around solutions. The structural model of the spacecraft has now been delivered to the prime contractor and a static load test is currently being performed to prove the strength of the spacecraft structure. This is an essential ingredient of the safety submissions required to permit launch on the Shuttle. The electrical ground support equipment has also been delivered and, following some problems, the mechanical ground support equipment is also nearing completion.

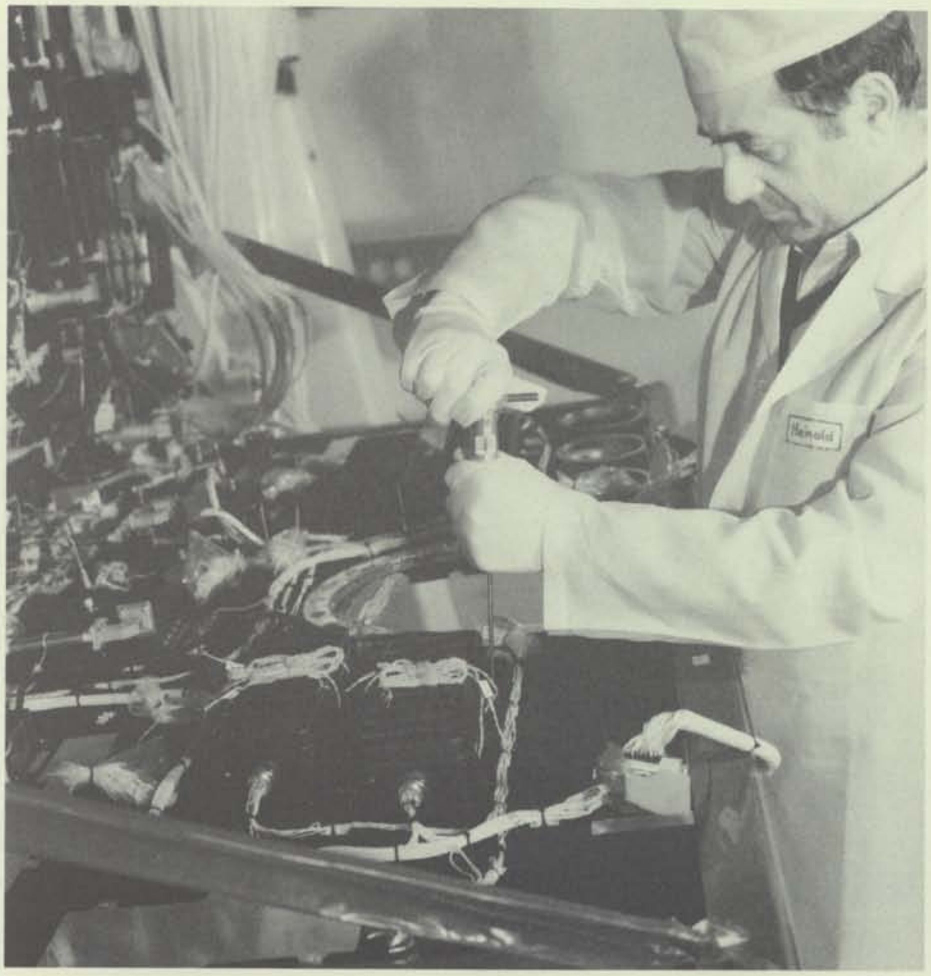
During May, a meeting of the Science Working Team, made up of the principal investigators of all experiments on both spacecraft, took place at Heidelberg in Germany.

A number of scientific issues were discussed, as well as the mission design and spacecraft interfaces. The meeting also passed resolutions strongly urging the retention of the two-spacecraft mission and asking NASA to reconsider its announced cancellation of the solar-imaging experiment on the NASA spacecraft.

ECS

ECS first flight unit assembly, integration and test (AIT) has started as foreseen at Matra's new facilities in Toulouse. The structural modifications and reinforcements already incorporated in the Marecs structure have also been introduced on ECS. So far the AIT activities have progressed according to schedule, with a minimum of problems.

As a result of recent requests from Intelsat and considering the likely calendar of Ariane launches in 1982, the launch of the first ECS flight unit will probably take place later than the previously planned date of April 1982. An obvious advantage of this delay is that the criticality of the MAGE-2 ABM planning is significantly reduced. On the other hand, the costs associated with this elongated planning could be significant. The impact on the launch date of ECS-2 has still to be evaluated, but stringent efforts will be made to minimise it.



ECS payload integration at AEG-Telefunken

Intégration de la charge utile d'ECS chez AEG-Telefunken *également été à celle d'ECS. Ces activités AIT se sont jusqu'ici déroulées conformément au calendrier et n'ont posé que peu de problèmes.*

A la suite des récentes demandes d'Intelsat et compte tenu du calendrier probable des lancements d'Ariane en 1982, le lancement du premier modèle de vol d'ECS interviendra vraisemblablement plus tard qu'avril 1982 comme on le prévoyait initialement. Ce retard aura un avantage certain: le calendrier du moteur d'apogée MAGE-2 qui était critique sera considérablement assoupli. Par contre, cette prolongation des déļais pourrait entraîner des coûts importants. Enfin, l'incidence de ce retard sur la date de lancement d'ECS-2 doit encore être évaluée mais tous les efforts seront faits pour la réduire au minimum.

Marecs

L'intégration du véhicule spatial Marecs-A s'est effectuée avec succès et l'on a fixé la performance de référence. Le satellite doit maintenant subir des essais d'ambiance, en commençant par les essais de bruit acoustique chez IABG à Munich.

Les problèmes qui se sont posés dans les domaines mécanique et électrique n'ont pas permis d'achever le programme d'essais de l'antenne en bande L. Le modèle de vol de cette antenne sera donc intégré plus tard sur le véhicule spatial Marecs-A. Le programme d'essais d'ambiance a été réorganisé pour tenir compte de ce retard, tout en préservant la validité technique de ces essais.

L'intégration de Marecs-B a commencé parallèlement et les activités d'intégration et d'essais doivent en principe suivre une progression voisine, pour aboutir à un lancement quatre mois et demi après celui de Marecs-A.

A la suite de la signature du contrat de location avec Inmarsat, l'ESA a passé un contrat avec KDD (Japon) pour la construction et le fonctionnement d'une station TTC à Ibaraki. Cette station assurera l'exploitation du satellite Marecs qui sera mis sur orbite au-dessus de l'Océan Pacifique.

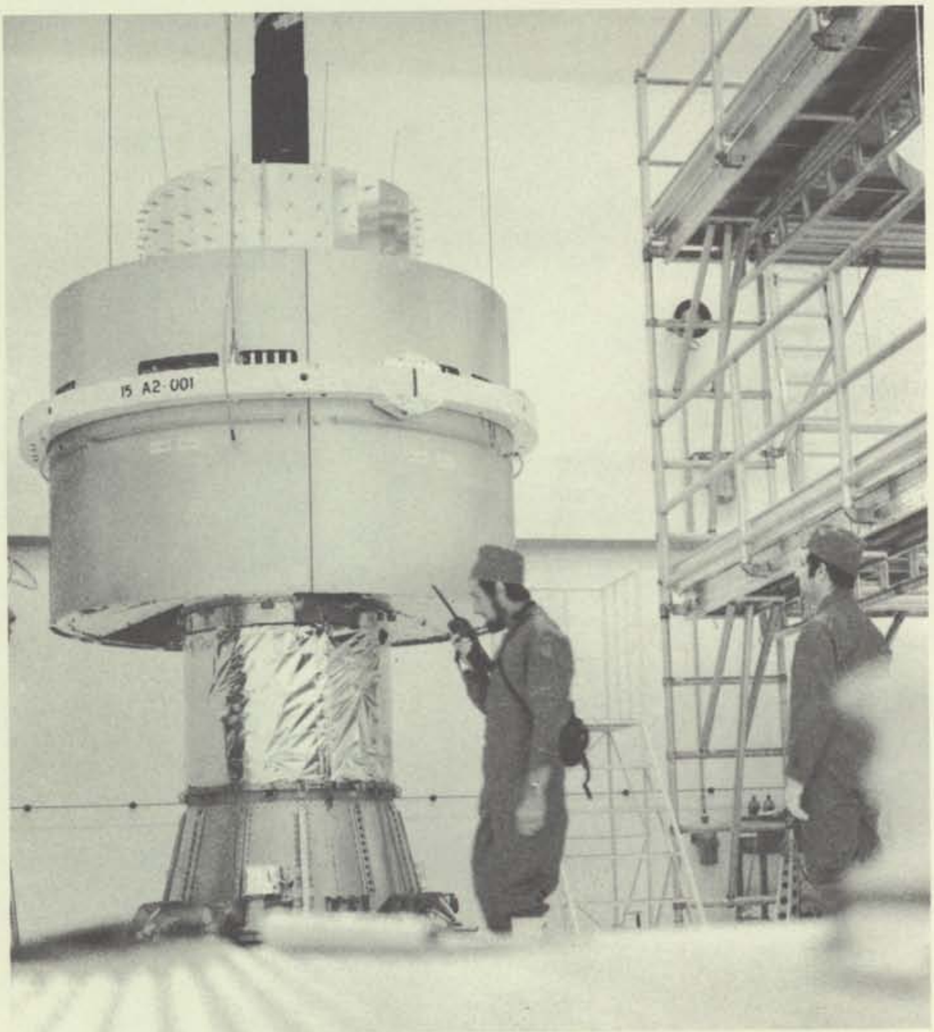
L-Sat

L'étape actuelle de définition du système, intitulée phase B2 principale du projet L-Sat, a commencé en décembre 1980, à l'issue de la phase B2 préliminaire au cours de laquelle ont été menées à bien les principales analyses de compromis au niveau système et la sélection concurrentielle des contractants chargés des sous-systèmes de la plate-forme.

La phase actuelle a pour principaux objectifs la définition du satellite jusqu'au niveau des équipements et l'achèvement des appels d'offres qui aboutiront au choix des fournisseurs des équipements. Au niveau système, un certain nombre de questions viennent d'être réexaminées, parmi lesquelles la conception du système et les plans de développement, les bilans techniques et enfin la mise au point définitive des spécifications. Au niveau sous-systèmes, la définition conceptuelle a été poursuivie en soutien de l'activité au niveau équipements, de sorte que l'on dispose pour les sous-systèmes d'un jeu complet de spécifications qui ont atteint un niveau proche de celui qui sera exigé pour la phase C/D.

L'activité dominante dans l'industrie au cours des deux derniers mois a porté sur la préparation des spécifications techniques et sur des études de compétitivité des équipements de sorte que tout soit prêt à temps pour le dernier examen d'ensemble de la proposition de phase C/D (phase principale de développement) prévu pour fin mai.

Les débats qui se sont déroulés au début de cette année entre l'Exécutif et les Etats membres participant au programme ont fait apparaître la nécessité d'une phase relais de trois mois, entre la fin de la phase B2 — prévue pour début juin — et le début de la phase C/D. Cette phase relais permettra de procéder aux



Météosat-2 au cours de son intégration pour le lancement à bord du 3ème vol d'essai d'Ariane

Meteosat-2 being integrated for launch on the third Ariane test flight

Marecs

The Marecs-A spacecraft has been successfully integrated and the performance baseline established. It is now due to start environmental testing, beginning with acoustic noise tests in IABG, Munich.

Mechanical and electrical difficulties have so far prevented the completion of the L-band antenna test programme. The flight antenna will therefore be integrated with the Marecs-A spacecraft at a later stage. The environmental test programme has been rearranged to take account of this late delivery, while maintaining the technical validity of the testing.

The Marecs-B integration has started in parallel and is due to follow a similar course of integration and test activities, with the launch four and a half months after Marecs-A.

Following signature of the lease contract with Inmarsat, ESA has placed a contract with KDD (Japan) for the construction and running of a TTC station in Ibaraki. This will operate the Marecs satellite placed in orbit above the Pacific Ocean.

L-Sat

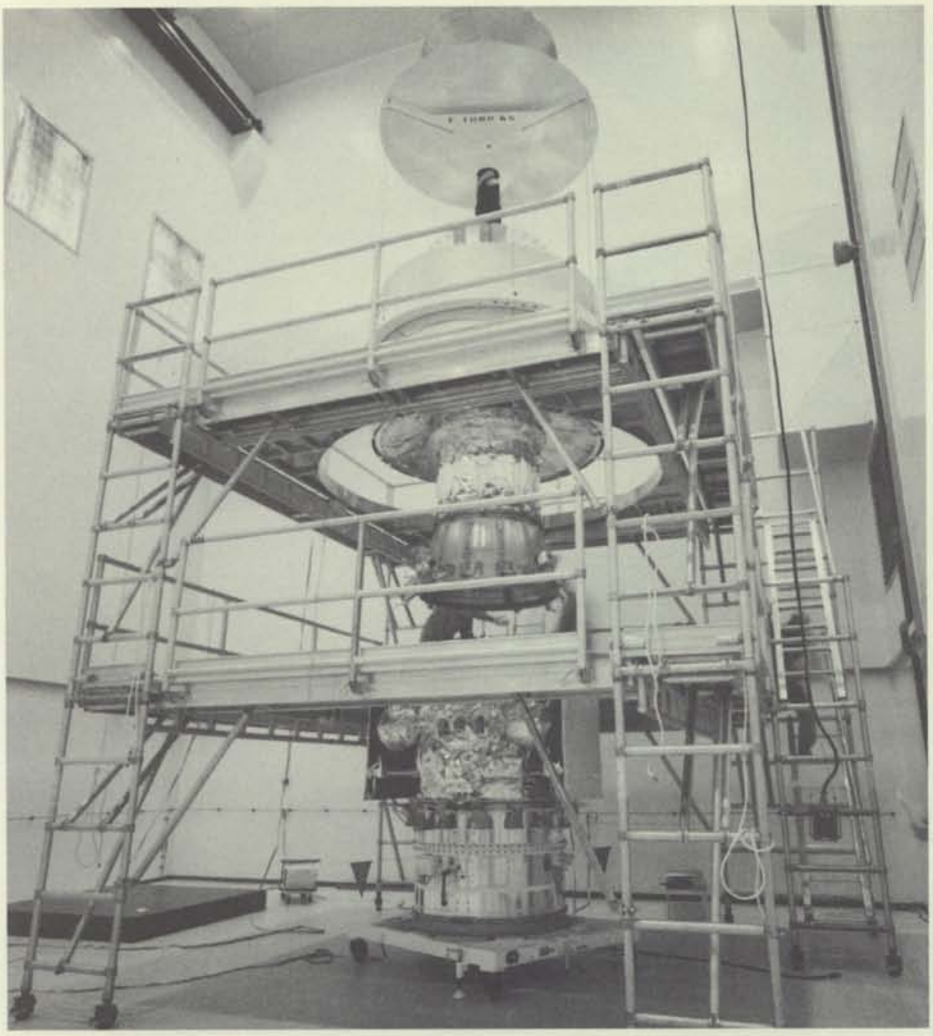
The current system definition stage, termed 'Main Phase-B2' of the L-Sat project, was initiated in December 1980, following completion of the Preliminary Phase-B2 during which key system-level trade-offs and competitive selection of platform subsystem contractors were completed.

The main objectives of the current phase are satellite definition down to equipment level and completion of tender actions for the choice of equipment suppliers. A number of system-level subjects have recently received further attention, among them the system design and development plans, system-level technical budgets and the finalisation of system-level specifications. A subsystem-level design definition has been pursued in support of the equipment-level activity, the result of which is a complete set of subsystem specifications of a near-Phase-C/D standard.

The dominating industrial activity in the last two months has been the preparation of technical specifications and equipment competitiveness studies, aimed at consolidation in time for final compilation of the Phase-C/D (Main Development Phase) proposal at the end of May.

Discussions earlier this year between the Agency and the Member States participating in the L-Sat programme identified the need for a three-month bridging phase, running from the end of Phase-B2, scheduled for early June, and the beginning of Phase-C/D. This phase will provide time for negotiation of the C/D proposal, including various preparations for the starting of that phase. Additionally, a certain number of schedule-critical activities will be continuing right through to the start of Phase-C/D. Proposals for the bridging phase are currently being evaluated by the ESA project team.

Phase-C/D is now scheduled to commence in September, subject to the envisaged proposal/negotiation activity progressing such that the necessary decisions can be taken by that time.



Meteosat

Space segment

Meteosat-1 continues to carry out the data-collection mission; its further exploitation will depend on the success of Meteosat-2.

Meteosat-2 has arrived at the Guiana Space Centre. After having successfully completed the final tests, the satellite was handed over to the launch authorities for mounting on the Ariane L03 launcher. Meteosat-2 is scheduled to be launched, together with the Indian Apple satellite, on 19 June 1981 (see page 75 for latest news).

Meteosat-2, Apple and the technology capsule (CAT) being integrated for launch on Ariane L03

Les satellites Météosat-2 et Apple et la 'capsule Ariane technologique' (CAT) au cours de leur intégration pour le lancement à bord d'Ariane L03 *négociations de la proposition couvrant la phase C/D ainsi qu'à divers préparatifs pour le démarrage de cette phase. Par ailleurs, un certain nombre d'activités critiques sur le plan du calendrier se poursuivront jusqu'au démarrage de la phase C/D. Les propositions couvrant cette phase relais sont en cours d'évaluation par l'équipe projet de l'ESA.*

Le démarrage de la phase C/D est actuellement fixé à septembre, sous réserve que les négociations de la proposition se déroulent de façon que les décisions nécessaires puissent être prises d'ici là.

Météosat

Secteur spatial

Météosat-1 continue à assurer la mission de collecte des données. L'extension de son exploitation dépendra du succès de Météosat-2.

Météosat-2 se trouve au Centre Spatial Guyanais. Le satellite, après avoir subi avec succès les derniers essais, a été remis aux responsables lanceur pour être installé sur Ariane (L03). Météosat-2 doit être lancé avec le satellite indien Apple le 19 juin 1981 (pour plus amples informations, voir page 75).

Segment sol

Les travaux de remplacement du système de calcul à Darmstadt sont en cours mais ceci n'a pas d'impact sur la date de lancement. Le Comité de Politique industrielle de l'Agence a accepté l'installation de matériels fournis par Siemens (RFA).

Programme opérationnel

Les travaux de définition d'un cadre institutionnel pour le système Météosat opérationnel continuent au sein du Groupe de travail mis en place fin janvier 1981. Diverses solutions sont en cours d'examen mais aucune n'a encore été retenue. En parallèle des travaux sont en cours afin de définir une version de référence pour le système.

Sirio-2

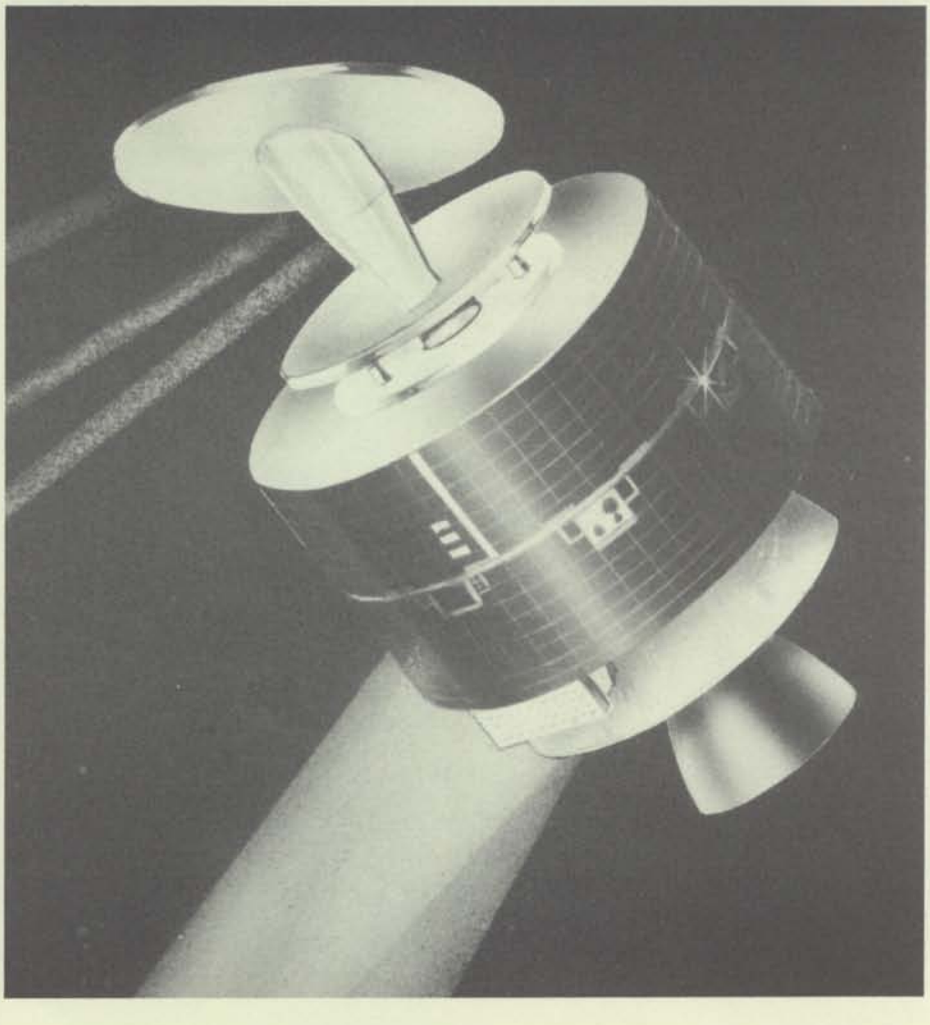
Les essais des sous-systèmes de soutien (alimentation électrique, commande d'orientation et correction d'orbite, TT&C) du modèle de vol du satellite se sont terminés avec de bons résultats. L'intégration et l'essai des charges utiles MDD et Lasso commenceront en juillet 1981 après l'exécution de mesures correctives destinées à éliminer de petits problèmes d'instabilité qui affectent le convertisseur et des tendances à l'apparition d'effets corona dans le circuit d'alimentation électrique. L'actuel calendrier de lancement Ariane prévoit le lancement combiné de Sirio-2 et de Marecs-B au printemps 1982.

Les préparatifs de la phase d'exploitation de Sirio-2 se poursuivent de façon satisfaisante depuis que le Conseil a pris la décision d'assurer le financement nécessaire à l'exécution des missions de démonstration MDD et Lasso, pour lesquelles il est prévu une période de deux ans en orbite. La sélection de sites africains pour y implanter les trois stations sol prototypes MDD progresse en étroite liaison avec l'Organisation météorologique mondiale. La tâche assez complexe que représente l'échange de messages entre les participants à l'expérience Lasso (il s'agit principalement de stations laser, de Bureaux de l'Heure, d'universités et du Centre de coordination Lasso) est en train de trouver une solution grâce à l'utilisation, pour la première fois à cette fin, du Système de Ressaisie de l'Information (IRS) de l'ESA, installé à Frascati.

L'intégration et les essais du Centre de contrôle des opérations de Fucino et de la station sol qui lui est associée auront lieu après un examen final de la conception qui se tiendra en juin 1981.

Télédétection

Au moment où nous rédigeons le présent article, la campagne SAR 580 est sur le point de commencer. Cette campagne fait suite à une série d'activités avant lancement qui étaient destinées à vérifier



Le véhicule spatial Sirio-2

The Sirio-2 spacecraft

Ground segment
Work on the replacement of the Darmstadt computer system is under way, but this will not affect the launch date. The Agency's Industrial Policy Committee has agreed to the installation of equipment supplied by Siemens (Germany).

Operational programme
The Working Group set up at the end of January 1981 is continuing its efforts to define an institutional framework for the operational Meteosat system. Various solutions are being considered, but no decision has as yet been taken. At the same time, work is also under way to define a baseline for the system.

Sirio-2

Tests have been successfully completed on the supporting subsystems (power supply, attitude/orbit control, TT&C) of the satellite flight model. Integration and test of the MDD and Lasso payloads will start in July 1981, following remedial actions to resolve minor problems with converter instability and power-supply coronal tendencies. The present Ariane launch schedule foresees launch of Sirio-2 with Marecs-B in spring 1982.

Preparations for the Sirio-2 exploitation phase are continuing satisfactorily, following the Council decision to provide adequate funding for the two-year in-orbit MDD and Lasso demonstration missions. The selection of African sites for the three MDD prototype ground stations is in progress, in close collaboration with the World Meteorological Organisation. The somewhat complex message-exchange task between Lasso participants (mainly laser stations, time institutes, universities and the Lasso Coordination Centre) is being resolved through innovative use of ESA's Information Retrieval Service (IRS) based in Frascati (Italy).

The operations control centre at Fucino and its associated ground station will be integrated and tested following a final design review in June 1981.

Remote Sensing

At the time of writing, the SAR 580 campaign is about to commence, following completion of a series of pre-campaign activities to check out the experimental equipment. During these activities, a notable 'first' was achieved, with the first-ever SAR imaging in the C-band.

The Remote Sensing Programme Board's approval of the nominal payload for ERS-1 (ESA Remote-sensing Satellite), as reported in the last Bulletin, has permitted the Agency to issue an invitation to European scientists to participate in the programme as members of instrument and data teams, and to propose small scientific experiment packages to take advantage of possible spare capacity on the satellite.

The principal programme activities during this period have been devoted to the preparation of the Call for Tender and finalisation of the Programme Proposal, which will be presented to the Programme Board on 23 June.

FSLP

The first launch date for Spacelab (SL-1) has again been put into question, with reports being received recently that NASA is considering shifting the date from May/June 1983 to September of the same year, for budgetary reasons.

In addition the US Department of Defense has apparently requested modifications to the TDRSS satellites, which might delay readiness of the complete data-relay system until the first quarter of 1984. If only one of the three TDRSS satellites is available for SL-1, the real-time data and command capability would be reduced to approximately one-half of that originally planned, and the mission profile would have to be considerably redesigned. Possible effects on the payload are under evaluation, but it appears that some experiments would be severely affected. Discussions between ESA and NASA are continuing on this subject.

Progress with European payload integration at Bremen is good. A total of 14 experiments had been delivered by the end of May, and a further three are expected in June.

The pallet bridge assembly has been completed and six experiments have been installed and checked-out. Work on the single racks has now commenced. The first encounter between hardware and operating software has produced very encouraging results.

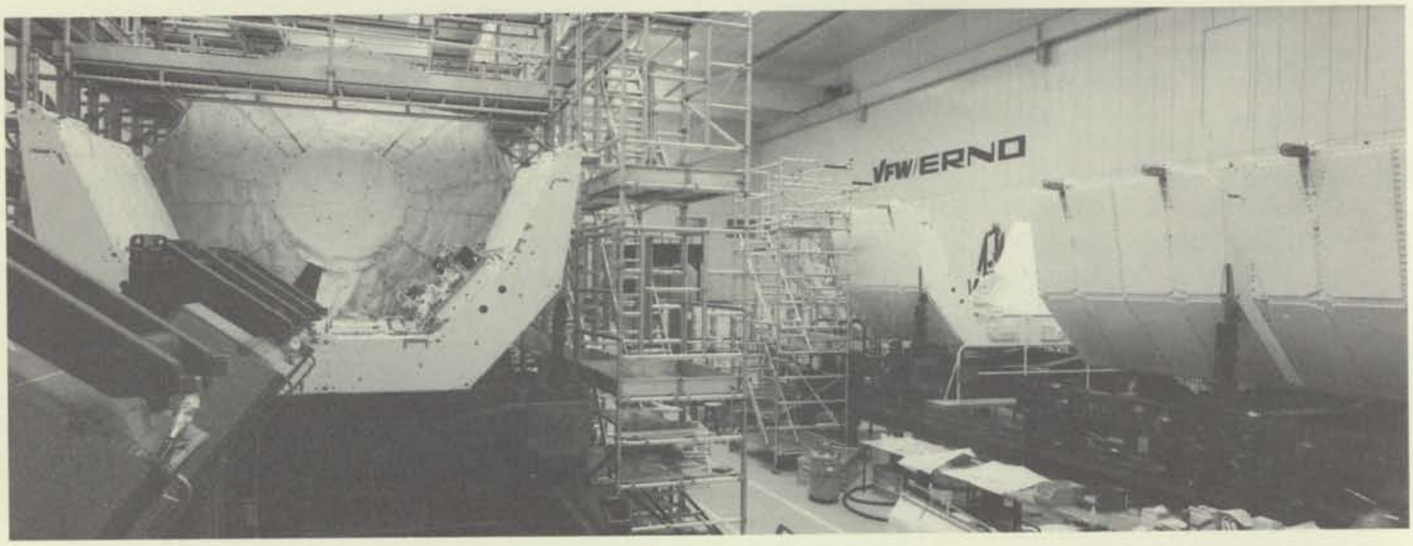
The Phase-2 Safety Review at NASA/JSC in April resulted in the rejection of the experiment 1ES332 'Organic Crystal Growth' (Technical University of Denmark), as the use of acetonitrile was regarded by NASA as posing an unacceptable risk to the Orbiter crew. Replacement of this substance by a nontoxic one is expected to enable the experiment to be retained on board.

Ariane

For latest news, see page 75.

Spacelab checkout computer at ERNO, Bremen

Installation de calcul pour les opérations de vérification du Spacelab chez ERNO à Brême



Intégration du premier modèle de vol du Spacelab avec son porte-instruments chez ERNO à Brême

First Spacelab flight model plus pallet during integration at ERNO, Bremen

les équipements d'expérimentation. Ces activités ont été marquées par une remarquable 'première', en l'espèce la première prise d'image SAR jamais effectuée en bande C.

Le Conseil directeur du programme de télédétection ayant approuvé la charge utile nominale d'ERS-1, comme nous le signalions dans le dernier Bulletin, l'Agence a pu lancer aux scientifiques européens une invitation à participer à ce programme en qualité de membres des équipes 'Instruments' et 'Données' et à proposer de petits ensembles d'expérimentation scientifique pour mettre à profit la capacité qui serait éventuellement disponible à bord du satellite.

Au cours de la période considérée les activités en matière de programme ont été principalement axées sur la préparation de l'appel d'offres et sur la mise au point définitive de la proposition de programme qui sera présentée au Conseil directeur du programme le 23 juin.

FSLP

La date de lancement de SL-1 a de nouveau été mise en cause. Selon des informations reçues récemment, la NASA envisage de la reporter de mai/juin 1983 à septembre 1983, essentiellement pour des raisons budgétaires.

En outre, il apparaît que le Ministère de la Défense des Etats-Unis a demandé d'apporter aux satellites TDRSS des modifications susceptibles de retarder jusqu'au premier trimestre de 1984 la certification de l'aptitude opérationnelle du système complet de relais de données. Si un seul des trois satellites TDRSS est disponible pour SL-1, la capacité de transmission de données en temps réel et de télécommandes sera réduite à environ 50% de ce qui était prévu au départ et le profil de la mission devra être considérablement remanié. Les répercussions éventuelles sur la charge utile sont en cours d'évaluation, mais il semble que certaines expériences risquent d'être gravement affectées. Les discussions sur ce point se poursuivent entre l'ESA et la NASA.

L'intégration de la charge utile européenne progresse de façon satisfaisante à Brême. Au total, 14 expériences avaient été livrées fin mai et trois autres sont attendues en juin.

La construction du pont du porte-instruments a été achevée et six expériences ont été mises en place et vérifiées. Les travaux à effectuer sur les bâtis simples ont commencé. La première confrontation entre matériels et logiciels d'exploitation a donné des résultats très encourageants.

L'examen de sécurité de phase 2 qui s'est déroulé en avril au JSC de la NASA a abouti au rejet de l'expérience 1ES332 'Croissance des cristaux organiques' (Université technique du Danemark), la NASA considérant que l'utilisation d'acétonitrile faisait courir à l'équipage de l'Orbiteur un risque inacceptable. On escompte que le remplacement de cette substance par une autre non toxique permettra de maintenir l'expérience.

Ariane

Pour plus amples informations, voir page 75.

The Phasing of Technological Developments

H. Stoewer, Head of System Engineering Department, ESA Technical Directorate, ESTEC, Noordwijk, Netherlands

Technology provides the basis upon which space projects are built. New space projects in the scientific and the applications fields normally require new technologies and generally push the technological state of the art in various ways. If a project is initiated without first assuring that the technologies needed are in fact available, or are state of the art, then performance compromises or schedule and cost overruns are the natural consequence.

The recent reorientation of the Agency's technology efforts (see ESA Bulletin No. 24) serves to increase visibility into the availability/timing of the technologies required for future space projects. It attempts to identify more clearly when new technologies can be expected to be available and to assess at distinct points in the technological development cycle what risks are associated with their application. This article attempts to quantify these risks and discusses the relationships between technology and spacecraft project developments.

The technology development cycle

Technological developments normally progress through various steps from the initiation of first exploratory studies, which initially define broad requirements, and terminate when the flight-qualified product is integrated and tested in a satellite project. The origin of such a cycle lies in a need identified for an anticipated future mission or in the advent of a new technology that promises advantages over other alternatives for future space projects (NASA refers to these forces as 'mission pull' and 'technology push').

ESA has defined five distinct steps within this cycle (Fig. 1). Particularly in cases where terrestrial technologies are adapted for space applications, the cycle may not be followed completely, and steps might be left out or combined.

Step 1: Definition of objectives and requirements

In this step, an exploratory study responds to a need for a new technology that has arisen through the identification of a new mission opportunity, or arises with the emergence of a new technology which may create future mission possibilities. The study attempts to define the requirement in broad terms and to identify alternative technical solutions that could meet the need. Cost, schedule and other resource considerations then lead to an initial development plan for one or more of the alternatives identified.

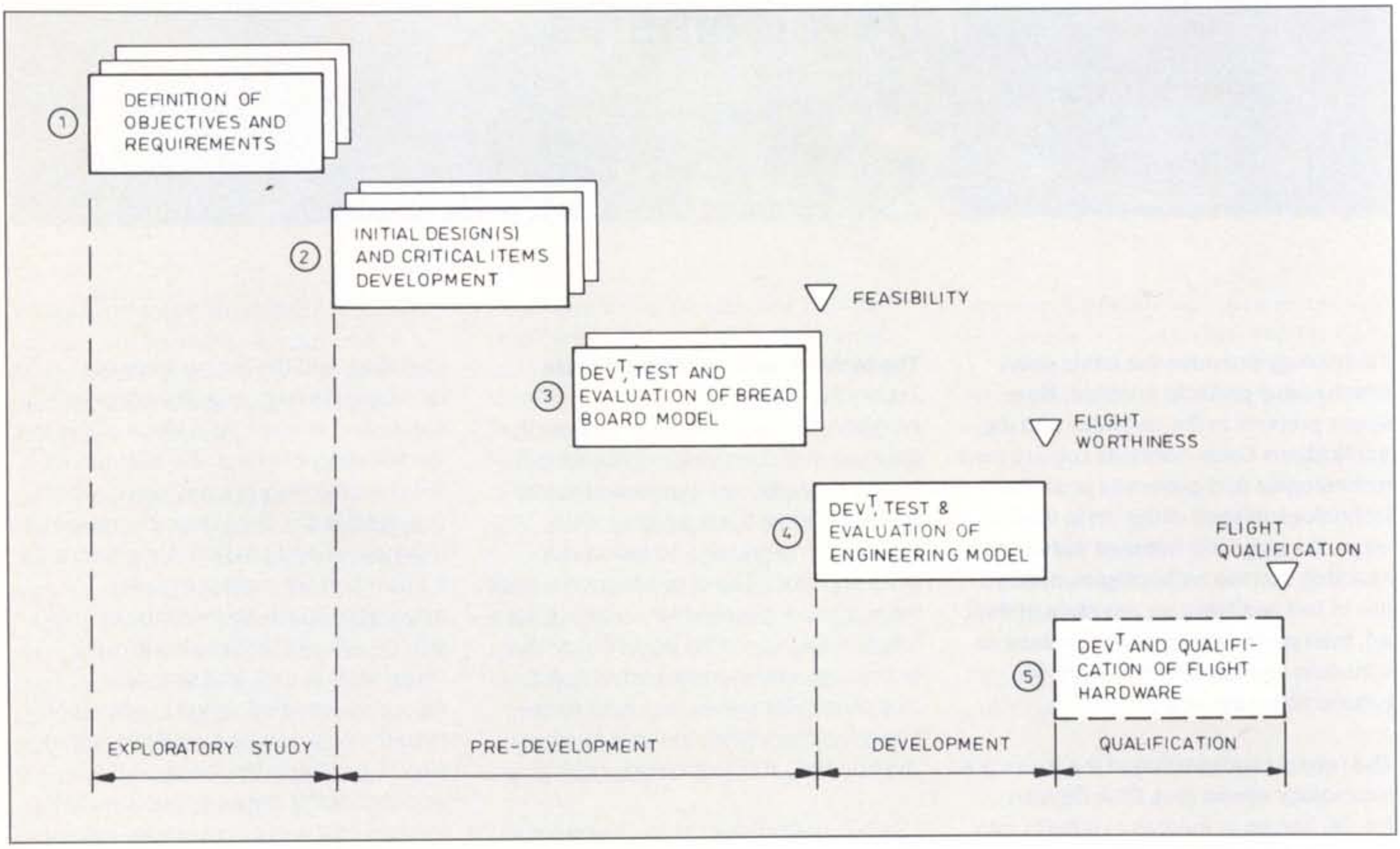
Step 2: Initial design(s) and critical-items development

In this step, initial designs are established for one or more of the alternatives identified, and the critical items are developed (mostly at assembly or subassembly level). As a result of this step, the feasibility of one of the alternatives may be preliminarily established, which may lead to the elimination of some of the alternatives and possibly already to a focusing on the most promising approach. The initial development plan can be adjusted in this step and the projections of cost and schedule resources updated. A first iteration of the requirements can be completed with a view to providing feedback on the updated performance projections to the mission analyses conducted at system-study level.

Step 3: Development, test and evaluation of a breadboard model

In this step, the individual activities at subassembly, assembly or even equipment level are combined into a first working system in the form of a (technology) breadboard model. The objective of this step is to test the interaction between the various technology elements that have to operate together. The result is a first demonstration of the feasibility of the technology with a level of confidence comparable to that normally achieved at the end of a Phase-A system feasibility study. Such a breadboard (or structural/mechanical model in nonelectronic technology) will lead to a first approximate verification that the performance will come up to the mark and will normally provide clear answers as to which of the alternative technology paths should be followed, since this is also normally the last phase during which

Figure 1 — Typical steps in space-technology development



alternative technologies are pursued in parallel. This step also leads to a development plan which, for the subsequent development phase and qualification of the technology, already predicts the quantifiable risks and the remaining efforts needed for the application of this particular technology in a satellite project. This step concludes what is generally considered to be the technological *pre-development* phase.

Step 4: Development, test and evaluation of an engineering model
In this step, the flight-worthiness of the technology is demonstrated based on a (technology) engineering model incorporating anticipated project-specific requirements, to the extent that they are known. The technology is verified to the point that fairly accurate performance predictions and a good estimate of the additional effort needed for flight qualification can be made. This allows an industrial contractor to incorporate the technology in a future project with sufficient confidence to make a sound proposal for the main development phase (Phase C/D). This step normally terminates what is considered to be the technological *development* phase, and from here on the process of incorporating the technology into the subsystems and subassemblies of an approved, ongoing project begins.

Step 5: Development and qualification of flight hardware
This step, which leads to 'qualification of the technology' by virtue of its inclusion in flight hardware, is normally performed as part of a spacecraft project-development phase. This qualification process is project-specific, in that it is conducted to test levels and standards based on the particular environment and constraints of the project, its launch system and its mission.

Looking again at Figure 1, which summarises the above development-cycle steps, ESA's Basic Technological Research Programme normally covers Steps 1 to 3. ESA's Support or Preparatory Technology Programme[1] focuses on the next and most costly step, Step 4; i.e. once a specific requirement for the next project has been established, the technology is further developed with an increasingly strong orientation (also from an industrial policy point of view) towards that particular project.

Qualification is approached as a spacecraft-specific task, funded as part of the project development.

---

1 At present the Support or Preparatory Technology Programme is comprised of the ASTP (Advanced Systems Technology Programme; telecom) and RSPP (Remote Sensing Preparatory Programme) elements.

Cost, schedule and performance risks of technological developments
Figure 2 shows average relative costs for each of the five steps in the technology development cycle. Clearly, each subsequent step becomes more expensive in that it calls for a greater effort to achieve it. Qualification costs within a project are the most difficult to estimate on a general basis and vary with the model and test philosophy adopted by the project and the closeness to 'real life' of the foregoing technology-development efforts.

There is a significant cost increment between Steps 3 and 4, due to the more stringent hardware quality, standards and documentation required, and the incorporation of flight-related constraints into the engineering model. This crucial phase is therefore the most expensive of

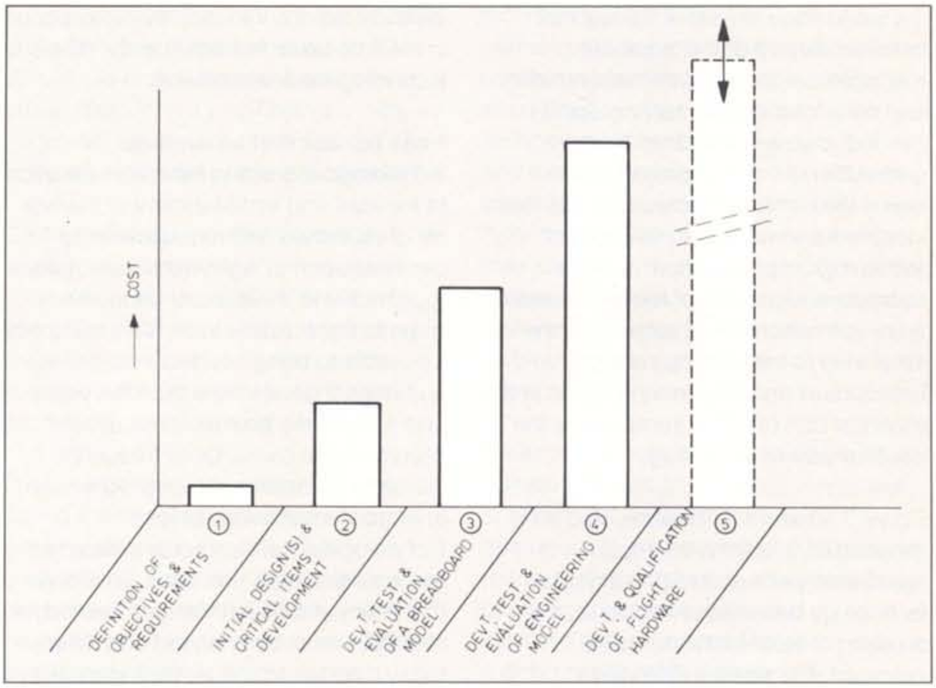


Figure 2 – Average costs (relative) for technology development

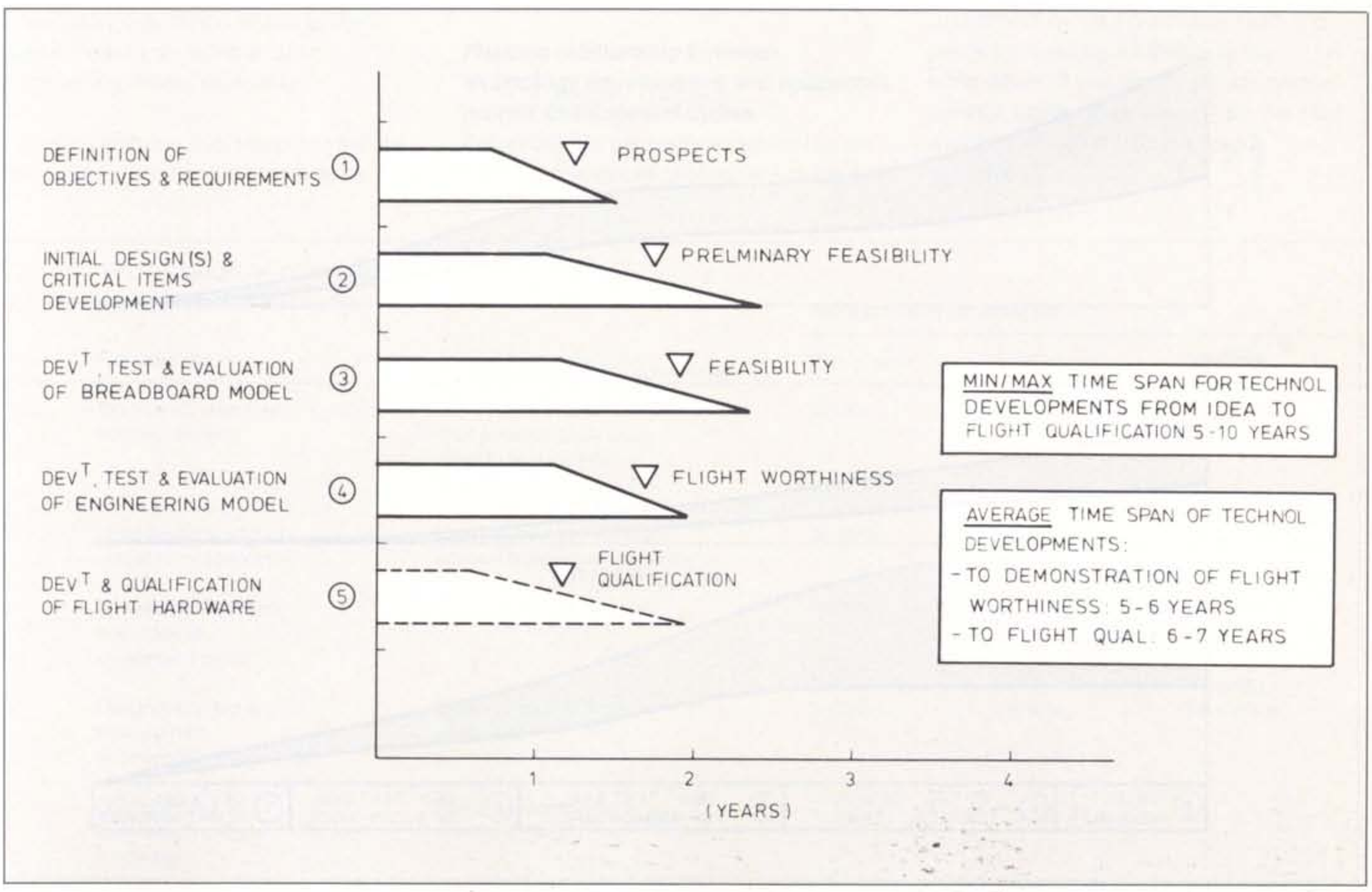


Figure 3 – Average times (relative) for technology development

the technology phases. It follows that between Steps 3 and 4, a careful management review of the requirements and uses for a specific technology is needed to ensure that Step 4 is only undertaken if the next project which needs the particular technology has been identified and warrants this depth of technological preparation. In fact a successive alignment of the requirements guiding the technology steps from the initial idea to the development of a breadboard and engineering model is an essential part of ESA's approach to the development of technology.

Figure 3 attempts to illustrate, also on a generalised basis, the time span associated with each step in a typical technology development cycle, i.e. the duration of each of the five steps indicated. The slope is intended to demonstrate the variation that may occur in the time taken in each step for different technological developments.

It can be seen that an average technological development, from initiation of the idea and establishment of the first set of objectives and requirements to demonstration of flight-worthiness, takes roughly five to six years, or six to seven years to flight qualification. Very seldom is it possible to bring new technologies to qualification level in less than five years and it may even take as much as ten years in some cases. Quite frequently, therefore, satellites are launched which are based on initial ideas and technological developments initiated as much as ten years previously. It follows that many of the technologies needed for the 1990s must be analysed and initiated today if we are to ensure their availability for the spacecraft for the end of this decade. (This does not apply to fields where space technologies are derivations of terrestrial developments, as is now frequently the case, particularly in the fields of microcomputers and data processing.) Additional financial and human resources can sometimes compress to some extent the time required for a particular development cycle, but experience tells us that the maturing of ideas and their testing have fairly fixed associated time constants and these are compressible only to a limited extent.

Expressing the risks remaining at any point during a development cycle in terms of schedule, performance and cost uncertainty, leads to the diagram shown in Figure 4. The remaining risks of applying a particular technology to a

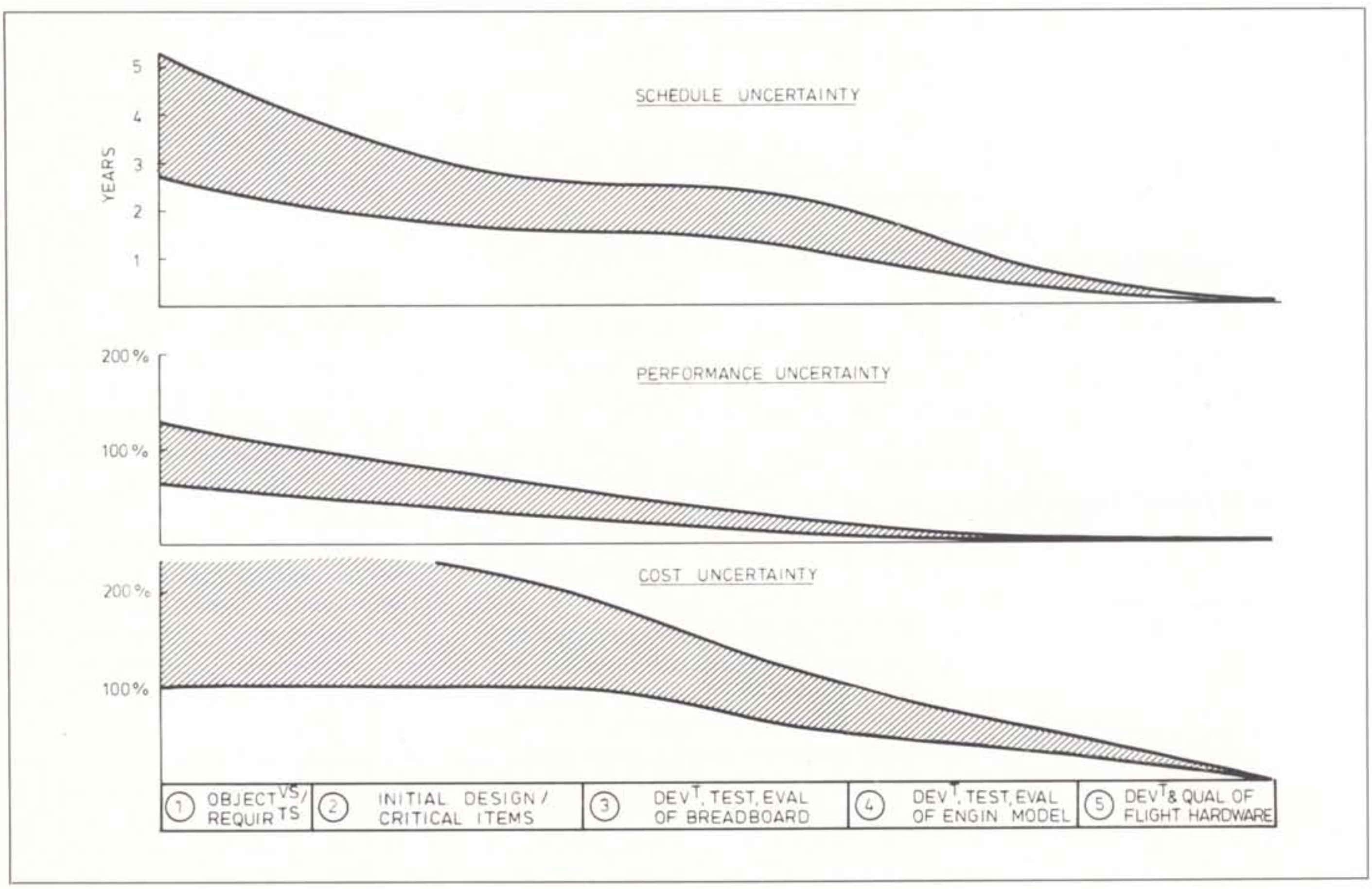


Figure 4 — Residual risks during the technology development cycle

space project may be considered as zero at the time flight qualification is completed, as all its implications have been reasonably well tested by then. In the pre-development phases, however, the remaining risks are quite high, their exact magnitude depending of course on which technology is being considered.

Quite frequently, the schedule uncertainty at the time of the initial study, i.e. the ability to predict the completion date for a technological development, is in the range of three to five years, and drops only to about one and a half to two years at the end of the pre-development phase, i.e. on completion of the breadboard-model evaluation. In other words, incorporating the technology at this point into a system study and project plan implies an associated schedule uncertainty of two years. This can be further aggravated by the inclusion of several critical technologies. The schedule uncertainty only drops significantly, to about three to six months, after engineering-model evaluation.

Experience shows that the performance uncertainty drops more consistently, from an uncertainty factor of the order of 100% at the initiation of the first study, to 10–30% at the end of the pre-development phase (Step 3). Uncertainties of 5–10% in the prediction of performance at the end of the development phase are common.

Cost-estimating uncertainties are very large at the outset of the development cycle. Uncertainties of 50–100% at the end of Step 3 are not unusual, and they are still in the order of 15–40% at the completion of the engineering model (technology development) phase.

The uncertainties and remaining risks during a technology development cycle are of course also very dependent on other criteria, such as industrial policies to be pursued in a specific development, project-specific requirements, etc. Table 1 summarises the end products and estimated remaining risks on completion of the five technology-development steps.

Phasing relationship between technology development and spacecraft project development cycles

A number of conclusions can be drawn from the foregoing assessment of the five technology steps in the life cycle of a normal satellite project. Generalisations concerning technological developments are difficult to make, particularly since 'technology' is never without surprises and exceptions. In addition the range of space technologies needed for the Agency's satellite programmes extends over such diverse subjects as CCD sensor arrays, heat pipes, composite structural materials, software architectures for distributed data processing, to name but a few.

Nevertheless, the risks associated with a normal technological development cycle are being progressively reduced, analogous to how overall project risks are reduced in spacecraft development, by applying successive study and implementation phases. Moreover, there is a direct relationship between the technological and spacecraft development cycles. Performance, cost and schedule risks associated with the plans for building a satellite at the completion of preparatory study phases cannot, however, be lower than the risks associated with the technologies employed.

Table 1 – End products on completion of each technology development step

			Average relative remaining risk		
Step	Task description	End products/milestones	Performance	Cost	Schedule
1	Definition of objectives and requirements	Demonstration of prospects (incl. potential application, development justification and plan)	50–100%	100–200+%	2–4 years
2	Initial design(s) and critical items development	Establishment of preliminary concept feasibility/practicability	30–60%	100–200%	1.5–2.5 years
3	Development, test and evaluation of breadboard model	Demonstration of feasibility	10–30%	50–100%	1–2 years
4	Development, test and evaluation of engineering model	Demonstration of flight-worthiness	5–10%	15–40%	3–6 months
5	Development and qualification of flight hardware	Flight qualification (for a specific project)	0	0	0

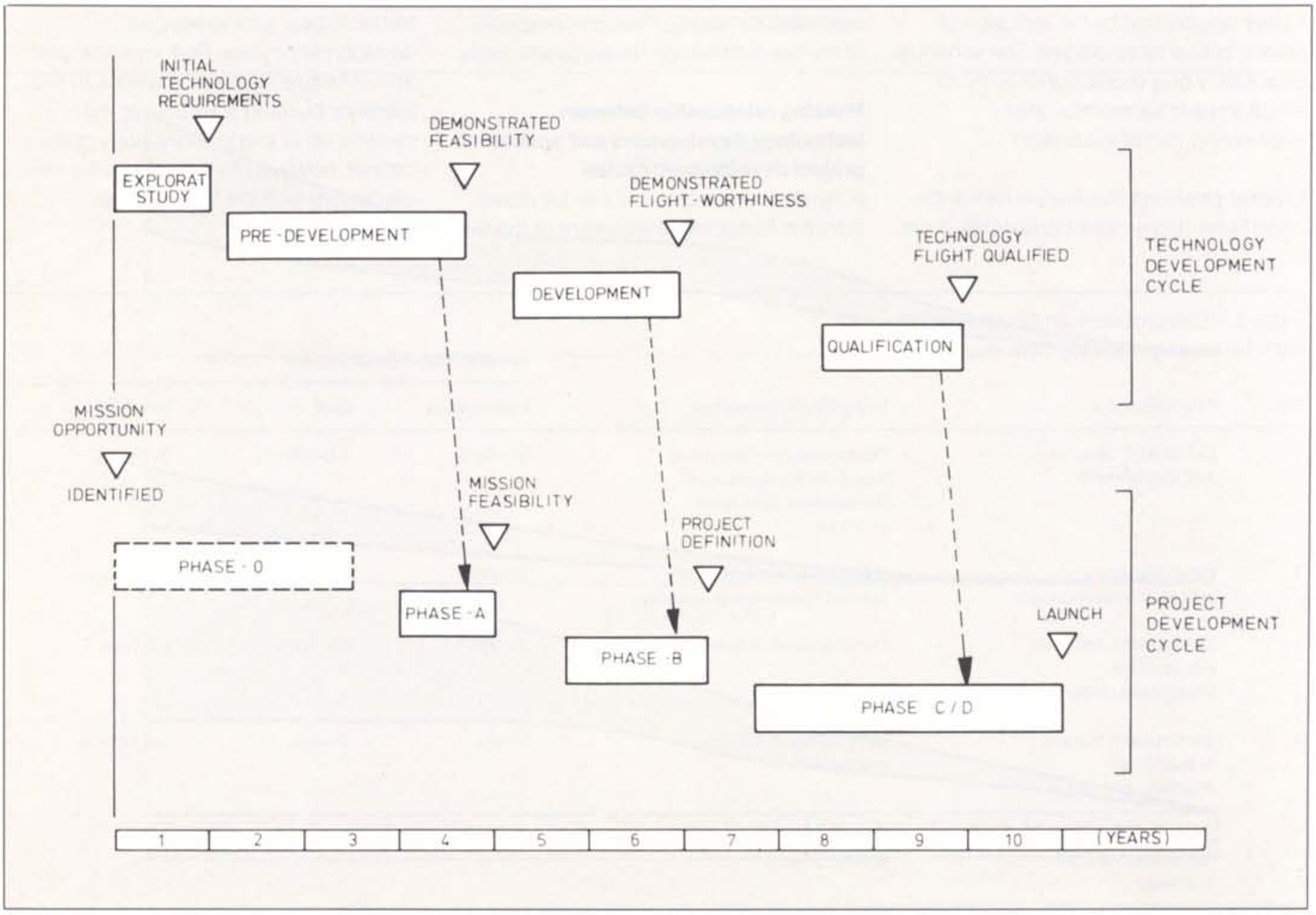
Figure 5 — Technology and project phasing relationship (idealised)

ESA uses the terminology: *Phase-0* for initial mission-assessment studies, *Phase-A* for feasibility studies, *Phase-B* for the project-definition phase, and *Phase-C/D* for the design and development phase of a project. The duration of Phase-0, from the initial identification of the mission opportunity to the point of reaching a decision to engage in a system feasibility study, may be several years. A Phase-A study usually takes about one year to complete, whereas a Phase-B, which results in an industrial offer for the design and development phase, takes in the order of one and a half years. There are decision periods between these phases in which the Agency assesses the results of the previous phase, prepares for initiation of the following phase's Invitation to Tender, and assures support from Member States, and from scientific, user and advisory bodies for engaging in the next phase. Phase-A results in the establishment of the mission's feasibility, Phase-B completes the project definition, and Phase-C/D results in the launch of a spacecraft.

Figure 5 shows a typical technology development cycle and its relationship to a project development cycle. This chart represents an 'idealised' situation, which is sometimes very difficult to achieve in real life. However, it serves to identify 'normal' schedule constraints for a technological development from the point of exploratory studies to the point of demonstrated flight-worthiness and technology qualification.

The figure further identifies the inputs that should become available from the technology development cycle for the project initiation phases and at what milestones these inputs should occur. Inputs from the technology development cycle should assure timely project 'realism', i.e. there should be a sound technological base available at feasibility and flight-worthiness demonstration level prior to completion of a mission-feasibility study and prior to the completion of the project definition phase.

Similarly, timely inputs from the results of project study phases will allow re-



definition and re-assessment of the technology requirements and developments.

Without first having demonstrated the technological feasibility of critical components through test and evaluation of a breadboard model (Steps 2 and 3), a Phase-A study objective cannot really be fully accomplished. Prior to this point, the risks associated with critical components of a new technology are considered too large to allow a realistic first-order performance prediction or cost and schedule assessment for a normal satellite project.

Similarly, the technological risks prior to the completion of engineering-model development and testing (Step 4), which results in demonstration of the flight-worthiness of the new technology, are considered too large to allow the completion of the project-definition phase and the associated system design. It is at this point that the project requirements must be frozen, the interfaces to the experiments fixed and the project schedule and cost projections established. If the option exists, the project manager can, of course, always resort to proven technologies. This is the step that normally results in the offers from industry for the execution of a satellite project.

Unfortunately, it is frequently the case that either the Agency, because of external schedule constraints, or industry for a variety of reasons, terminates a Phase-B prior to having achieved fundamental readiness of the most critical (new) technologies. The effects of this are well known and usually result in changes to performance specifications and interfaces to the payload or ground segment during Phase-C/D, which in turn results in cost and schedule overruns.

As has already been said, in real life an idealised phasing relationship of the sort shown in Figure 5 is not always easy to achieve. It is, however, extremely important that a project-initiation plan be established which, from the outset, systematically anticipates and plans to avoid risks and uncertainties, particularly for Phase-C/D. This may occasionally delay the initial project-study and project-initiation schedule, or necessitate the selection of available and proven technologies in place of more advanced ones. However, following such a phasing relationship will contribute to ensuring that later modifications due to 'technological surprises', having cost and schedule impacts, arise less frequently, and that the offers from industry for the Agency's projects can be considered sound from the point of view of the technologies upon which they are based.

Conclusions

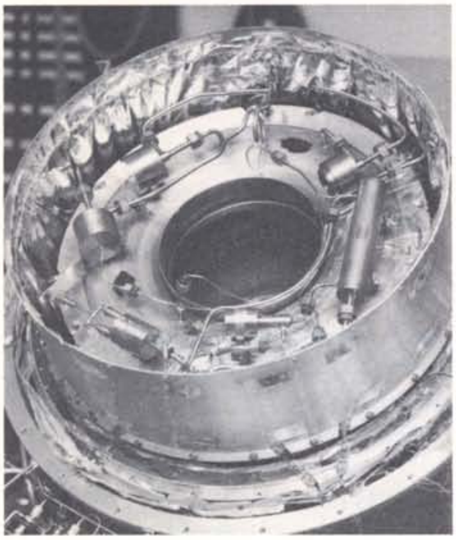
1) Technology developments normally evolve through several steps (five) from the initial idea to flight qualification, independent of whether they are initiated on the basis of a 'mission pull' or a 'technology push'.

2) Performance, cost and schedule prediction uncertainties associated with technological developments are high during initial study and pre-development phases. They become more limited once technology feasibility and especially flight-worthiness demonstrations have been completed through the first testing of breadboard or engineering-model-type hardware of the new technologies, normally at assembly or equipment level.

3) The period needed for the development of new technologies ranges from five to ten years.

4) The confidence in the results of mission and feasibility studies and the project-definition phase of a new satellite project is usually not better than that associated with the risks and uncertainties associated with the inherent technologies.

5) Technological feasibility and flight-worthiness should be demonstrated prior to completion of project feasibility studies and the completion of a project definition phase, respectively. Technology qualification is normally performed as part of and during the spacecraft development phase (Phase-C/D).



CRHESUS – un cryostat spatial pour très basses températures – Etat du développement

J. Lizon-Tati, Division Structure et Contrôle Thermique ESTEC, Noordwijk, Pays-Bas

L'une des fonctions de l'Agence spatiale européenne est de stimuler le développement de la technologie et d'en promouvoir la qualification spatiale. Le développement d'un Cryostat à Hélium Superfluide pour Utilisation Spatiale (CRHESUS) est actuellement l'une des activités importantes entreprises par l'Agence dans le cadre de son programme de recherche technologique. Cette activité doit aboutir à la livraison mi-1982 d'un prototype de vol de cryostat standard, réutilisable, dimensionné pour le refroidissement de charges utiles scientifiques pendant des missions de courte durée. La technologie mise en oeuvre pour la fabrication de ce modèle de cryostat sera qualifiée au cours d'un prochain vol du Spacelab et sera ainsi disponible dans le futur pour des projets plus importants de l'Agence. L'Aérospatiale (Cannes) et L'Air Liquide (Sassenage) ont été chargés du développement de ce cryostat.

Dès 1974, la cryogénie spatiale a été reconnue, grâce à des analyses prévisionnelles effectuées par l'Agence, comme un domaine nécessitant à court terme un effort particulier en Europe. La demande la plus immédiate provenait de propositions de missions d'astronomie infrarouge, de physique de l'atmosphère et d'observation de la Terre.

Pour la plupart des expériences scientifiques ou charges utiles utilisant la détection infrarouge, la plage de température de 4 K et au-dessous correspond à une sensibilité maximum des détecteurs. Cette zone de température est celle de l'hélium liquide (normal pour des températures inférieures à 4,2 K, ou superfluide pour des températures inférieures à 2,2 K). C'est la raison pour laquelle le programme de l'Agence a porté en priorité sur la technologie relative à l'hélium liquide.

Définition du programme

Un certain nombre de similitudes parmi certaines charges utiles du Spacelab se proposant d'utiliser l'hélium liquide comme agent réfrigérant, il a été possible d'identifier le besoin d'un cryostat de dimensions moyennes et de définir les caractéristiques principales de ce qui pouvait se présenter comme un dispositif standard mis à la disposition d'éventuels utilisateurs.

Les exigences de base suivantes ont donc été définies: fournir aux utilisateurs une température de fonctionnement inférieure à 2 K pendant une durée de mission de 7 à 30 jours, pour une charge thermique moyenne de 40 mW. La conception du cryostat devait d'une part permettre de loger dans une cavité interne une expérience de dimension moyenne (40 litres environ), mais devait également d'autre part fournir les réserves nécessaires à de possible adaptations ultérieures. La possibilités de réutilisation au cours de plusieurs vols faisait également partie des critères de conception.

Difficultés technologiques

Les principales difficultés liées au développement d'un tel cryostat concernent l'isolation thermique, pour satisfaire la durée de vie, la tenue mécanique lors du lancement, le contrôle du cryogène en gravité nulle, les caractéristiques physiques de l'hélium superfluide, et les contraintes d'opération au sol du véhicule de lancement.

Aspect thermique

L'hélium est le seul cryogène liquide permettant d'obtenir des températures inférieures à 4,2 K. Sa chaleur de vaporisation très faible (10 fois inférieure à celle de l'azote liquide) impose une isolation limitant au maximum les entrées thermiques sur le réservoir. La chaleur spécifique très élevée de l'hélium gazeux est utilisée en faisant circuler les vapeurs quittant le réservoir dans les écrans entourant celui-ci. Les entrées thermiques provenant de l'enveloppe externe du cryostat sont ainsi captées par les écrans et réduites à une valeur qui est compatible avec la durée de vie demandée au cryostat.

Tenue mécanique

Les supports structuraux du réservoir

contribuent d'une manière non négligeable au bilan énergétique sur le coeur du cryostat: les dimensions et le choix du matériau de ces supports doivent donc être le résultat du meilleur compromis entre les contraintes thermiques et mécaniques.

Séparation de phase

L'un des problèmes particuliers à l'environnement spatial concerne la séparation des phases liquide et vapeur du cryogène. En effet, alors que sur terre cette séparation se fait naturellement sous l'action de la pesanteur, il est nécessaire dans l'espace d'avoir recours à un dispositif particulier permettant d'éviter l'écoulement du liquide hors du réservoir. L'hélium superfluide (He II) permet de résoudre ce problème en utilisant l'une de ses propriétés physiques, l'effet thermo-mécanique ou effet fontaine se produisant dans les milieux poreux. On utilisera ainsi un bouchon poreux ('porous plug') à la sortie du réservoir, où se produira l'évaporation du liquide. Bien qu'utilisant une propriété physique simple de l'hélium superfluide, ce dispositif demande une mise au point assez délicate afin de contrôler le phénomène.

Caractéristiques de l'hélium superfluide

La viscosité pratiquement nulle et la très grande conductivité thermique de l'hélium superfluide sont d'une très grande utilité pour réduire le gradient thermique au sein du cryogène. Ces mêmes propriétés rendent par contre délicate la mise au point de vannes étanches du point de vue hydraulique comme du point de vue thermique.

Contraintes opérationnelles

L'une des difficultés majeures du développement a été le problème de la tenue du cryostat pendant la phase d'attente après le remplissage jusqu'au moment du lancement. Ce problème de la phase d'attente, lié aux contraintes d'opération au sol de la Navette spatiale, a eu une très grande importance sur le choix du système cryogénique.

Configuration d'ensemble

Le cryostat est contenu dans une enveloppe étanche en aluminium de 1230 mm de haut et de 750 mm de diamètre, permettant d'assurer le vide nécessaire à l'isolement. Ce conteneur est composé d'une partie centrale cylindrique et de deux couvercles identiques (Fig. 1).

L'ensemble des deux réservoirs d'hélium (réservoir principal et réservoir auxiliaire) est de forme toroïdale et construit en acier inoxydable. Ces deux réservoirs ont des volumes de 57 et 23 litres. Les composants cryogéniques sont situés au-dessous du réservoir auxiliaire. Les réservoirs entourent une cavité interne de

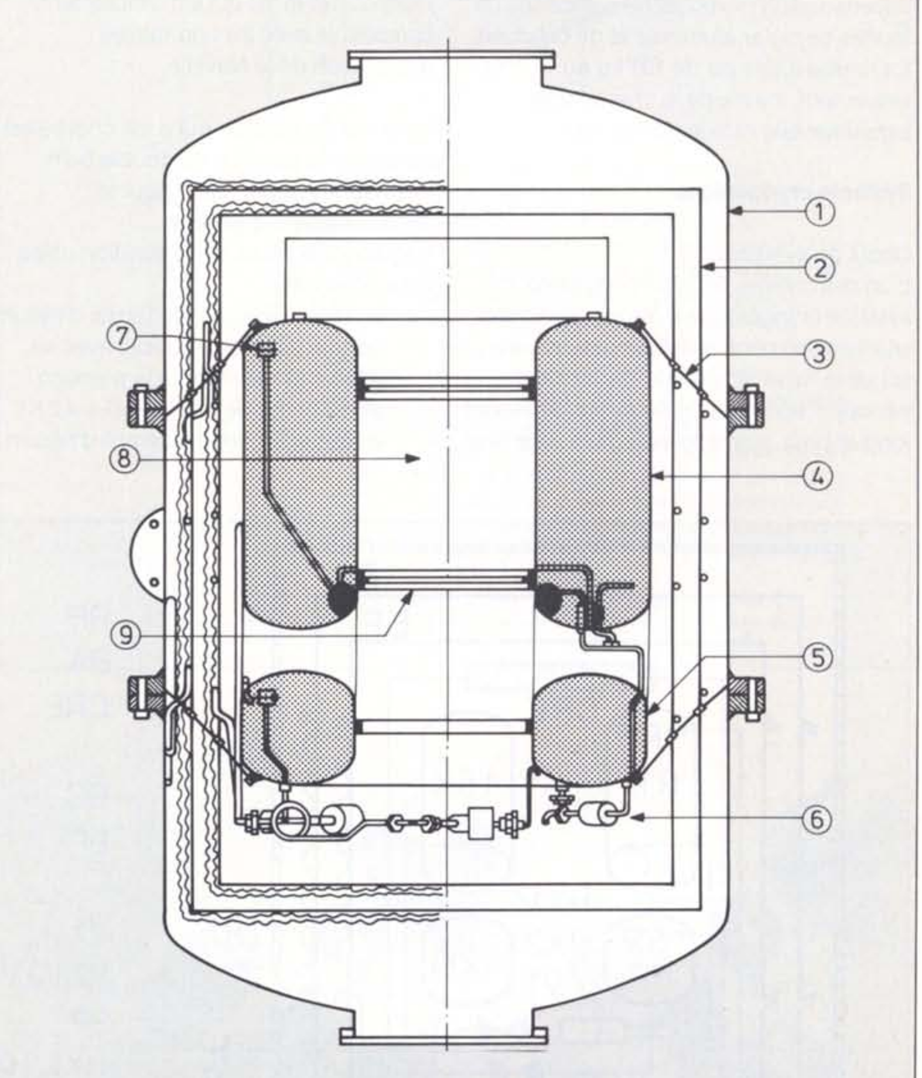


Figure 1 – Configuration générale du cryostat

1	Conteneur externe étanche	6	Composants cryogéniques
2	Ecran refroidi	7	Séparateur de phase
3	Supports du réservoir d'hélium	8	Cavité expérimentale
4	Réservoir principal	9	Bride de fixation de l'expérience
5	Réservoir auxiliaire		

Figure 2 – Schéma de principe du circuit cryogénique

40 litres environ réservée à la charge utile à refroidir. Les réservoirs sont maintenus par 24 supports réalisés en fibre de verre. Chaque support est composé de trois éléments raccordés au niveau de chaque écran de manière à faciliter l'intégration. La protection thermique est assurée à l'aide de deux écrans réalisés en aluminium et refroidis par les vapeurs d'hélium provenant du réservoir auxiliaire. Chaque écran est recouvert d'une superisolation multicouche composée de feuilles de mylar aluminisé et de cellulose. La masse totale est de 101 kg au lancement, masse de la charge utile expérimentale exclue (15 kg max.).

Système cryogénique

Choix du système

L'un des critères principaux du choix du système cryogénique a été sa capacité à satisfaire les contraintes d'opération au sol de la Navette spatiale. La dernière période d'accès au cryostat, suffisamment longue pour permettre le remplissage final de celui-ci, se situe environ 10 jours avant le lancement et juste avant la fermeture de la soute de la Navette. Une première solution pour conserver le bain d'hélium superfluide à une température satisfaisante est de maintenir au-dessus de celui-ci une pression inférieure à 50 mbar (point λ). Cette solution nécessite l'utilisation d'une pompe à vide, un accès facile au cryostat, et une disponibilité d'énergie électrique tout au long des 10 jours d'attente, ce qui est difficilement compatible avec les contraintes d'opération de la Navette.

La seconde solution qui a été choisie est basée sur le principe du double bain Roubeau-Claudet utilisé pour le refroidissement d'aimants supraconducteurs. Cette solution utilise deux réservoirs:

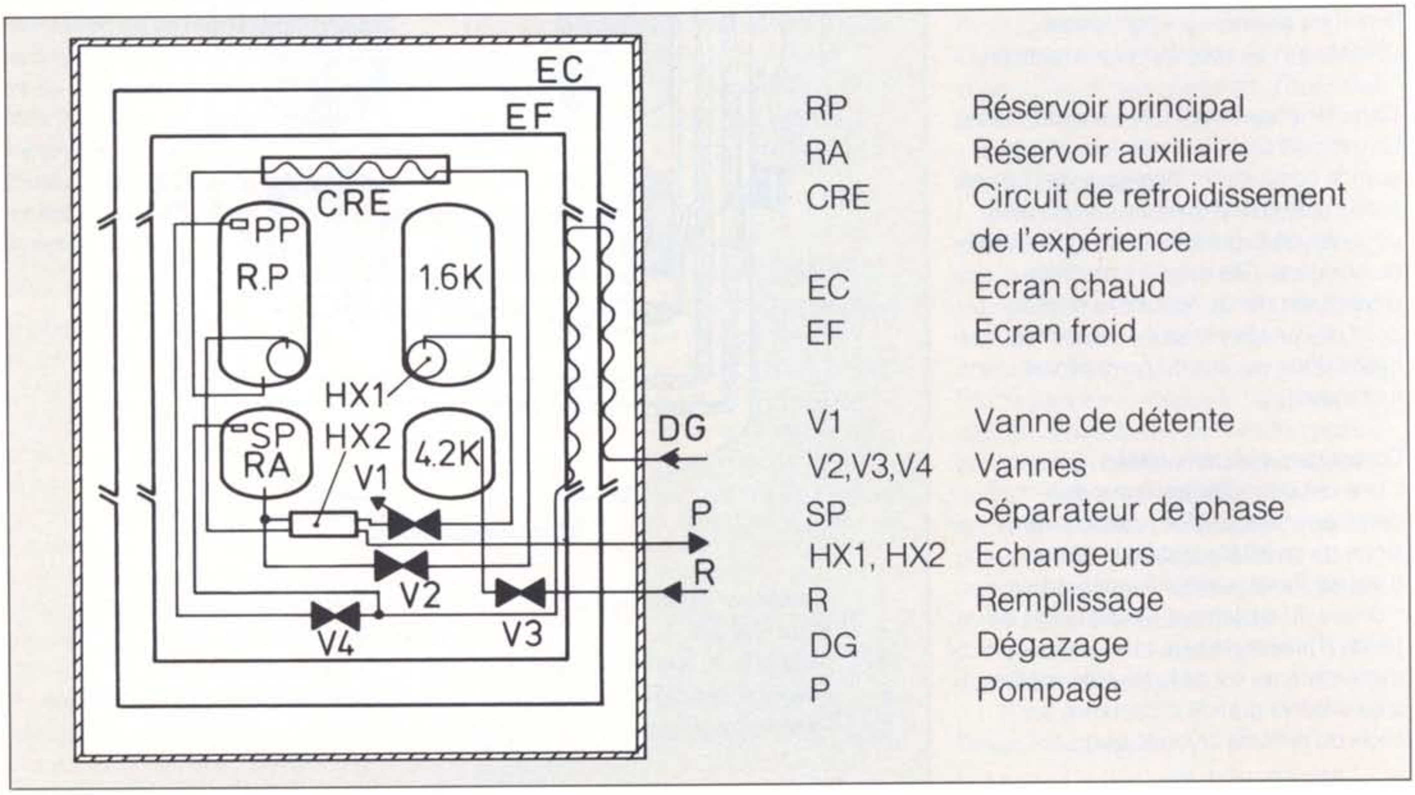
- un réservoir auxiliaire rempli d'hélium normal (He I) en équilibre avec sa vapeur et maintenu à la pression atmosphérique normale ($T \simeq 4{,}2$ K);
- le réservoir principal rempli d'hélium superfluide (He II), également maintenu à la pression atmosphérique ($T < 2{,}17$ K).

Les vapeurs provenant du réservoir auxiliaire refroidissent les écrans du cryostat pendant la phase d'attente et limitent l'échauffement du réservoir principal.

L'avantage d'un tel système est que le réservoir auxiliaire (He I) comme le réservoir principal (He II) restent à pression atmosphérique normale pendant la phase d'attente. Ainsi, le pompage pour le maintien à une température inférieure à 2,17 K (point λ) n'est pas nécessaire. En outre la très faible différence de pression sur les vannes réduit le risque de fuites.

Description du système et opération

Le schéma de principe du système cryogénique est donné à la Figure 2. Le réservoir principal (RP) et le réservoir auxiliaire (RA) sont respectivement équipés de bouchons poreux (SP) et



d'une vanne de fermeture (V 4) sur la tuyauterie de dégazage. Le remplissage des deux réservoirs se fait par la vanne V 3. Le transfert d'hélium et la communication entre RA et RP se fait via la vanne V 2. Après que les deux réservoirs ont été remplis d'hélium normal, on procède au sous-refroidissement de RP par pompage de l'hélium contenu dans RA au travers de la vanne Joule-Thomson (V 1) et de l'évaporateur (HX 1). Refroidissement de RP et complément d'hélium dans RA s'effectuent simultanément. Pendant la phase d'attente, les écrans sont refroidis par les vapeurs provenant de RA et permettent de limiter l'échauffement de RP. Sur orbite, les deux réservoirs sont mis automatiquement en communication. La Figure 3 donne, sur le diagramme de l'hélium, la position du point de fonctionnement de chaque réservoir durant les diverses séquences.

Toutes les vannes sont commandées par pression d'hélium gazeux pendant le remplissage. Après cette opération, ainsi que sur orbite, tout le système est parfaitement autonome.

Développement et essais des composants critiques

Les composants critiques du cryostat CRHESUS sont les vannes cryogéniques, le séparateur de phase, les supports du réservoir. Des études détaillées sur ces composants et des essais de développement ont été effectués pendant les deux premières phases du programme.

Vannes cryogéniques

Deux types différents de vannes de fermeture (V 3, V 4), une vanne de communication (V 2) et la vanne Joule-Thomson (V 1) ont été développées. Les premières sont conçues pour un taux de fuite à l'hélium gazeux de 10 cm³/s sous une pression différentielle de 1 bar et pour une fuite thermique inférieure à 1,5 mW, entre 4,2 K et 1,6 K (Fig. 4).

La vanne Joule-Thomson permet de

Figure 3 – Diagramme de phase de l'hélium et diagramme de fonctionnement du cryostat

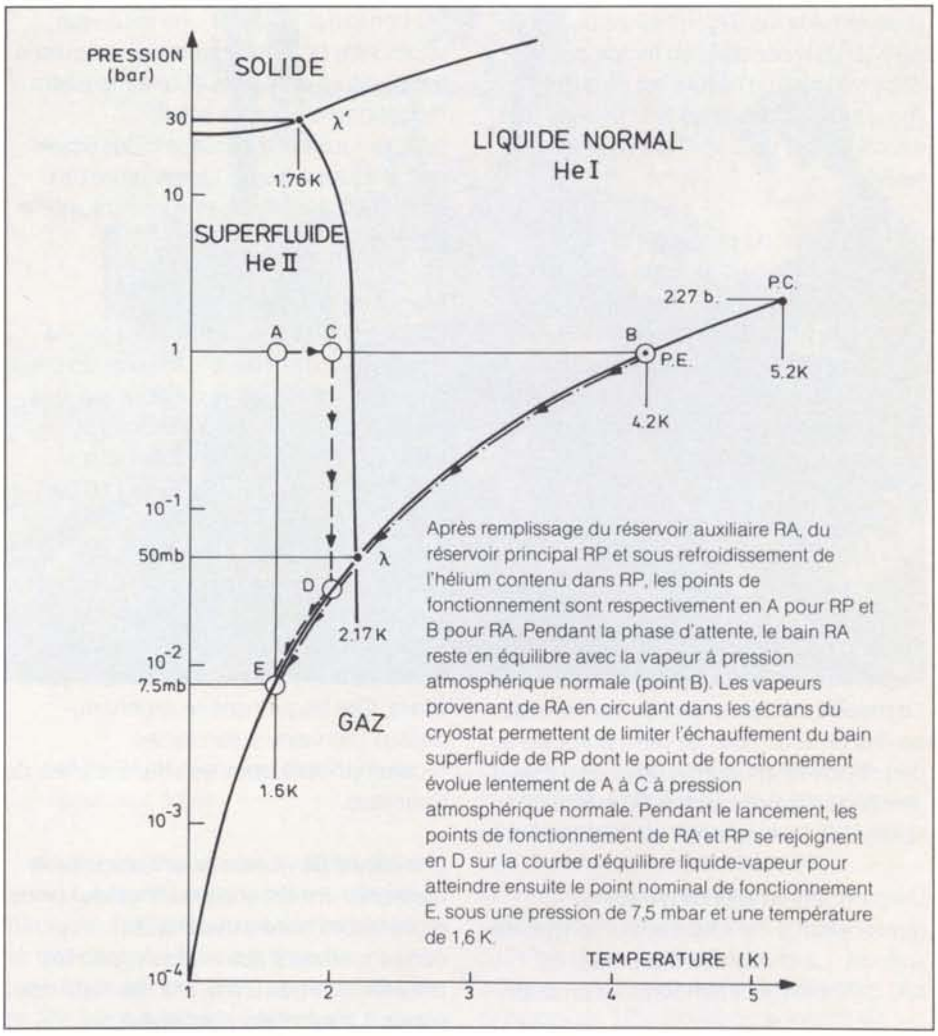


Figure 4 – Vue éclatée des vannes de fermeture

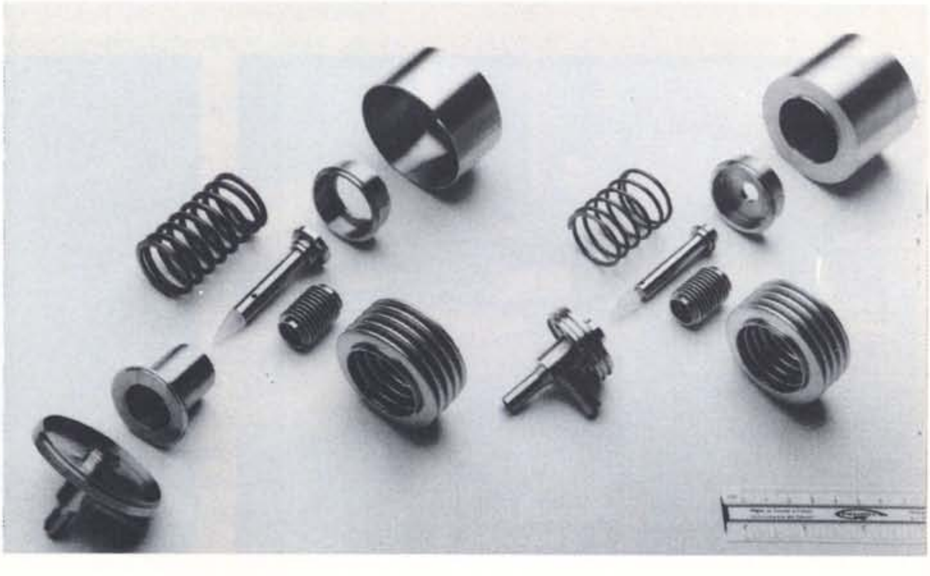


Figure 5 – Installations d'essais de la maquette fonctionnelle

Figure 6 – Implantation des vannes de la maquette fonctionnelle

sous-refroidir les 8 kg d'hélium du RP de 4,2 K à 1,6 K pendant un temps donné. Le débit minimum d'hélium est de 3 litres à l'heure (vanne ouverte) et le taux de fuite maximum est de 5.10^{-5} g/s (vanne fermée).

Le séparateur de phase est du type passif. Divers types de matériaux ont été testés et finalement un bouchon poreux en bronze fritté, avec des pores inférieurs à 15 µm et une surface effective de 10 cm², a été choisi. Ce séparateur est couplé à un clapet de surpression dans un même assemblage.

Tous ces composants cryogéniques ont subi des essais de qualification thermique et mécanique.

Supports de réservoir

Plusieurs types de supports ont été testés. Le modèle définitivement choisi consiste en des brins de fibre de verre enroulés sur deux bobines en aluminium. La longueur de chaque support est de 50 mm et la section de fibre de verre est de 4 mm².

Un programme intensif d'essai de qualification a été effectué sur ce type de support. La charge de rupture est de 490 daN environ à température ambiante.

Essais de développement sur modèles

Deux différents modèles de cryostat ont été construits jusqu'ici: une maquette structurale pour les essais mécaniques à température ambiante et une maquette fonctionnelle pour les essais cryogéniques et thermiques. Des essais mécaniques à basse température ont également été effectués sur ce deuxième modèle.

Maquette structurale

Le programme d'essais sur ce modèle comprenait des essais statiques, un essai de modes et les essais de vibration. Les essais statiques ont été effectués sur le réservoir d'hélium pour vérifier son comportement en surpression (1,5 bar) et sous une compression axiale de 1400 daN. Les essais de modes ont permis de mettre en évidence les résultats suivants: le premier mode longitudinal (*X*) se situait à 59 Hz, le premier mode transversal (*Y*) à 44 Hz et le second (*Z*) à 55 Hz. Ces fréquences se situent au-dessus des valeurs minimales recommandées pour les charges utiles de Spacelab.

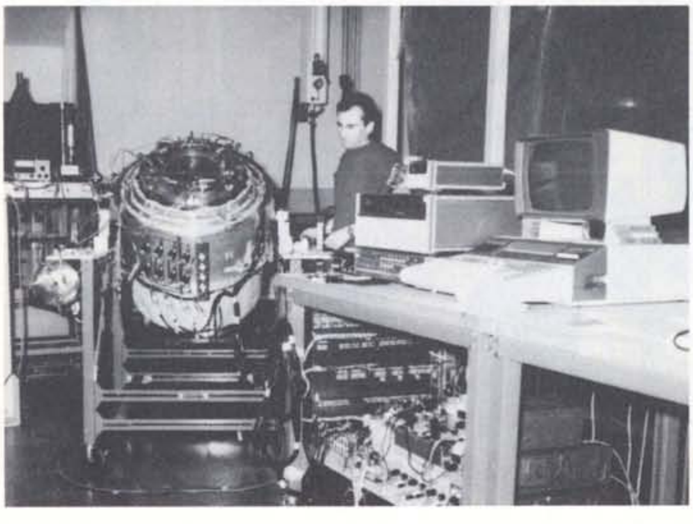
Des essais de vibrations sinusoïdales et aléatoires ont été ensuite effectués sur ce modèle. Les niveaux appliqués correspondaient aux niveaux spécifiés pour les charges utiles. Les résultats des essais à haut niveau ont révélé un abaissement des fréquences de résonance par rapport aux essais modaux, avec une fréquence critique à 40 Hz. En conséquence, il a été décidé de modifier la conception des supports et d'augmenter leur section (4 mm² au lieu de 3 mm²), de manière à garantir une première fréquence de résonance nettement supérieure à 50 Hz.

La maquelle fonctionnelle a été équipée de ces nouveaux supports.

Maquette fonctionnelle

Les essais de la maquette fonctionnelle ont constitué en fait l'activité la plus importante de la deuxième phase du programme.

Ces essais avaient pour but de vérifier le système cryogénique et les performances thermiques du cryostat. La vérification fonctionnelle devait s'appliquer au comportement du système cryogénique pendant la simulation de chacune des phases d'opération du cryostat (remplissage, attente, phase orbitale etc.) y compris les vibrations simulant le lancement. La vérification thermique devait essentiellement se rapporter à la confirmation des principaux paramètres de dimensionnement définis par l'analyse (température, bilan thermique, durée de vie etc.). La Figure 5 montre les installations d'essais et la Figure 6 une vue partielle de la maquette fonctionnelle.



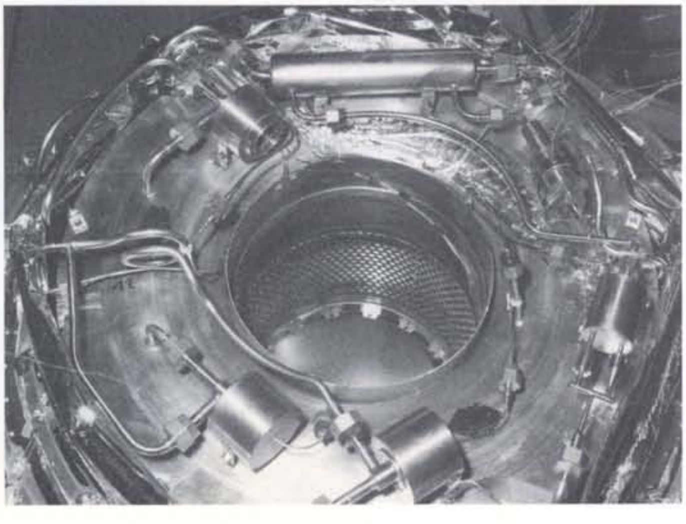
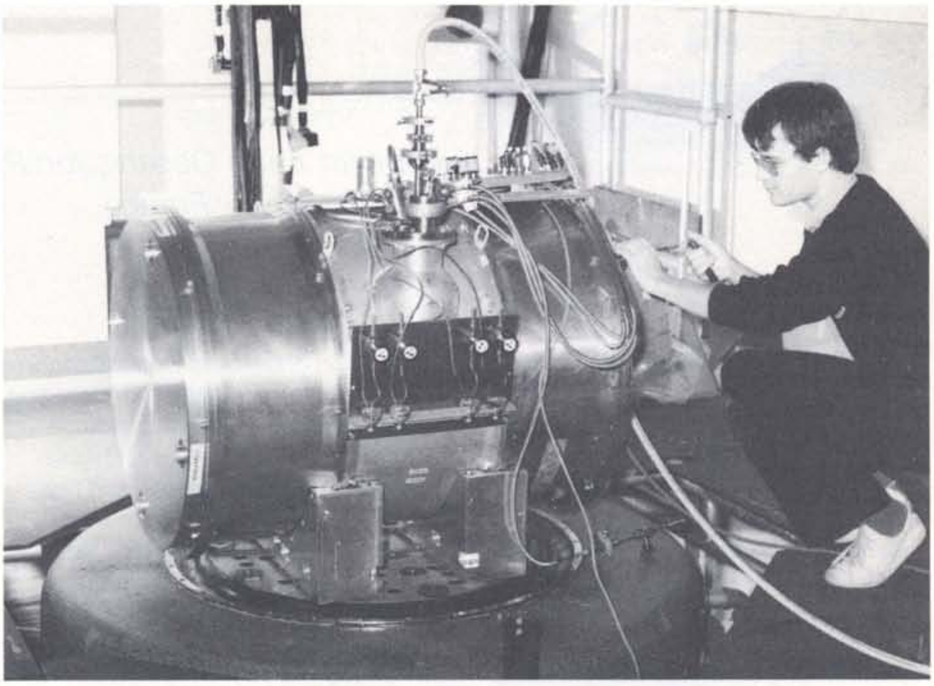


Figure 7 — Essais de vibration du cryostat à basse température



Il est difficile de résumer en quelques phrases une série d'essais qui s'est déroulée sur une période de plusieurs mois. Il est apparu très rapidement au cours de ces essais que l'application stricte du programme tel qu'il était prévu à l'origine était difficile. En effet, divers incidents rencontrés en cours d'essais, les résultats plus ou moins satisfaisants durant les premières séries, ont conduit à une adaptation permanente du programme, des moyens de mesure, des procédures utilisées et du spécimen d'essais lui-même. Les diverses améliorations apportées au cours des essais ont permis d'obtenir des résultats dans l'ensemble satisfaisants pour l'aspect fonctionnel du cryostat comme pour l'aspect performance. Les enseignements tirés de ces essais sont les suivants:

- La phase de mise sous vide de l'espace interparoi peut être relativement longue et il est nécessaire d'améliorer la qualité des matériaux internes en réduisant leur taux de dégazage (superisolation en particulier).
- Le transfert d'hélium pour remplissage des réservoirs s'effectue sans problème particulier.
- La température minimale obtenue par le pompage sur la vanne Joule-Thomson est de 1,62 K. Le pilotage de cette vanne demande l'application d'une procédure très précise.
- Le comportement du cryostat, équipé des nouveaux supports, a été satisfaisant pendant les essais de vibrations effectués à basse température. Aucune anomalie n'a été constatée dans le comportement de l'hélium contenu dans le réservoir (Fig. 7).
- La durée maximale de maintien du réservoir principal au-dessus du point λ (phase d'attente au sol) est de huit jours avec les capacités actuelles de réservoirs au lieu des 10 jours requis.
- Par contre, le volume du réservoir principal actuel permet une durée de vie de 24 jours au lieu des 20 jours requis sur orbite.

L'une des conclusions principales de ces essais sur la maquette fonctionnelle est que toute amélioration de performance est très délicate. Trois points ont cependant été identifiés qui seront mis en oeuvre sur le prototype lors de sa fabrication: amélioration globale de l'efficacité de la superisolation (par colmatage des ouvertures parasites), réduction des fuites thermiques par les vannes, et réduction des fuites thermiques par les supports du réservoir principal.

Conclusions

Avec la fin des essais cryogéniques, le programme a atteint un niveau très satisfaisant permettant d'entreprendre sans risque majeur la construction du prototype. Une inconnue majeure du développement consistait en la tenue des supports du réservoir lors des sollicitations mécaniques provoquées pendant le décollage et l'atterrissage: cette inconnue a été levée et le comportement du cryostat est jugé satisfaisant.

En ce qui concerne les performances thermiques, la durée de vie à température opérationnelle du cryostat sur orbite avec son dimensionnement actuel est supérieure à la durée requise. Seule l'exigence de tenue au sol n'est pas satisfaite pour l'instant. Une augmentation du volume du réservoir principal de 12% environ permettra de résoudre ce problème. Cette modification ainsi que les améliorations identifiées auparavant seront mises en oeuvre dans la construction du prototype qui doit être livré à l'Agence à la mi-1982.

World – Space – Time

P. Berlin, Earth Observation Programme Office, ESA, Toulouse, France

In our geometrical perception, time is often thought of as a somewhat cryptic fourth dimension after distance, area and volume. Similarly, time synchronisation can be likened to a fourth dimension in our social awareness, preceded by sight, hearing and feeling. Our audiovisual and tactile faculties are tools of communication, and communicating means synchronising ourselves with the world around us – intellectually, emotionally, and timewise. But why are vast sums of taxpayers' money being spent to achieve time synchronisation with accuracies of a few billionths of a second when the average wristwatch is perfectly adequate for keeping appointments and respecting deadlines?

At the dawn of civilisation, measuring time consisted of knowing day from night and adapting the daily survival routine accordingly. Soon the need for higher diurnal time resolution arose, and the sundial was born – initially just a tree's shadow meandering from stack to stone to stump as the day wore on, and only centuries later came the scientific variety with graduated scale. All was well until the sun disappeared behind a cloud, or night fell.

Uninterrupted time measurement clearly required some kind of time interpolation, and it was the ancient Egyptians and the Chinese who thus invented the *water clock*. An ordinary pail with a small calibrated hole in its bottom was filled with water when the sun's disc set on the horizon. As the water trickled out through the hole, the water level was read off against a scale on the inside wall of the pail, providing a measure of elapsed time until the sun appeared once more. The use of the water clock subsequently spread to all time-conscious cultures of the world. Analogous designs such as the hour-glass, using sand instead of water, were invented to make the timepiece more easily transportable. By the 16th century, the growing interest in astronomy put more stringent requirements on accuracy, and the *mechanical resonator* was born in the form of the gravitational pendulum, as found in the grandfather clock. Once more, the need for ease of transport brought about a more compact reasonator, namely the torsion pendulum relying on springs, as used in wristwatches to this very day. Other types of mechanical resonators employ tuning forks or quartz crystals. Only in the last fifty years has the mechanical resonator met with serious competition from new inventions: e.g. *electronic resonators* like tank circuits and microwave cavities, and especially *atomic resonators* using the rapidly oscillating properties of atomic gas beams of cesium, rubidium and hydrogen.

The desire to *synchronise* clocks over large distances arose in the days of the water clock, not least in warfare, when a battle might be won or lost depending on the timely execution of pincer-movement assaults. Today, clock-synchronisation accuracies of 1 nanosecond ($\sim 10^{-9}$s) or better are required to trigger and correlate actions, movements and observations in navigation, deep-space tracking, communications, and in the geosciences.

The expression 'it is written in the stars' evokes visions of philosophers gazing into the nocturnal sky in search of ultimate answers to the meaning of life when the world around them fails to offer the clues they seek. The same method is used by geodesists and geodynamicists in their endeavour to establish geographical distances and to discern the shape and movement of the earth. Ideally, the measures should have been obtained by observing the earth using theodolites from some fixed point in space, but until ESA's Spacelab becomes operational we are obliged to do the opposite, namely to study the relatively constant celestial sphere from our restless and deformed planet and draw our conclusions backwards.

Figure 1 – Very Long Baseline Interferometry (VLBI)

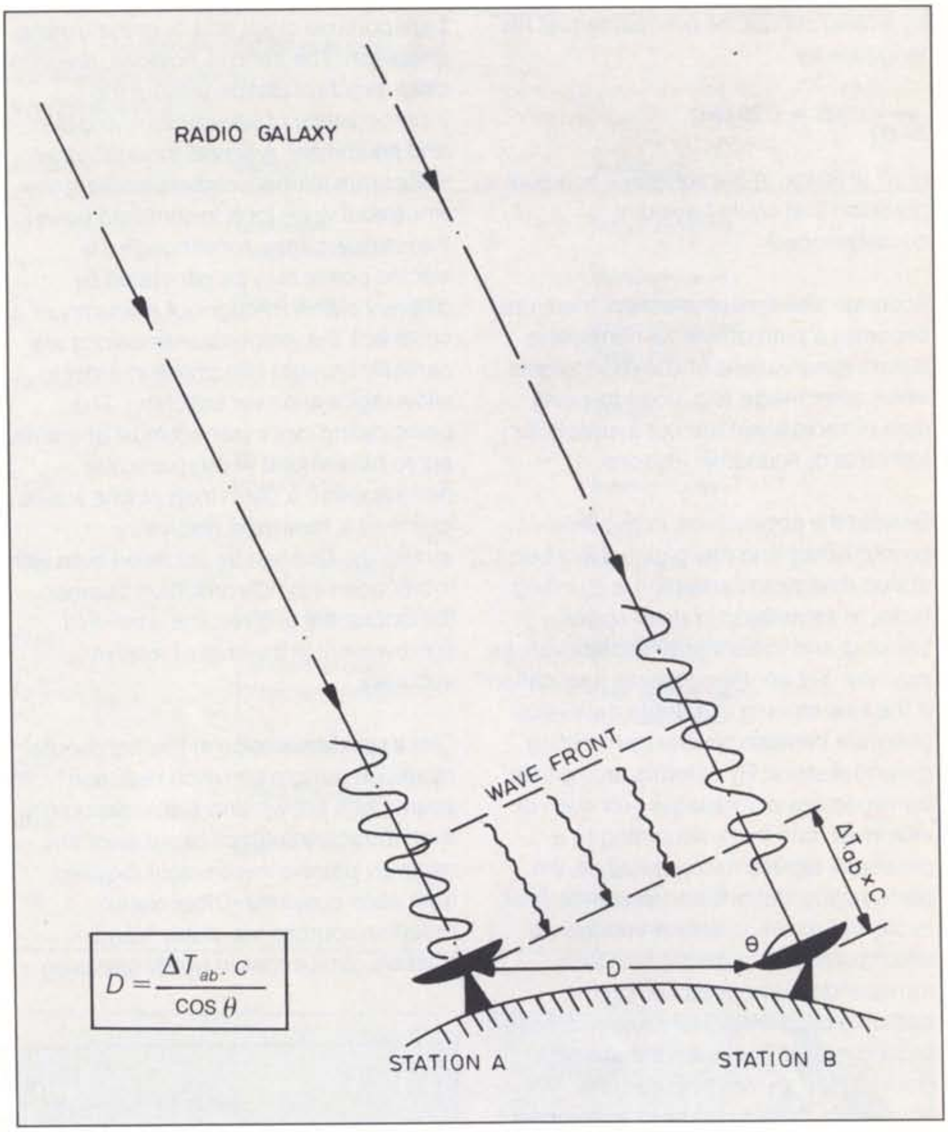
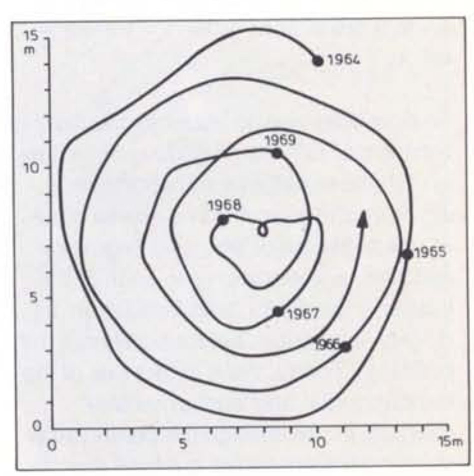


Figure 2 – Polar precession



In geodesy, transcontinental distances can now be measured with an accuracy of a few metres thanks to a method known as Very Long Baseline Interferometry (VLBI). Two astronomical observatories at each end of the distance to be measured aim their radio telescopes towards a common celestial source, usually a known radio galaxy. The incoming radio waves are recorded at each observatory, and the distance 'D' between them is obtained by simple interferometric trigonometry, as illustrated in Figure 1. In practice one obtains the difference in arrival time ΔT_{ab} of a given radio wave front. Consequently, the more accurate the synchronisation between the observatories' atomic clocks, the more precise the estimate of 'D'.

In geodynamics it is common practice to examine the apparent drift of satellite orbits against the starry background in order to monitor the precession of the earth's spin axis, and accurate time synchronisation is again a prerequisite for correlating observations recorded by participating tracking stations. A pedantic historian might question whether explorers like Peary and Amundsen really reached the North Pole at the beginning of the century, for only lately have the positions of the poles been determined with sufficient accuracy to permit explorers to place their nation's flag on the spot to say: 'I was here!'. To make things worse, the poles have been found to be moving almost imperceptibly in circles of up to 15 m diameter with a periodicity of 14 months (Fig. 2). This restlessness is thought to be caused by gravitational pull from the sun and the moon, and by convective flow in the earth's molten interior.

Navigators at sea and in the air also seek the truth among the stars, at least those who still need to use a sextant. This instrument measures the elevation of a selected star (such as the sun) above the horizon. If the navigator is lucky, the star happens to be at its highest point in the sky at the moment of observation, allowing him to determine his latitude directly from the elevation and the indispensable star almanac. Usually, however, the navigator does not know how far the star is from its highest point; in addition he has yet to establish his longitude. In both cases he must know the earth's rotational phase, i.e. the time of the day. Consequently, the navigator requires a clock on board which is well synchronised with the astronomically determined standard time of his nearest time and frequency institute. Since the earth turns approximately 360 deg in 24 hours, if the navigator's clock is wrong

Figure 3 – The Lasso principle

$$\Delta T_{ab} = \Delta T_s + \tfrac{1}{2}(T_a - T_b)$$

where ΔT_{ab} = *clock asynchronism between stations A and B*
T_a = *laser pulse travel time Transmitter A – Satellite – Receiver A*
T_b = *laser pulse travel time Transmitter B – Satellite – Receiver B*
ΔT_s = *time difference measured by satellite clock and telemetered to the ground*

by a mere minute, he will misinterpret his longitude by

$$\frac{1}{24 \cdot 60} \cdot 360 = 0.25 \text{ deg}$$

or all of 30 km at the equator – a lack of precision that could have dire consequences!

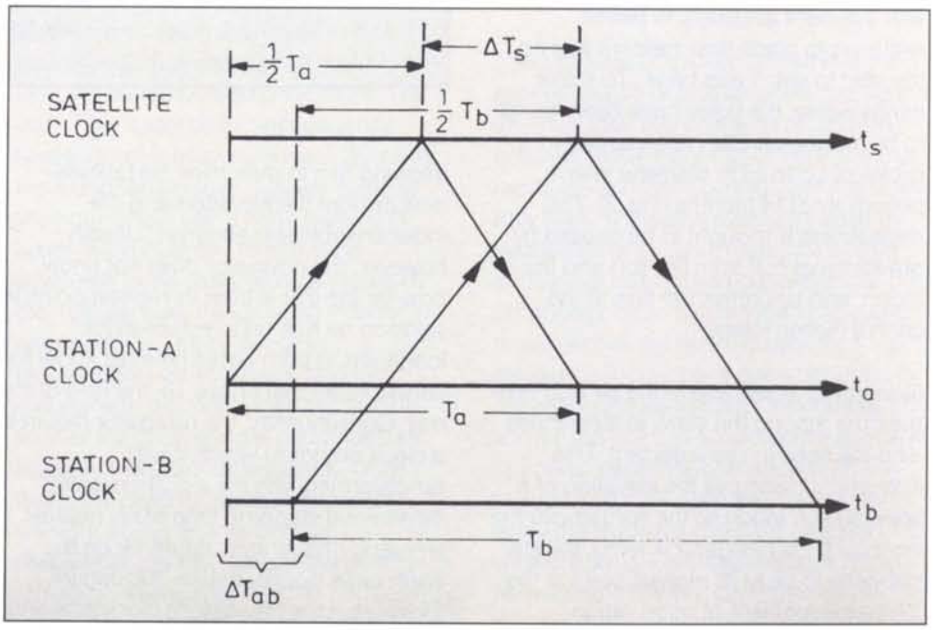
Accurate time synchronisation, therefore, becomes a prerequisite for correlating distant observations of common targets when other media (e.g. point-to-point data or radio links) are not available for technical or economic reasons.

Besides the applications in geodesy, geodynamics and navigation described above, time synchronisation is a uniting factor in astronomy, in deep-space tracking, and in earthquake prediction, for example. Yet another possible application is the time sharing of satellite data-relay channels between several transmitting ground stations. By carefully timing their transmissions of messages – or even of individual data bits – according to a previously agreed micro-schedule, the participating stations can intertwine their traffic into a minute web of intelligence which passes through the satellite's transponder without exceeding the available bandwidth. Here again, precise synchronisation between the atomic clocks at the transmitting stations becomes a must if mutual interference is to be avoided. Of course, the same is true for the receiving stations which have to unravel the strands within the message fabric.

So how does one go about synchronising atomic clocks? The most obvious method is perhaps to obtain a transportable clock, synchronise it with a master clock at one of the major time and frequency institutes, and dispatch it to each of the customer clocks for 'time fertilisation' as quickly as possible, before significant drift builds up. Today, this is in fact one of the most accurate and least expensive methods in use, though the perennial air travel sometimes wears out both the transportable clock and its globe-trotting chaperon. The trend is, however, towards clock synchronisation without the inconvenience of constantly roving staff and equipment. A simple though rather inaccurate method involves tracking the sinusoidal wave form in standard power transmission lines, for although the electric power may be generated by different plants throughout a country or a continent, the various transmissions are carefully brought into phase in order to allow regional power switching. The participating clock owners must of course agree beforehand which particular periods within a given train of sine waves to use – i.e. they must resolve the ambiguity. This can be achieved even with rather coarse synchronisation between the clocks; the end result is a ten-fold improvement in the level of relative accuracy.

Clock synchronisation in this 'lighthouse' mode, i.e. using a common radiation source with known and stable periodicity, is an attractive solution because of the relatively passive involvement required from each customer. Other useful radiation sources are: pulsars and quasars, sync codes in public television broadcasts, navigational aids such as Loran-C and Omega, and programmable clocks carried on satellites.

A more active form of clock synchronisation holds promise for the future; namely the exchange of microwave or laser pulses via satellite between the participating clock owners. Microwave synchronisation, in its simplest form, requires each participant to transmit a brief pulse towards the satellite at precisely the same *assumed* time (each according to his own clock) and to subsequently time-tag the arrival time of his own and his partner's pulse as relayed by the satellite. This two-way mode not only permits relative clock synchronisation over large distances, it also obviates the need for making corrections due to the travel times of the pulses. Laser synchronisation likewise relies on the participants transmitting a laser pulse at the same *assumed* time towards a satellite equipped with an event timer and a laser retro-reflector (Fig. 3). The on-board event timer clocks-in the arrival of the individual laser pulses in terms of spacecraft time. This time interval is then transmitted via housekeeping telemetry to a central ground station for decommutation and



forwarding to the participants. The time interval is a direct measure of the actual synchronisation discrepancies between the participating clocks, apart from a correction imposed by the different laser travel times between each participant and the satellite. The travel time is measured by the originating laser station simply by receiving and time-tagging the echo of the laser pulse as it bounces off the satellite's retro-reflector.

The techniques described enable today's customers for atomic-clock synchronisation to obtain relative accuracies of between 1 millisecond and 1 nanosecond ($=10^{-9}$ s), depending on their technical and financial resources. Precisions down to fractions of a nanosecond are envisaged after further refinement of the active methods. A summary of methods and applications for atomic-clock synchronisation is shown in Table 1.

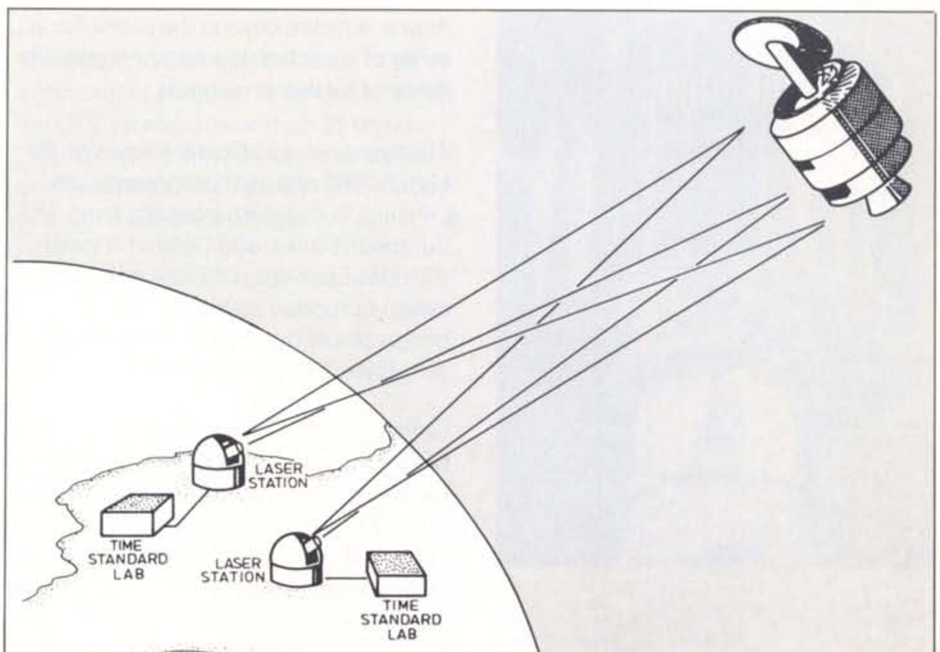
ESA's involvement in improving clock-synchronisation techniques is embodied in the Laser Synchronisation from Stationary Orbit (Lasso) experiment which will be flown on board the Sirio-2 satellite (detailed descriptions are to be found in ESA Bulletin No. 19, 1979, and ESA Journal No. 1, 1980). Lasso employs the laser pulse method in conjunction with the geostationary Sirio satellite and existing laser stations in Europe, Asia and the Americas (Fig. 4).

Scientists affiliated with time and frequency institutes, universities and laser stations all over the world are enthusiastically collaborating with ESA in the detailed definition of Lasso schedules, formats and procedures which form the skeleton of the inevitably rather complex space – time system. The launch of the satellite is planned for early 1982 and Lasso promises to become thereafter an institution in man's quest for grasping and exploiting that elusive fourth dimension we call 'time'.

Table 1 – Summary of methods and applications for atomic-clock synchronisation

Accuracy	Method	Application
10 s	Wristwatch	Man in the street
	Telephone service	
		Radio amateurs
1 s	Digital clock	Pleasure navigation
		Airline operations
		Radio stations
100 ms		
		Industry
10 ms		
	HF radio	
1 ms	Power lines	Seismic studies
	LF radio	
100 μs	Loran-C, Omega	Mapping
	Satellite relay	
10 μs		Commercial navigation
	Satellite with clock	
1 μs	TV line sync (VHF)	Orbit determination
		Air-traffic control
	Transportable clock	
100 ns		
	TV line sync (SHF)	
10 ns		
	VLBI	
		Astronomy
1 ns	Lasso	Geodesy
		Geodynamics

Figure 4 – The Sirio-2 Lasso experiment concept



In brief

New ESA Chairman Elected

At its meeting on 30 June 1981, the ESA Council elected Prof. Hubert Curien (France) as its new Chairman. He succeeds Mr. Jan Stiernstedt (Sweden). Dr. H.H. Atkinson (United Kingdom) and Dr. H. Grage (Denmark) were elected Vice-Chairmen.

Prof. H. Curien (56) is an 'Agrégé de Sciences physiques' and a 'Docteur ès-Sciences' and has been President of France's Centre National d'Etudes Spatiales since 1976 and President of the European Space Foundation since 1980.

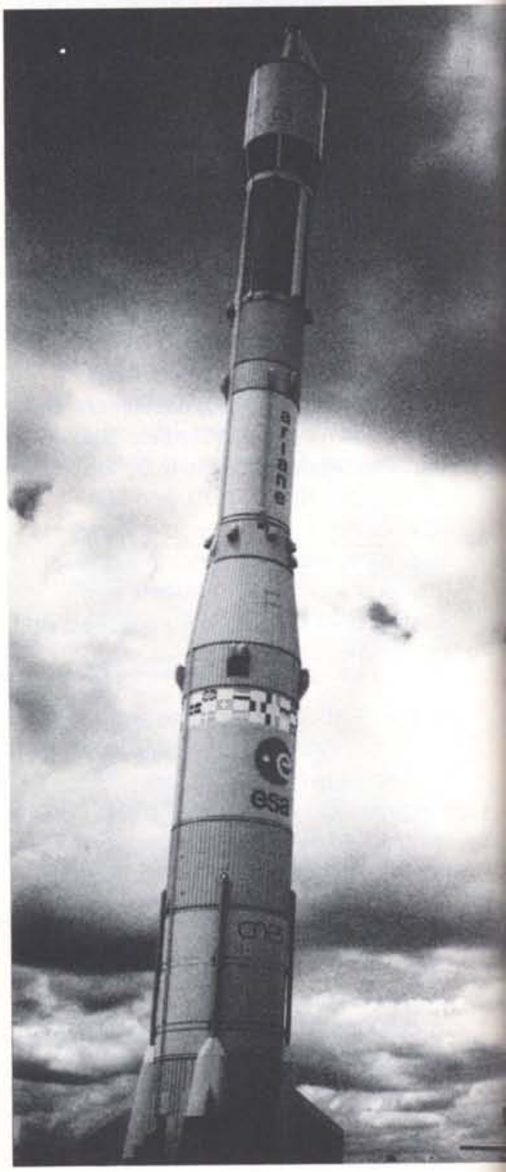
ESA Arianespace Convention Signed

The Convention that sets out the practical arrangements for putting into effect the Declaration on the Ariane launcher production phase was signed on 15 May by Mr. E. Quistgaard, ESA's Director General, and Mr. F. d'Allest, Chief Executive of Arianespace.

Under the terms of this Convention, Arianespace, a limited company under French law, is to be entrusted with the marketing, manufacture and launching of Ariane vehicles, beyond the promotional series of launches, to meet the worldwide demand for launch services.

Arianespace was officially formed on 26 March 1980 and its shareholders – 36 principal European aerospace firms, 11 European banks, and Centre National d'Etudes Spatiales (CNES) – reside in eleven European countries. The geographical distribution of funding is as follows (figures in percent):

Germany 19.6	Italy 3.6
Belgium 4.4	Netherlands 2.2
Denmark 0.7	United Kingdom 2.4
Spain 2.5	Sweden 2.4
France 59.25	Switzerland 2.7
Ireland 0.25	



Cooperation Agreement Signed between ESA and IERA

The Institut d'Etudes et de Recherche pour l'Arabisation (IERA) in Morocco and ESA's Information Retrieval Service (IRS) based in Frascati (Rome), signed a contract on 22 May for the development of the tools needed for the constitution of a dual-alphabet lexicographical data bank, as part of the Lexar programme.

This programme has been implemented, with the help of the United Nations Development Programme and UNESCO, to establish a multilingual Arab bank of lexicographical data that will constitute a practical reservoir of Arabic terminologies.

The Moroccan Documentation Centre has been connected to the IRS network for the past five years and the cooperation between the Agency and Morocco has already led to the development of a dual-alphabet terminal (Eurab) that can acquire and display dual-alphabet texts (in this case Latin and Arabic).

Under the terms of the new contract, software permitting the local acquisition, validation and transmission of dual-alphabet data will be installed in the IERA computer in Rabat. In addition, IRS will adapt the ESA-QUEST software to enable dual-alphabet data to be retrieved for interactive interrogation of the lexicographical files established in Latin and Arabic characters.

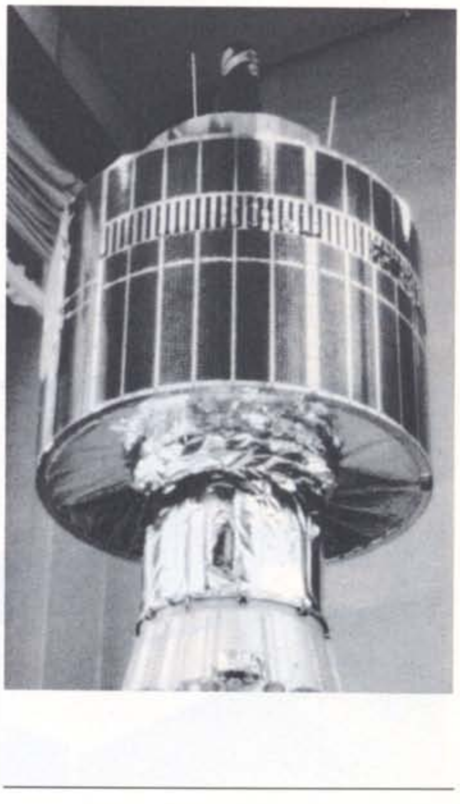
Australian Communications Evaluation Contract Awarded to ESA

The Agency has been awarded a contract by the Overseas Telecommunications Commission of Australia to participate in the evaluation of offers for the future Australian satellite communications system. ESA will support the Overseas Telecommunications Commission (OTC) in their technical evaluation of the bids and the bulk of the work will be carried out by a team of Agency staff based temporarily in Sydney, from 11 May.

The award to ESA was the result of an international invitation to tender, to which the OTC received more than 25 replies. This contract is a follow-up to an earlier one awarded to the Agency for the study of a satellite system design.

Meteosat-2 Readied for Operation

Meteosat-2 was launched on Ariane L03 on 19 June. After successful injection into transfer orbit, the MAGE-1 apogee boost motor was fired on 20 June. Spin-axis erection took place the following day, followed by manoeuvres to increase drift and spin rates. As of 10 July, the spacecraft was at about 30°W longitude and drifting towards its planned position at 0°, to be reached on 20 July. Meanwhile, the MPT (mission performance transponder), the SIC (synchronisation and image channel) and the EDA (electrically despun antenna) have been switched on and found to be operating normally. Transmission tests with previously recorded images (from Meteosat-1 archives) have started. During the initial phase, a problem in switching on the Data Collection Mission indicated that uplink signals were not being accepted by the spacecraft. This phenomenon is presently under investigation. Once the spacecraft is on station, further antenna tests will be performed and the radiometer will be commissioned. Dissemination of the first low-resolution raw images to users is scheduled to take place in mid-August, and dissemination of high-resolution images will commence one month later.



ESA's Presence at Le Bourget Air Show

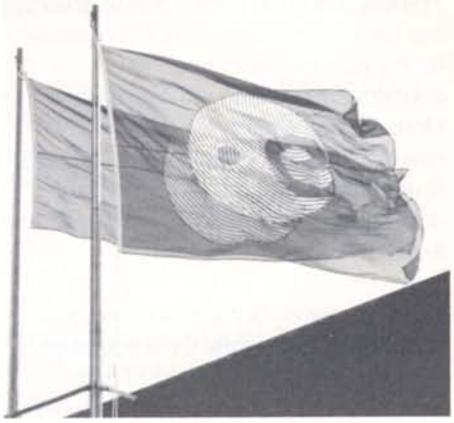
This year's ESA pavilion at the International Air and Space Salon was designed to appeal to a wide public, from the young enthusiast to the well-informed specialist. Sited next to the full-scale model of Ariane that is now a permanent feature of the aviation museum at Le Bourget, the pavilion reflected both the present and future programmes of the Agency. Full-scale models of the satellites Meteosat-2 (for meteorology), Exosat (for scientific research), and ECS (for telecommunications), were on display, as was a quarter-scale model of Europe's Giotto spacecraft that will be launched in 1985 to rendezvous with Halley's Comet in March of the following year.

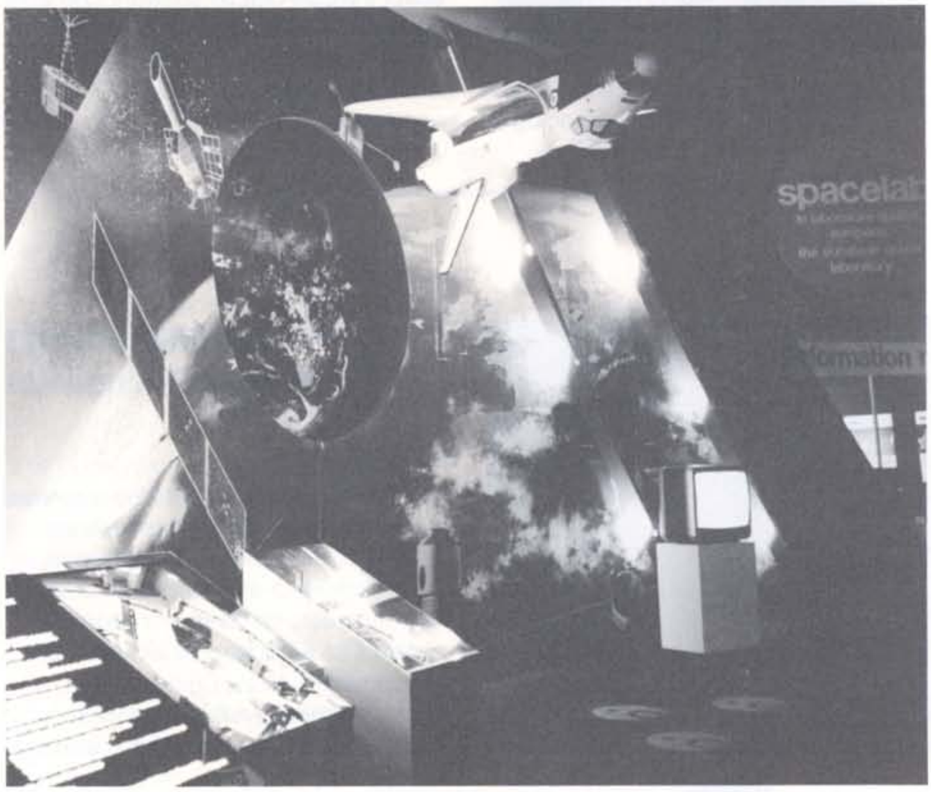
One corner of the pavilion was devoted to Spacelab, with a 1/15 scale model of the Shuttle Orbiter and a large model of the Spacelab pressurised module, intended to give visitors a first-hand impression of the role that the European payload specialists will play during Spacelab flights.

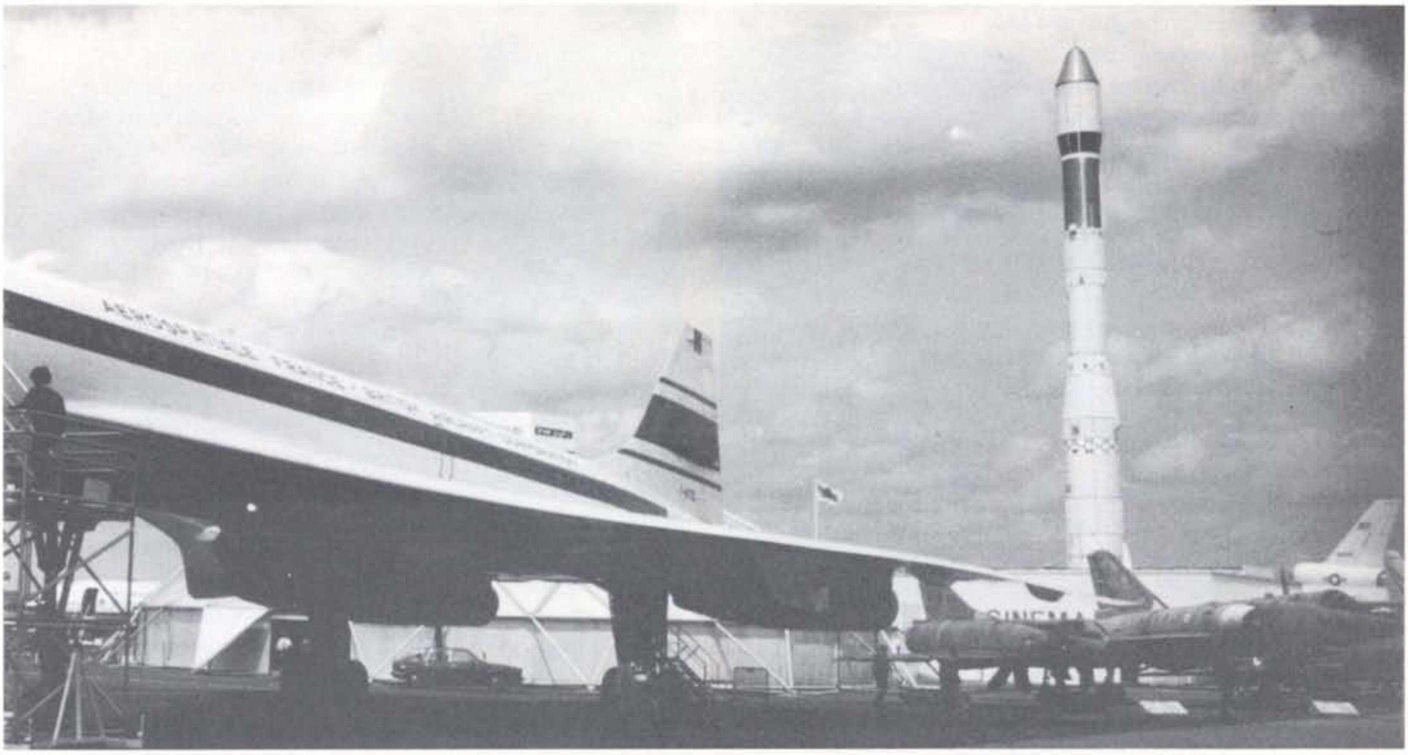
The Sirio-2 programme was also represented, with a full-scale model of the spacecraft supported by a mobile illustrating Sirio's Lasso experiment payload (for the laser synchronisation of atomic clocks).

Throughout the show, broadcasts from European television stations were relayed to the ESA pavilion via the Agency's experimental communications satellite, OTS.

A reading room provided visitors to the stand with a quiet corner in which to browse through the latest documentation from ESA's Scientific and Technical Publications Branch.







Third Ariane Test Flight Success

After the spectacular success of the first test flight (L01) of the Ariane launcher on 24 December 1979, the failure of the second launch (L02) in May 1980 caused some consternation. Failure of one of the four first-stage engines, owing to combustion instability, resulted in the L02 launcher being destroyed some 100 s after lift-off. The investigations and tests to determine the cause of this failure finally led to the conclusion that the combustion-stability margin of the Viking engine, which depends essentially on the geometrical configuration of the propellant injector, was too narrow. A number of static tests were made to determine the most effective modification for the injector, which was then qualified in a series of tests in which the operating conditions were distinctly more stringent than those laid down for the third test flight (L03).

The engines for this third flight were equipped with the new injectors, so removing any danger of a recurrence of the phenomenon that led to the failure of the second test flight.

Launch campaign

The launcher and supporting equipment left Le Havre by sea on 17 April and reached Kourou on 29 April 1981.

The launch campaign began on 4 May and lasted for 34 working days (compared with 56 days for L01). No significant difficulties were encountered.

The payload, consisting of the Agency's own Meteosat-2 (the second European meteorological satellite), the Apple* experimental communications satellite being launched for the Indian Space Research Organisation (ISRO), and the CAT (technological capsule flown systematically on each test flight), was erected on the launcher on 3 June.

After the fitting of the fairing and final preparations, the launcher and payload were ready for the countdown to start on 17 June.

Launch

The countdown, which lasts 29 h, began at 06.20 UT on 18 June.

After two holds in the final phase of the countdown (automatic sequence):
- the first due to an on-board battery voltage in the third stage being slightly outside limits
- the second due to one of the two Bretagne radars being out of phase,

the launch took place at 12 h 32 m 59 s, (the H0 corresponding to the moment of the ignition command for the four first-stage engines).

During the flight, all the stages and systems of the launcher functioned normally. The separation of the payload composite, of Meteosat and finally of Apple took place exactly as planned, less than 17 min after lift-off, and the satellites were placed in their nominal elliptical transfer orbits.

The two satellite control centres – the European Space Operations Centre (ESOC) in charge of Meteosat and the Apple Mission Control Centre in Shar (India) in charge of Apple – reported nominal on-board performances after the first acquisition of telemetry data by the ESA and the Indian tracking networks, respectively.

Preliminary results

The transfer orbit of the composite after separation was well within the nominal tolerances:

	Actual	Planned
Perigee altitude	201.5 km	200.0 km
Apogee altitude	36 175 km	35 962 km
Inclination	10.48°	10.5°

Two modifications made to the L03 launcher since the L01 flight proved their effectiveness:

Second-stage Pogo effect
It will be remembered that while there was no Pogo effect during the L01 launch in the first stage, the Pogo correction system (SCP) of which had been activated, there was such an effect during part of the flight of the second stage, whose SCP had not been activated. During L03, the second-stage SCP was activated, and this resulted in virtual elimination of the Pogo phenomenon.

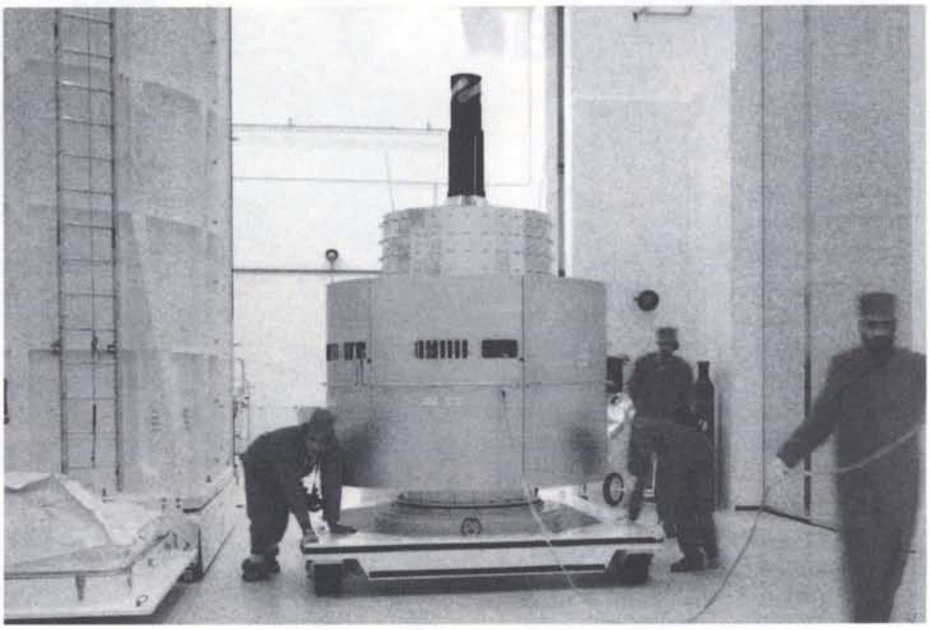
Payload contamination
During L01, thermal flux and contamination were observed, both phenomena stemming from the second-stage retro-rockets. The moving of these from the top towards the bottom of the stage, together with the closure of the fairing vents, has solved these two problems.

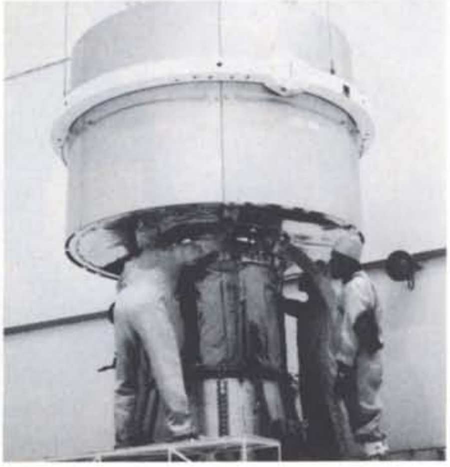
Conclusion

The launcher's third test flight met the general criteria imposed for a qualification flight and therefore represents an important step towards definitive qualification of the launcher.

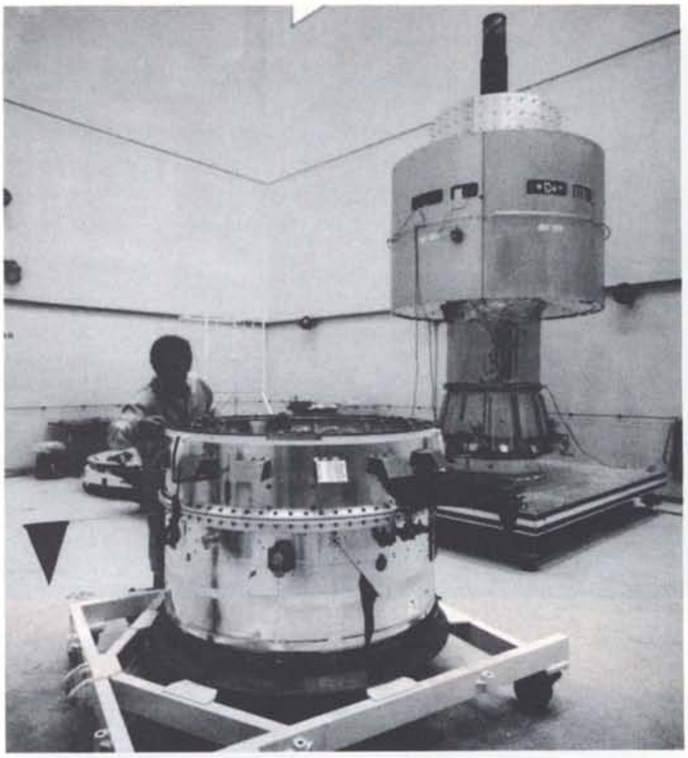
The excellent results achieved with this third test flight also mean that no major modifications to the L04 vehicle are necessary and the fourth test flight is currently scheduled for November of this year.

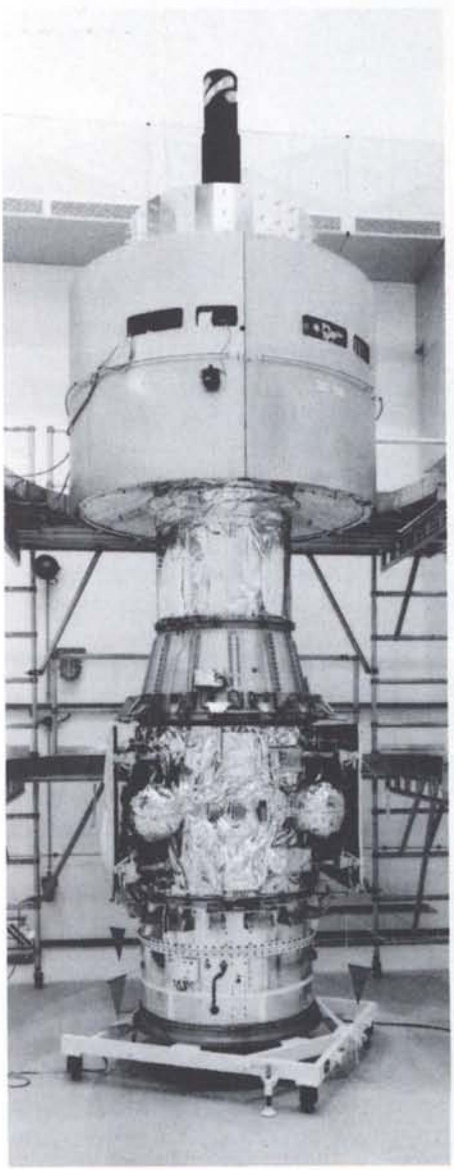
PAYLOAD INTEGRATION

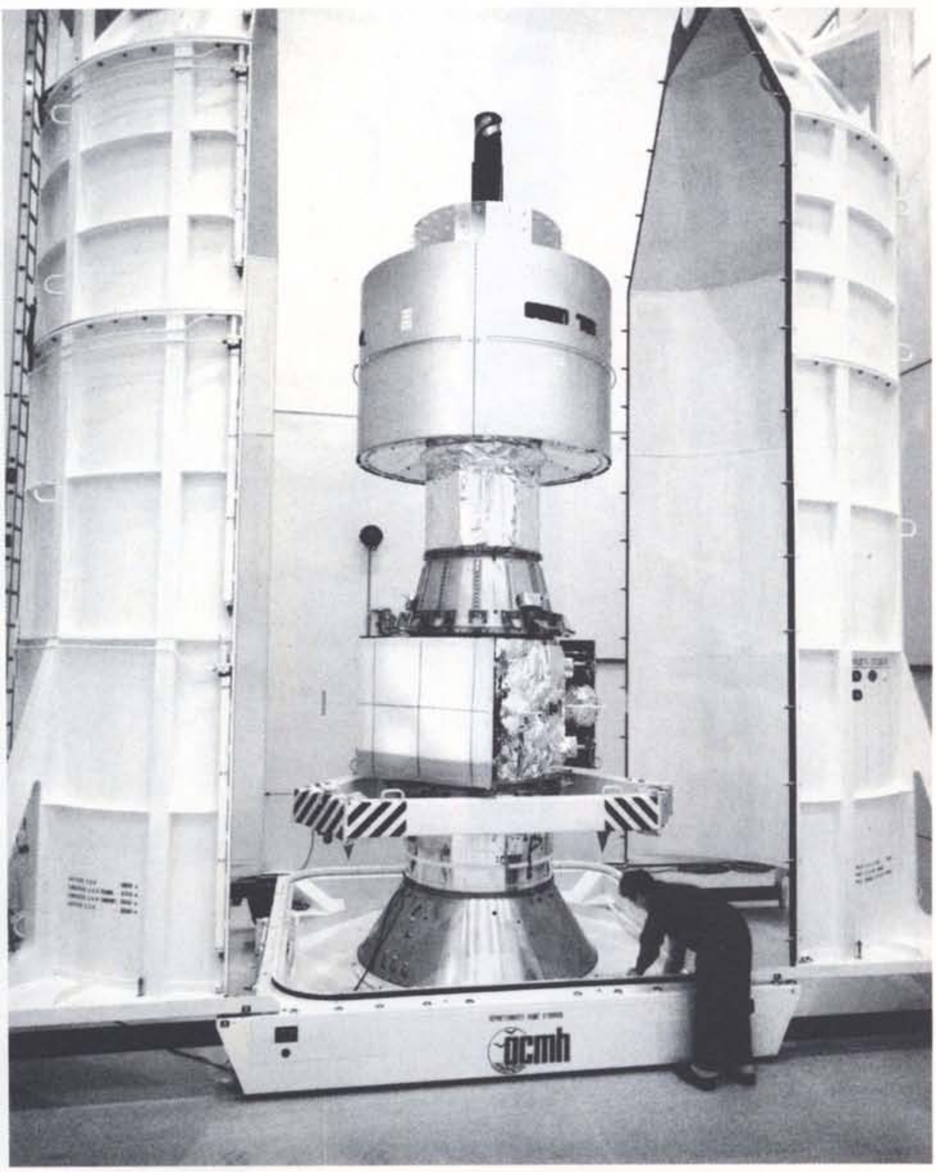


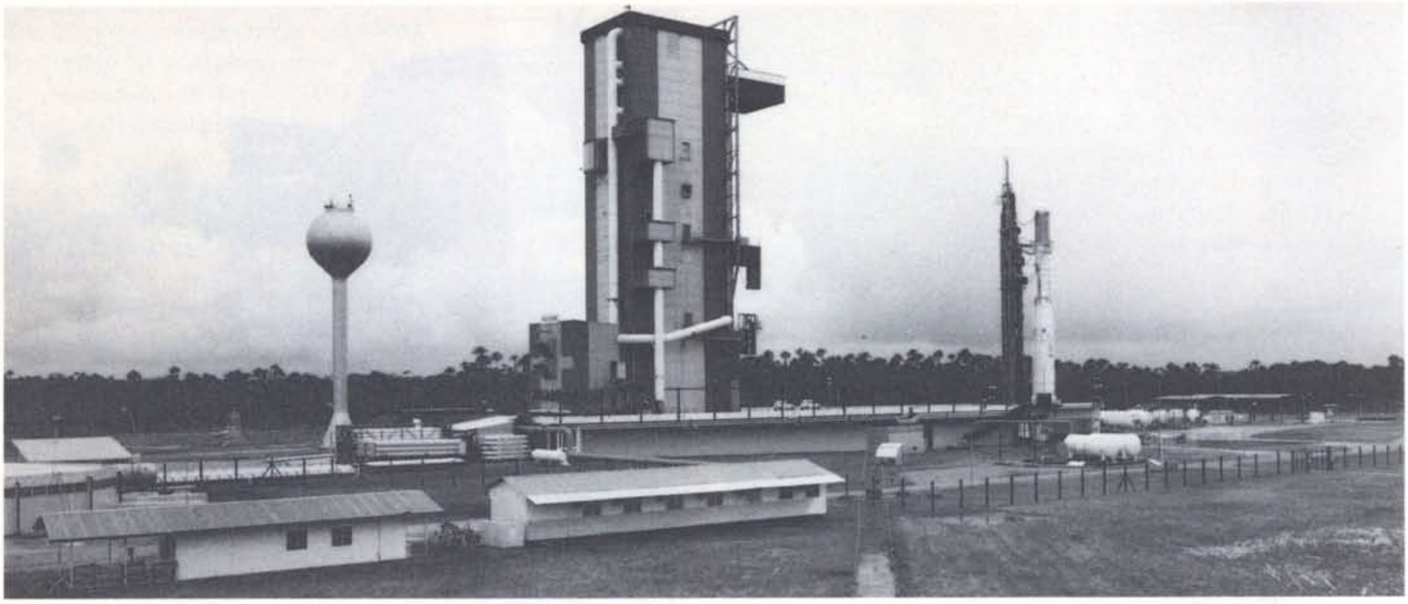


*Ariane Passenger Payload Experiment

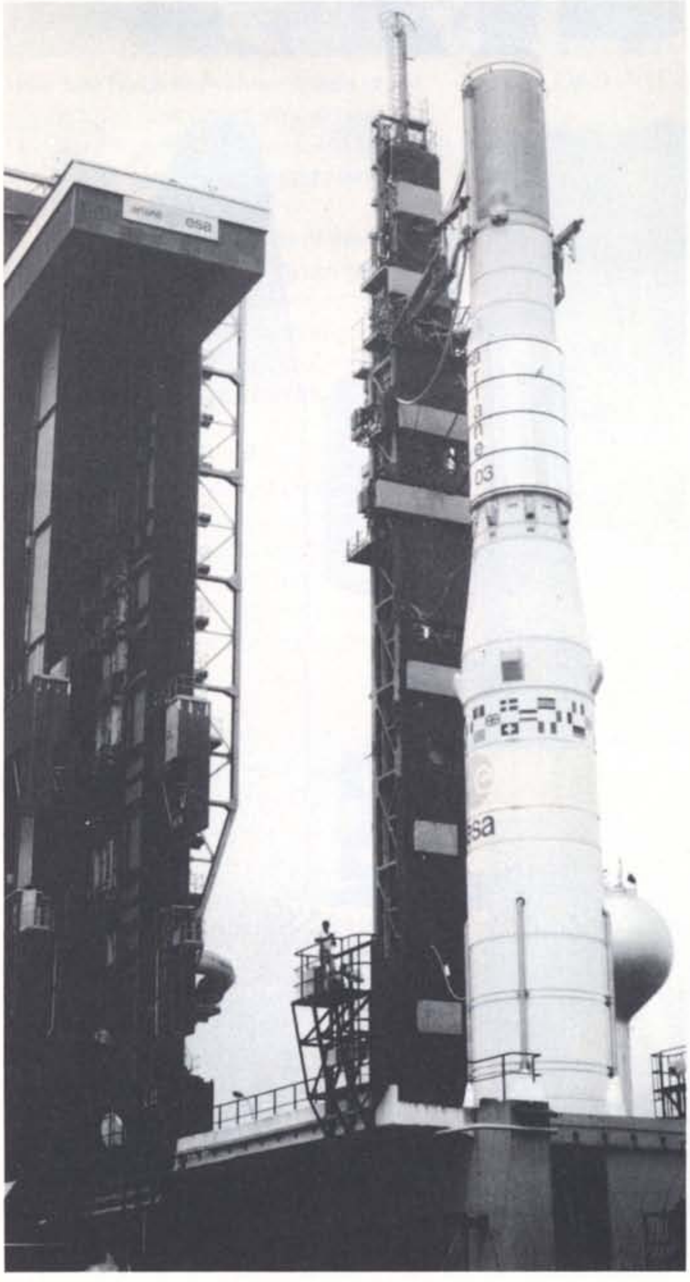


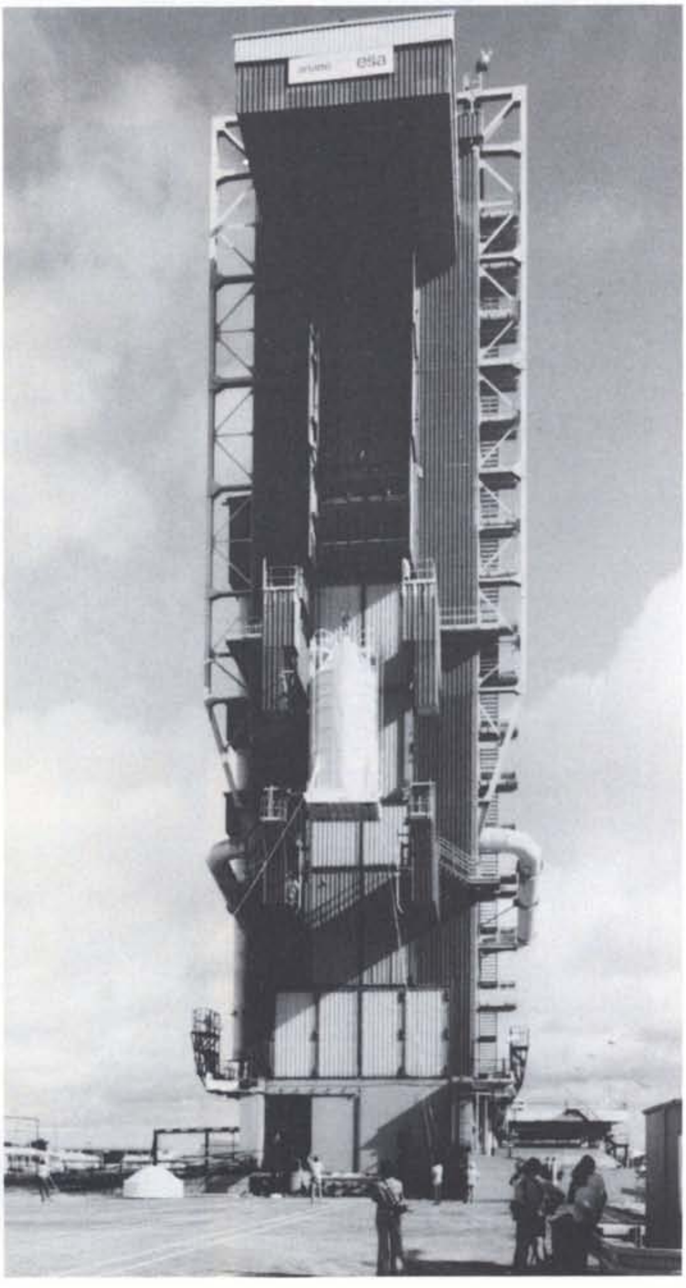




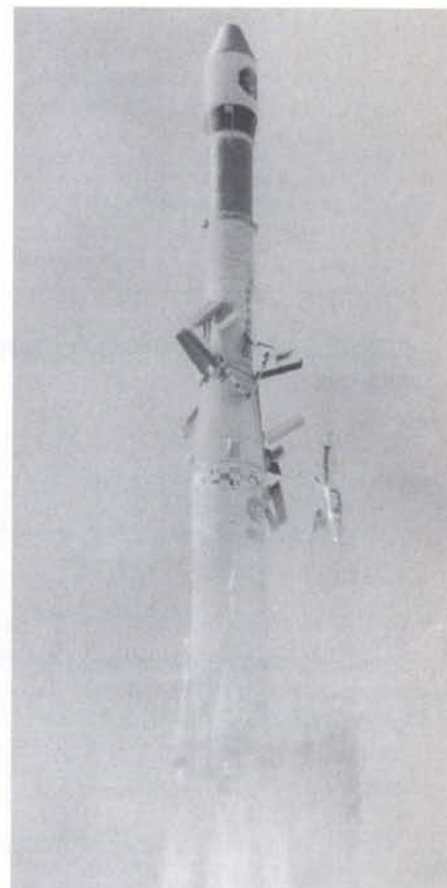


LAUNCHER PREPARATION





LIFT-OFF



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 on page 86 and using the Order Form on page 87

ESA Journal

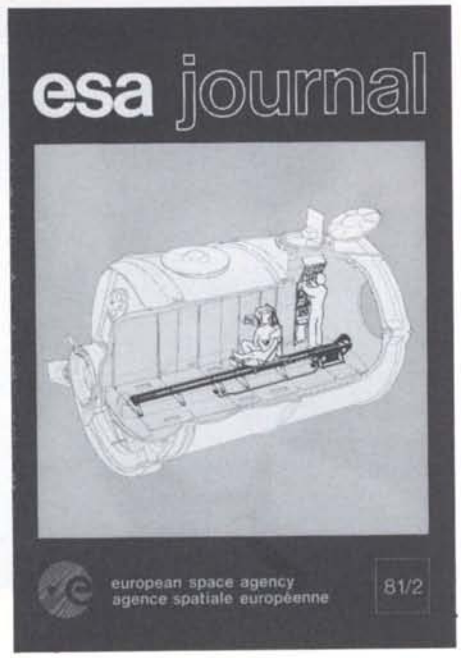
The following papers were published in ESA Journal Vol 5 No 2:

CO_2 LASER COMMUNICATION TECHNOLOGY FOR INTERSATELLITE DATA LINKS
BONEK E & LUTZ H

THE SPACE SLED – A EUROPEAN FACILITY FOR LIFE-SCIENCE EXPERIMENTS ON SPACELAB
SOONS A F L, BURDEN D F, GARVIN M J & WYN-ROBERTS D

THE ATLAS PROGRAMME
KONECNY G, MISKI T, REYNOLDS M & SCHROEDER M

INVESTIGATION OF MICRO-PACKAGING TECHNIQUES FOR HI-REL ACTIVE CHIPS
BOETTI A, LYNCH J T, McCARTHY J P & HEPHER M R



MATERIAL AND CIRCUIT EVALUATION FOR MILLIMETRE-WAVE APPLICATIONS: A MICROSTRIP 3 DB HYBRID COUPLER WITH LOW-DIELECTRIC SUBSTRATE FOR MILLIMETRE WAVES
ARNDT F, BORNEMANN J, GRAUERHOLZ D & VAHLDIECK R

MATERIAL AND CIRCUIT EVALUATION FOR MILLIMETRE-WAVE APPLICATIONS: A BROADBAND FIN-LINE MIXER FOR MILLIMETRE WAVES
ARNDT F, BORNEMANN J, GRAUERHOLZ D & VAHLDIECK R

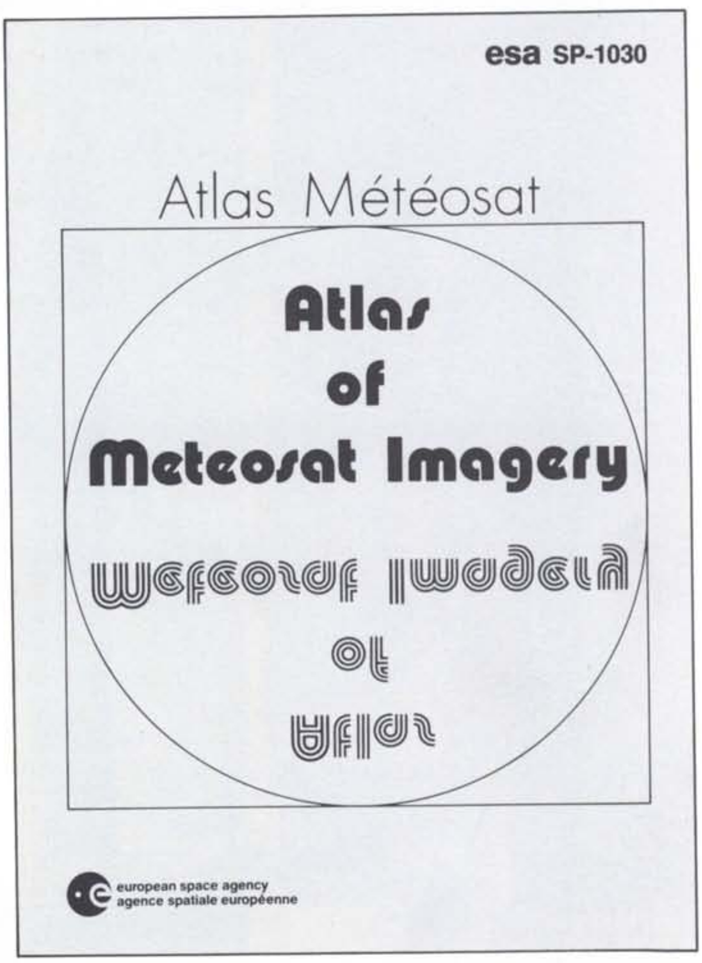
ESA SP-1030 Atlas of Meteosat Imagery – Atlas Météosat

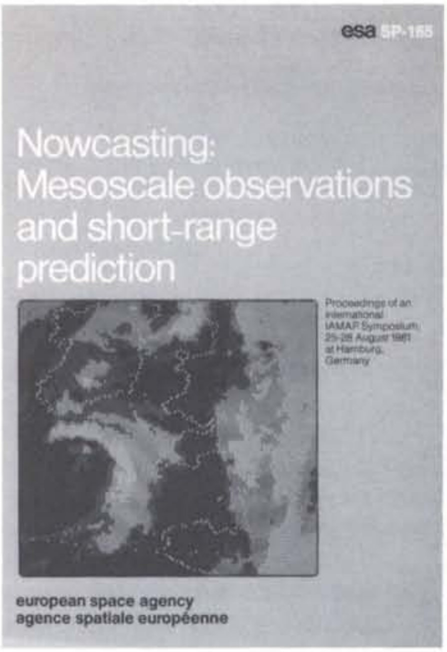
Compiled by C A Brimacombe, Meteosat Data Management Department, European Space Operations Centre (ESOC), Darmstadt, Germany. Edited and published by ESA's Scientific and Technical Publications Branch.

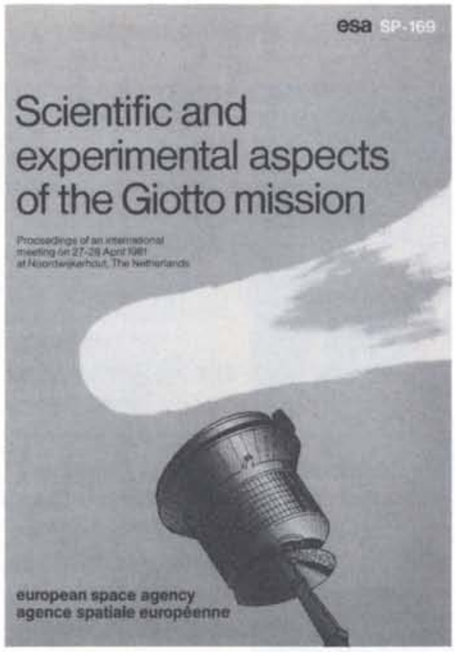
One of the Meteosat system's main functions is to provide images showing cloud, temperature and water-vapour distributions over about one-third of the globe. This Atlas presents a selection of the images received from Meteosat-1 during its first two years of operation. It explains and illustrates:

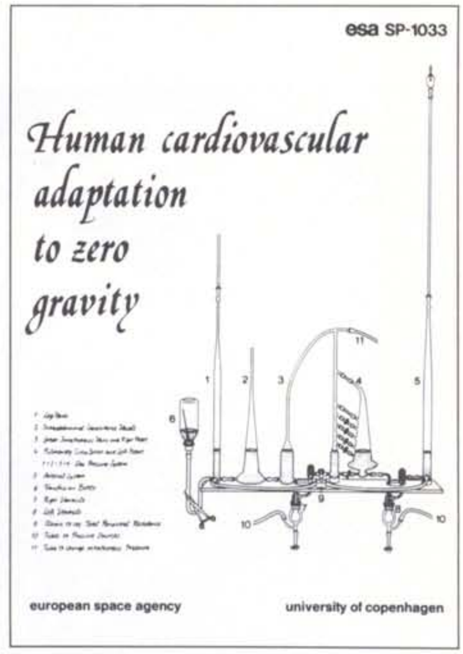
- the Meteosat system
- characteristics of Meteosat images
- cloud classification
- surface features
- mesoscale cloud formations
- synoptic scale cloud patterns
- planetary scale cloud systems
- some aspects of tropical cloud systems
- miscellaneous aspects of satellite meteorology.

A bilingual text (English and French) in one volume, format 21 cm × 29 cm, 494 pages including nine full-colour pictures and 560 black and white photographs. Price 200 FF (postage included).









Special Publications

ESA SP-165 NOWCASTING: MESOSCALE OBSERVATIONS AND SHORT-RANGE PREDICTION. PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM, 25-28 AUGUST 1981, GERMANY (PART OF THE IAMAP THIRD SCIENTIFIC ASSEMBLY), SPONSORED BY THE INTERNATIONAL COMMISSION ON CLOUD PHYSICS, CO-SPONSORED BY INTERNATIONAL COMMISSION ON DYNAMIC METEOROLOGY, INTERNATIONAL RADIATION COMMISSION, WMO, ESA AND COSPAR (JUNE 1981)
BATTRICK B/MORT J (EDS)
ESA PRICE CODE C4

ESA SP-169 SCIENTIFIC AND EXPERIMENTAL ASPECTS OF THE GIOTTO MISSION. PROCEEDINGS OF AN INTERNATIONAL MEETING, 27–28 APRIL 1981, NOORDWIJKERHOUT, NETHERLANDS (JUNE 1981)
BATTRICK B/MORT J (EDS)
ESA PRICE CODE C2

ESA SP-1030 ATLAS OF METEOSAT IMAGERY/ATLAS METEOSAT (BILINGUAL) (MAY 1981)
BRIMACOMBE CA
PRICE: 200 FF

ESA SP-1033 HUMAN CARDIOVASCULAR ADAPTATION TO ZERO GRAVITY (JANUARY 1981)
BONDE-PETERSEN F (ED)
ESA PRICE CODE C1

Scientific and Technical Memoranda

ESA STM-217 FUTURE SPACE SEGMENT CONCEPTS FOR LOWER COST COMMUNICATION SATELLITE SYSTEMS. (JAN 1981)
PREUKSCHAT, A.W.
ESA PRICE CODE E1

Scientific and Technical Reports

ESA STR-207 REFLECTIONS ON THE ECONOMICS OF THE EUROPEAN SPACE PROGRAMME. (JAN 1981)
VANDENKERCKHOVE, J.A.
ESA PRICE CODE C1

Procedures, Standards and Specifications

ESA PSS-55 (QRM-28P) ISSUE 1, REQUIREMENTS FOR REPAIR AND MODIFICATION OF SPACE-STANDARD PRINTED-CIRCUIT BOARDS AND SOLDER JOINTS. (OCT 1980)
PRODUCT ASSURANCE DIVISION, ESTEC
ESA PRICE CODE E1

Contractor Reports

ESA CR(P)-1374 CODIFICATION OF THE HIGH-TEMPERATURE PROPELLANT TRHA – FINAL REPORT. (JUL 1980)
NOBEL EXPLOSIVES CO. LTD., UK
ESA PRICE CODE C1

ESA CR(P)-1375 PHASE A STUDY OF SAR FOR THE EUROPEAN REMOTE SENSING PROGRAMME – ADDITIONAL STUDIES – FINAL REPORT – EXECUTIVE SUMMARY. (JUNE 1980)
THOMSON-CSF, FRANCE
ESA PRICE CODE C1

ESA CR(P)-1376 FIELD EMISSION ELECTRIC PROPULSION ION OPTICS OF SLIT EMITTERS AND BEAM FOCUSSING – FINAL REPORT. (JUN 1980)
CULHAM LABORATORY, UK
MICROFICHE ONLY

ESA CR(P)-1377 EVALUATION AND ASSESSMENT OF LOW-NOISE PRE-AMPLIFIERS FOR INFRA-RED DETECTORS – FINAL REPORT. (AUG 1980)
PLESSEY RESEARCH (CASWELL) LTD., UK
ESA PRICE CODE C3

ESA CR(P)-1378 FEASIBILITY ASSESSMENT OF A MAGNETICALLY SUSPENDED REACTION/MOMENTUM WHEEL. (JAN 1980)
TECHNISCHE UNIVERSITAET BRAUNSCHWEIG, FRG
MICROFICHE ONLY

ESA CR(P)-1379 STUDY ON THE COMPATIBILITY OF SURSAT AND LASS/COMSS TECHNICAL MISSION REQUIREMENTS – FINAL REPORT. (OCT 1979)
CANADIAN ASTRONAUTICS LTD., CANADA
MICROFICHE ONLY

ESA CR(P)-1380 STUDY OF HEAT REJECTION SYSTEMS. (JUL 1980)
AERITALIA, ITALY
ESA PRICE CODE C1

ESA CR(P)-1381 (VOLS 1 & 2) THE DESIGN STUDY OF A FAR INFRARED HETERODYNE SPECTROMETER ASSEMBLY – FINAL REPORT. (APR 1980)
BADG, UK
MICROFICHE ONLY

ESA CR(P)-1382 STUDY OF INTERACTION BETWEEN SOLAR ARRAYS AND ATTITUDE AND ORBIT CONTROL – FINAL REPORT. (APR 1980)
BADG, UK
MICROFICHE ONLY

ESA CR(P)-1384 (VOL 1) FINAL REPORT ON THE SAR PROCESSOR DEFINITION STUDY EXTENSION – VOLUME 1: TECHNICAL DESCRIPTION OF HARDWARE. (MAY 1978)
MARCONI, UK
MICROFICHE ONLY

ESA CR(P)-1384 (VOL 2) FINAL REPORT ON THE SAR PROCESSOR DEFINITION STUDY EXTENSION – VOLUME 2: THEORETICAL DESCRIPTION OF PROCESSING. (MAY 1978)
MARCONI, UK
MICROFICHE ONLY

ESA CR(P)-1384 (VOL 3) FINAL REPORT OF THE SAR PROCESSOR DEFINITION STUDY EXTENSION – VOLUME 3: SPECIFICATION. (MAY 1978)
MARCONI, UK
MICROFICHE ONLY

ESA CR(P)-1385 (VOL 1) STUDY ON SYNTHESIS AND CHARACTERISATION OF LARGE SPACE SYSTEMS – FINAL REPORT PHASE I: PART 1 – MISSION SURVEY. (APR 1980)
CONSULENZE GENERALE, ROMA, ITALY
MICROFICHE ONLY

ESA CR(P)-1385 (VOL 2) STUDY ON SYNTHESIS AND CHARACTERISATION OF LARGE SPACE SYSTEMS – FINAL REPORT PHASE I: PART II – PROBLEM SURVEY. (APR 1980)
CONSULENZE GENERALE, ROMA, ITALY
MICROFICHE ONLY

ESA CR(P)-1385 (VOL 3) STUDY ON SYNTHESIS AND CHARACTERISATION OF LARGE SPACE SYSTEMS – FINAL REPORT PHASE I: PART III – CHARACTERISATION AND SYNTHESIS. (APR 1980)
CONSULENZE GENERALE, ROMA, ITALY
MICROFICHE ONLY

ESA CR(P)-1386 (VOL 1): STUDY ON FLUID PHENOMENA INFLUENCING THE DESIGN OF ZERO-G EXPERIMENTS – FINAL REPORT. (JAN 1980)
TECHNO SYSTEM DEVELOPMENTS, ITALY
MICROFICHE ONLY

ESA CR(P)-1386 (VOL 2): STUDY ON FLUID PHENOMENA INFLUENCING THE DESIGN OF ZERO-G EXPERIMENTS – USER'S GUIDE.(DEC 1979)
TECHNO SYSTEM DEVELOPMENTS, ITALY
MICROFICHE ONLY

ESA CR(P)-1387 (VOL 1): DATA RATE REDUCTION – CLASSIFICATION OF RAW AND COMPRESSED MULTISPECTRAL DATA. (JUL 1980)
MATRA, FRANCE
MICROFICHE ONLY

ESA CR(P)-1387 (VOL 2): DATA RATE REDUCTION – APPLICATION OF A TEXTURE ANALYSIS ALGORITHM ON A RAW AND A COMPRESSED LANDSAT SCENE; BIOMASS ESTIMATION ON COMPRESSED SATELLITE MULTISPECTRAL DATA. (JUL 1980)
MATRA, FRANCE
MICROFICHE ONLY

ESA CR(P)-1387 (VOL 3): DATA RATE REDUCTION – CASCADED CLUSTERING OF COMPRESSED MULTISPECTRAL IMAGE DATA; CLASSIFICATION OF CASCADED CLUSTERED DATA. (JUL 1980)
MATRA, FRANCE
MICROFICHE ONLY

ESA CR(P)-1387 (VOL 4): THE EFFECT OF IMAGE COMPRESSION ON A PARALLELEPIPED CLASSIFIER. (AUG 1980)
LOGICA LTD., UK
MICROFICHE ONLY

ESA CR(P)-1388 DATA RATE REDUCTION – RANKING VARIOUS CLASSIFICATIONS OF THE SAME MULTISPECTRAL DATA FROM GROUND TRUTHS AND CONTINGENCY TABLES. (JUL 1980)
MATRA, FRANCE
MICROFICHE ONLY

ESA CR(P)-1389 ADDITIONAL STUDIES OF EARTH RESOURCES SYNTHETIC APERTURE RADAR PAYLOAD – FINAL REPORT VOLUME 1. (JUN 1980)
MARCONI, UK
ESA PRICE CODE C1

ESA CR(P)-1390 EVALUATION CRITIQUE DES EXIGENCES RADIOMETRIQUES POUR UN EQUIPEMENT MESURANT A BORD D'UN SATELLITE LA COULEUR DES OCEANS. (JUL 1980)
UNIVERSITE DE LILLE, FRANCE
MICROFICHE ONLY

ESA CR(P)-1391 STRAPDOWN INERTIAL OPTICAL SYSTEM – FINAL REPORT. (UNDATED)
MATRA, FRANCE
MICROFICHE ONLY

ESA CR(P)-1392 AN APPRAISAL OF LINEAR ANALYTIC SYSTEMS THEORY WITH APPLICATIONS TO ATTITUDE CONTROL. (MAY 1980)
APPLIED SYSTEMS STUDIES, UK
MICROFICHE ONLY

ESA CR(P)-1395 STUDY ON ADDITIONAL PROPELLANTS FOR FIELD EMISSION THRUSTERS – FINAL REPORT. (JUN 1980)
FULMER RESEARCH INSTITUTE, UK
MICROFICHE ONLY

ESA CR(P)-1396 YAW SUN SENSOR STUDY – FINAL REPORT. (FEB 1980)
OFFICINE GALILEO, ITALY
MICROFICHE ONLY

ESA CR(P)-1397 STUDY OF A REAL-TIME X-Y ADDRESSABLE SPATIAL FILTER – FINAL REPORT. (JUN 1980)
PLESSEY, UK
MICROFICHE ONLY

ESA CR(X)-1383 DEVELOPMENT FOR A LOW GAIN C BAND TT & C ANTENNA – FINAL REPORT ON PHASE I. (JAN 1980)
INTA, SPAIN

ESA CR(X)-1393 STUDY OF MAGNETIC ATTITUDE-CONTROL SYSTEMS FOR FUTURE GEOSYNCHRONOUS COMMUNICATION SATELLITES – FINAL REPORT. (AUG 1980)
FOKKER, NETH.

ESA CR(X)-1394 (VOLS 1 & 2) STUDY OF APPLICATION OF 'ON-OFF' SHUTTER FOR THERMAL CONTROL OF TELECOMMUNICATION SPACECRAFT – FINAL REPORT. (JUL 1980)
CONSTRUCCIONES AERONAUTICAS S.A., SPAIN

Technical Translations

ESA TT-532 CONTRIBUTIONS TO THE NINTH SYMPOSIUM OF AIRCRAFT INTEGRATED DATA SYSTEMS, 26-27 SEPTEMBER 1978, FRIEDRICHSHAFEN (FEB 1981)
HARDEGEN H (SCIENTIFIC COORDINATOR), DFVLR, GERMANY

ESA TT-541 DEVELOPMENT, MANUFACTURE AND TESTING OF A PLANAR-ARRAY L-BAND ANTENNA (FEB 1981)
FRISCH, E, SIEGLING, H-F & FASOLD, D, BUNDESMIN. FUER FORSCH. U. TECHNOL., GERMANY

ESA TT-616 DETERMINATION OF THE FAR-FIELD FROM MEASURED NEAR-FIELD DATA. THEORY AND MEASURING TECHNIQUE OF THE NEAR-FIELD FAR-FIELD TRANSFORMATION (DEC 1980)
SCHROTT, A & STEIN, V, DFVLR, GERMANY

ESA TT-622 INVESTIGATION OF THREE-DIMENSIONAL SUBSONIC FLOW IN STRAIGHT CASCADES BY MEANS OF POTENTIAL FLOW CALCULATIONS AND EXPERIMENTS (JAN 1981)
RENKEN, J, DFVLR, GERMANY

ESA TT-634 FLIGHT SAFETY OF ROGALLO HANG-GLIDERS. THEORETICAL AND EXPERIMENTAL STUDY OF THE FLIGHT ENVELOPE (FEB 1981)
LA BURTHE, C & WALDEN, S, ONERA, FRANCE

ESA TT-640 COLORED MEASUREMENT NOISE DIGITAL PREFILTERING BY AVERAGING (DEC 1980)
FRORIEP, R, DFVLR, GERMANY

ESA TT-641 UNSTEADY PRESSURE MEASUREMENTS DURING STALL AND BUFFETING (JAN 1981)
BUBLITZ, P, DFVLR, GERMANY

ESA TT-642 THE PRECIPITATION ENHANCEMENT PROJECT – PEP (JAN 1981)
PAFFRATH, D, DFVLR, GERMANY

ESA TT-643 A METHOD OF PRODUCING ANALYTICAL ORBIT MODELS FOR GEOSTATIONARY SATELLITES (DEC 1980)
ECKSTEIN, M, DFVLR, GERMANY

ESA TT-647 EXPERIMENTAL INVESTIGATION OF THE PARTICLE-NUMBER CONCENTRATION IN A WIND TUNNEL FOR USE IN LASER ANEMOMETRY (JAN 1981)
BESSLING, H, KIOCK, R, HELSPER, C & FISSAN, H, DFVLR, GERMANY

ESA TT-649 LINEAR-ELASTIC AND PLASTIC FRACTURE MECHANICS OF STRUCTURAL MATERIALS (DEC 1980)
MUNZ, D, DFVLR, GERMANY

ESA TT-650 INFLUENCE OF PROCESSING CONDITIONS ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF REACTION SINTERED SILICON NITRIDE (DEC 1980)
HEINRICH, J, DFLVR, GERMANY

ESA TT-655 FUNCTIONAL ANALYSIS AND OPERATIONAL ASSESSMENT OF AN ONBOARD GLIDE PATH GUIDANCE SYSTEM FOR VISUAL APPROACHES (VISUAL APPROACH MONITOR VAM) (DEC 1980)
THOMAS, J & STEIN, H, DFVLR, GERMANY

ESA TT-662 CONTRIBUTION TO THE STUDY OF SUPERSONIC LAMINAR SEPARATION: UTILIZATION AND IMPROVEMENTS IN INTEGRAL METHODS OF CALCULATION (DEC 1980)
ABOUT, G, ONERA, FRANCE

ESA TT-663 THEORY AND CALCULATION METHODS OF VIBRATING STRUCTURES (DEC 1980)
VALID, R, ONERA, FRANCE

ESA TT-664 MIXED VARIATIONAL PRINCIPLES FOR STATIC PROBLEMS: COUPLING (OF THESE PRINCIPLES) WITH THE DISPLACEMENT PRINCIPLE (FEB 1981)
CHRYSSAFI, S, ONERA, FRANCE

ESA TT-668 APPLIED TECHNIQUES FOR THE CONTROL OF APPROACH TRAFFIC (JAN 1981)
SEYFRIED, A, SCHUBERT, M & VOELCKERS, U, DFVLR, GERMANY

Advertise in ESA Bulletin

The Readership

Through the nature of its content and the role that the Agency plays in shaping Europe's space research and development activities, the Bulletin has come to have a fast-growing (currently 7500 copies per issue compared with 6000 just a year ago) but *select* distribution among "decision makers" in space matters not only in Europe but around the world. The Bulletin is distributed in about 80 countries. It is read by managers and senior staff in space-oriented organisations—both national and international—in ministries, in industry, and in research institutes. It forms a fundamental part of the continual dialogue between ESA and its national counterparts and between ESA and the industrial firms to whom the contracts and subcontracts are awarded that account for the major part of the Agency's $ 550 million per year budget (contract awards on a geographical-return basis linked directly to the financial contributions of the individual ESA Member States).

The Bulletin therefore offers the commercial company—large or small—which already provides space-related products and/or services or which wishes to develop its markets in that direction, a direct entree to a very special readership with a much *higher than average* rating as far as *market potential* is concerned. This commercial market potential is growing steadily each year with a constantly increasing percentage of readers being faced with a need to apply in their own environments the technologies that ESA, the national agencies, and industry have been developing to meet European needs.

CIRCULATION

Algeria
Andorra
Argentina
Australia
Austria
Belgium
Brazil
Burma
Canada
Chile
China
Colombia
Czechoslovakia
Denmark
Ecuador
Egypt
Falkland Islands
Finland
France
French Guiana
German Democratic Republic
Germany
Greece
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Ivory Coast
Jamaica
Japan
Jordan
Korea
Kuwait
Lagos
Libya
Luxembourg
Madagascar
Malaysia
Mexico
Morocco
Mozambique
Netherlands
New Guinea
New Zealand
Niger
Norway
Pakistan
Peru
Philippines
Poland
Portugal
Qatar
Romania
Saudi Arabia
Senegal
Singapore
South Africa
Soviet Union
Spain
Srilanka
Sudan
Sweden
Switzerland
Thailand
Trinidad
Turkey
United Kingdom
Upper Volta
U.S.A.
Venezuela
Yugoslavia
Zaire
Taiwan

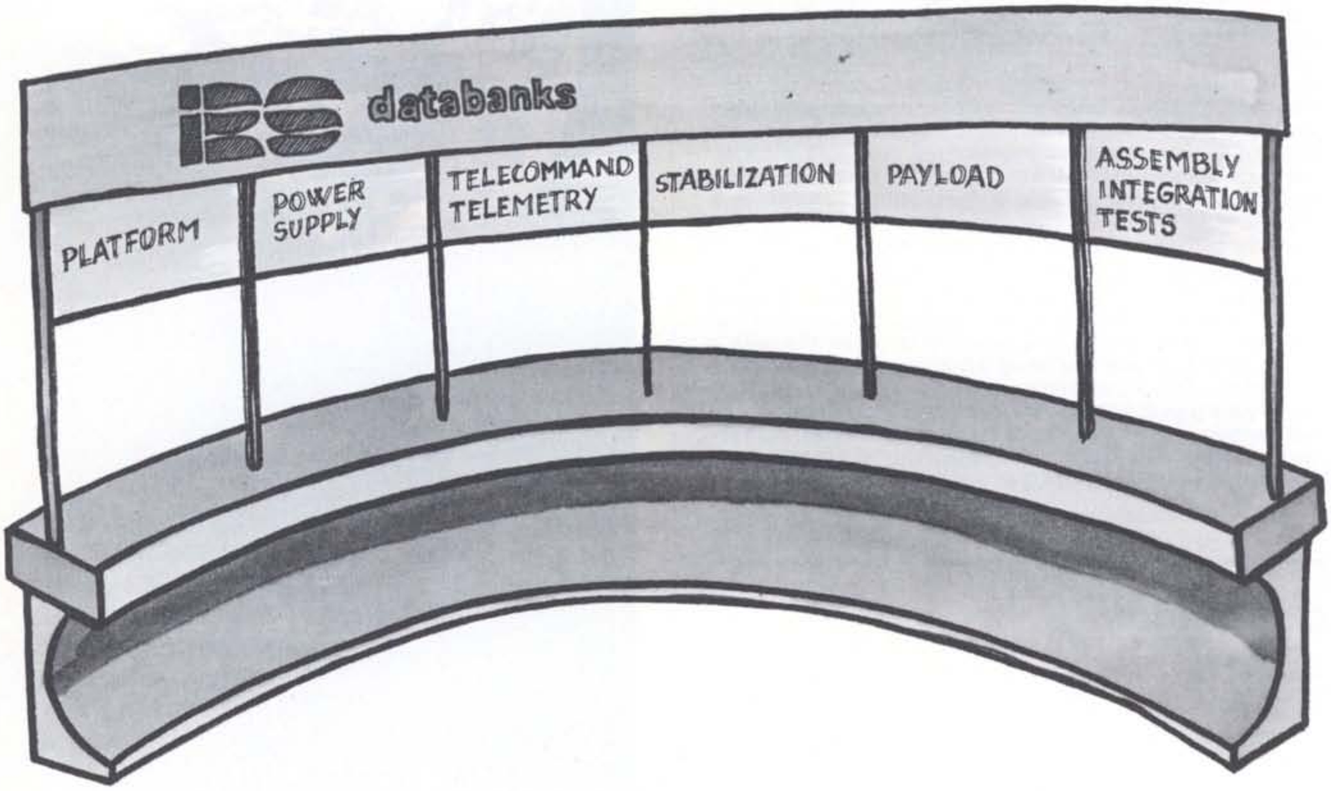
Advertising representative

LA PRESSE TECHNIQUE S.A.

3a, rue du Vieux-Billard – P.O. Box 108
CH-1211 Genève 4 (Switzerland)
Tél. 21 92 26 – Télex: 28 456 ptsa ch

SAVE TIME AND MONEY WITH ESA-IRS.

STRIKE pubblicità - roma



One of the best investments you could make at present is to buy «online information». Do not waste time looking for something that others have already discovered. Do not repeat previous unsuccessful experiences. Your investment: the price of a good meal! Your benefit: locating literature from around the world on your specific scientific or technical subject in less than 15 minutes! We are the Number One bank in Europe — Our capital is information. Why not start investing today?

coverage:
aeronautics, space, astronomy, astrophysics, pollution and environment, earth and ocean sciences, energy and combustibles, metallurgy and material sciences, physics, electronics, data processing, agriculture, water management; electrical, electronic, chemical and mechanical engineering; nuclear sciences and applications; news; organic and macromolecular chemistry; biochemistry, medicine, food sciences, management, translations of reports of all kinds.

the European approach to online information

ESA - Information Retrieval Service
Esrin, Via Galileo Galilei, - I 00044 Frascati (Italy) tel: (39/6) 94011 - twx: 610637


ariane
and
aerospatiale
we put all the
pieces together
ARIANE is built in Europe by some fifty firms in 10 countries*. One industrial company puts it all together. One firm checks out all the interfaces between the numerous subsystems and components.
It's AEROSPATIALE, France.
Studies, Technical management, Production, Integration, Testing.
* ESA sponsored program, Prime contractor, CNES.
Société Nationale Industrielle
aerospatiale
DIVISION SYSTEMES BALISTIQUES ET SPATIAUX
B.P. 96 - 78130 Les Mureaux - France

Availability of ESA and NASA Publications

Publications	Series	Available as	From
Special Publications	SP	Hard (printed) copy as long as stocks last; thereafter in microfiche or photocopy	ESA Scientific and Technical Publications Branch, ESTEC, 2200 AG Noordwijk, Netherlands
Brochures	BR		
Tribology series	TRIB		
Scientific Reports, Notes and Memoranda	SR, SN, SM		
Technical Reports, Notes and Memoranda	TR, TN, TM		
Scientific and Technical Reports	STR		
Scientific and Technical Memoranda	STM		
Procedures, Standards and Specifications	PSS		
Contractor Reports	CR		
	CR(P)	Microfiche or photocopy only	
	CR(X)	Restricted distribution; not for sale	
Electronics Component Databank Catalogue	ECDB	Hard (printed) copy as long as stocks last	
Technical Translations	TT	Microfiche or photocopy only	
Periodicals			
ESA Bulletin		Available without charge as a regular issue or back numbers (as long as stocks last)	
ESA Journal			
Public relations material		General literature, posters, photographs, films, etc.	ESA Public Relations Service 8-10 rue Mario-Nikis, 75738 Paris 15, France

Printed documents Number of pages	Code	Price
001—100	E1	FF 55
101—200	E2	FF 80
201—350	E3	FF 125
over 350	E4	FF 160
001—100	C1	FF 55
101—200	C2	FF 80
201—350	C3	FF 125
over 350	C4	FF 160

Photocopy and Microfiche

Photocopy	FF 110 per title plus FF 25 per 25 pages
Microfiche	FF 115 per title

All prices exclude postage and value-added tax

1 Photocopies will be supplied if the orginal document is out of print, unless microfiche is specified.
2 These charges apply to Member States, Austria, Canada and Norway. A 20 per cent surcharge will be levied on orders from 'other states'.
3 These prices are subject to change without prior notice.

N.B. FOR HARD-COPY CHARGES, SEE FACING PAGE

ESA and NASA Scientific/Technical Publications ORDER FORM Before using this Order Form read the important information on the reverse.	To: DISTRIBUTION OFFICE ESA SCIENTIFIC & TECHNICAL PUBLICATIONS BRANCH ESTEC, POSTBUS 299, 2200 AG NOORDWIJK THE NETHERLANDS From: ______ ______ ______

PLEASE SUPPLY:

Customer's Ref ______

Date ______ Signature ______

No. of copies: Printed	Microfiche	Photocopy	ESA or NASA Reference	Title	For ESA use	

IF OUT OF PRINT SUPPLY / DO NOT SUPPLY IN MICROFICHE

MAILING LABEL (Print or type carefully)

ESA Order No.

Customer's Ref ______

To Name or Function ______

Organisation ______

Street Address ______

Town, Province, Postal Code ______

Country ______

INFORMATION

1. Use this form for your order.

2. (a) Except as mentioned below, publications are available in printed form (as long as stocks last), in microfiche and as photocopies.

   (b) If a publication ordered in printed form is out of print, a microfiche copy will be supplied (unless NOTE 1 on the form has been completed to indicate otherwise) and the Order Form will be amended accordingly.

   (c) Publications in the following series are not available in printed form:

   – the ESA CR(P) series;
   – the ESA TT series;
   – all NASA series.

   (d) Publications in the ESA CR(P)* and CR(X) series are not available from ESA. (They are given a very restricted distribution in printed form to the States participating in the relevant programme. The addressees in that distribution can be supplied on request).

EXECUTION OF ORDER

3. After the handling of your order has been completed, the form will be returned to you, marked with the following symbols:–

   A circle – the items encircled have been despatched
   X – out of print or unavailable in printed form
   Z – not available from ESA in any form
   R – publication is restricted and cannot be supplied on this order
   N – publication is in hand, stock not yet received.
   C – unable to identify the publication from the information provided.
   Y – publication requested from NASA, delay of at least 2 months expected.

4. In any subsequent correspondence, please QUOTE THE ESA ORDER NUMBER.

5. Printed copies are despatched from ESTEC, and microfiche and photocopies from ESA Head Office. They will arrive in different packages at different times.

european space agency
agence spatiale européenne

member states	**etats membres**
belgium	allemagne
denmark	belgique
france	danemark
germany	espagne
ireland	france
italy	irlande
netherlands	italie
spain	pays bas
sweden	royaume-uni
switzerland	suède
united kingdom	suisse