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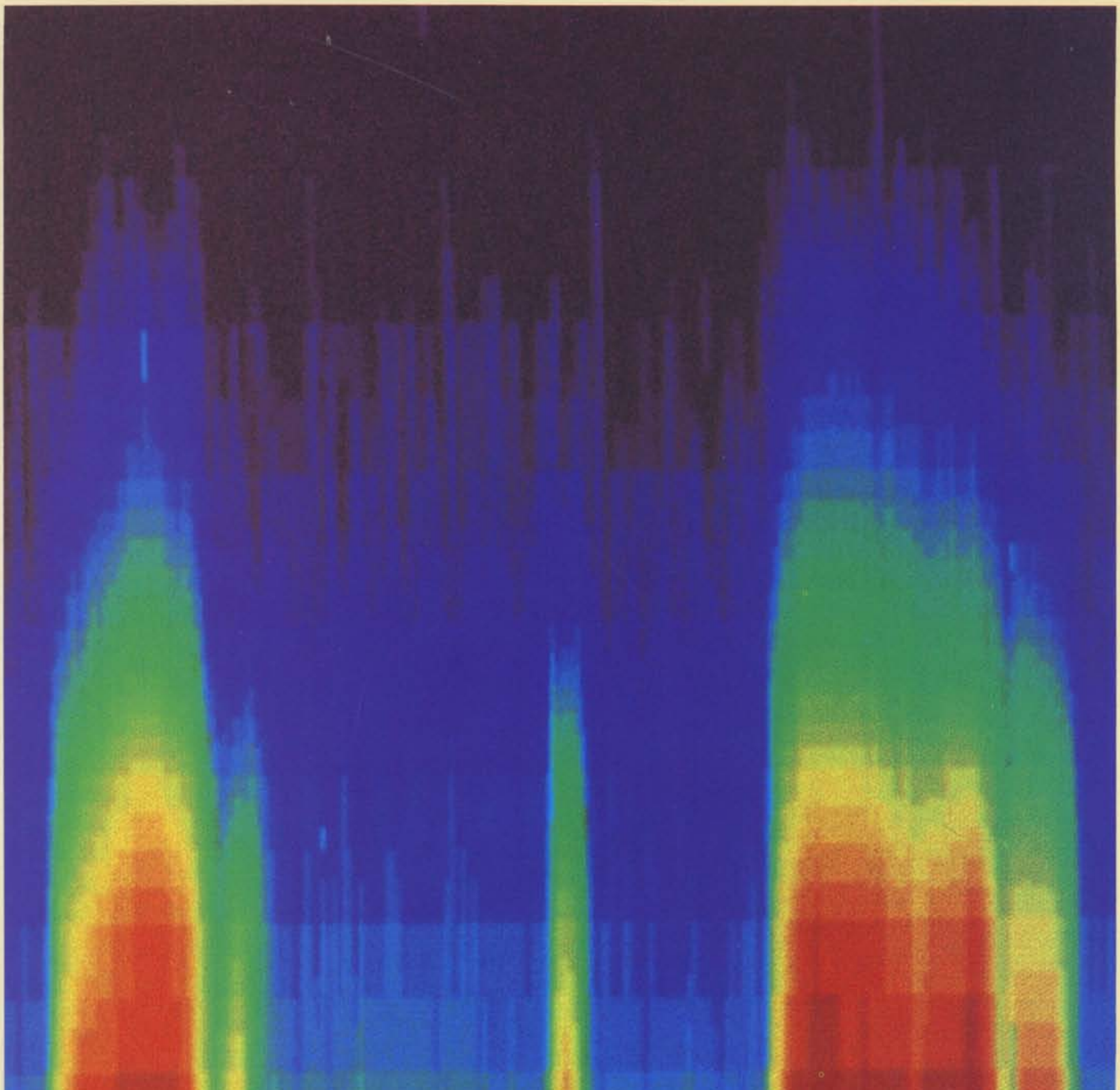

european space agency

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, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Ireland has signed the ESA Convention and will become a Member State upon its ratification. Austria, Canada and Norway have been granted 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 Planning and Future Programmes; the Director of Administration; the Director of Scientific Programmes; the Director of Applications Programmes; the Director of the Spacelab Programme; the Technical Director and the Director of ESOC.

The ESA HEADQUARTERS are in Paris.

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr. J. Stiernstedt (Sweden).

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'Italie, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse. L'Irlande a signé la Convention de l'ESA et deviendra Etat membre de l'Agence lorsque la Convention aura été ratifiée. L'Autriche, 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;

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(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

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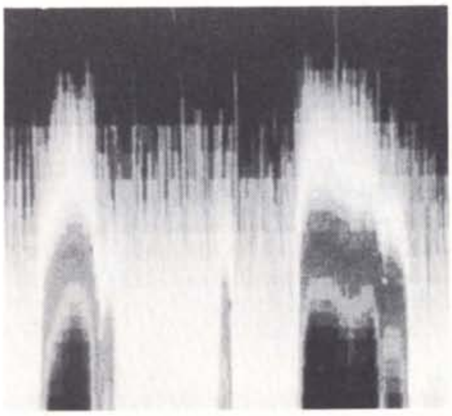

Front cover: Spectrogram of 35–1600 keV protons measured by the joint ESA Space Science Dept./Space Research Laboratory, Utrecht/Imperial College London experiment on the ISEE-3 spacecraft (in an orbit around the sunward libration point, 1.5 million kilometres from earth).

Back cover: Space Sled protoflight model on the test floor at ESTEC.

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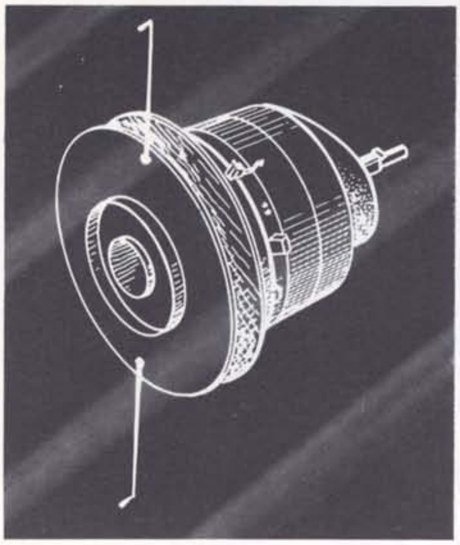


Giotto – A Mission to Halley's Comet

R. Reinhard, Giotto Project Scientist & D. Dale, Giotto Project Manager, ESTEC, Noordwijk, Netherlands

Comet Halley is predicted to reappear in early 1986. Since this comet appears only every 76 years and since it is the most outstanding target for a cometary mission because of its size and activity, Halley's next apparition is an opportunity for scientific study not to be missed. At its meeting on 8/9 July 1980 ESA's Science Programme Committee decided to approve a mission to Halley. The spacecraft, which is of a Geos-based design, will be launched in July 1985 and will fly by the comet in March 1986. The principal goals for the spacecraft's scientific payload include imaging of the comet's nucleus, and measurements of the elemental and isotopic composition of the cometary gases and dust.

The recently approved European space mission to Comet Halley is named Giotto after the Italian painter Giotto di Bondone who observed Comet Halley in 1301 and depicted it with great accuracy in one of his frescoes in the Arena chapel in Padua. The first recorded sightings of Comet Halley date back to 239 BC and possibly even to 1057 BC (deduced from old Chinese records). It was Edmond Halley who found that the comets of 1531, 1607 and 1682 were one and the same comet, and he predicted early in the eighteenth century that it would reappear in 1758, which was indeed the case. The comet was subsequently named 'Halley' after the discoverer of its periodicity.

Comet Halley passed very close to the earth in 1910. Calculations of its orbit made it possible to predict that the earth would pass through the comet's tail and it was feared by many that this encounter would mark the 'end of the world'. Although the earth did indeed pass through Halley's tail, there were no adverse consequences.

During its next appearance Halley will not come closer to the earth than 60 million kilometres, on 11 April 1986. Two months earlier the comet will go through perihelion and will then be at its most active. Unfortunately, at that time Halley will be 230 million kilometres from earth and will not be a very spectacular object in the sky.

Giotto's encounter with Halley is scheduled for 13 March 1986. This is not simply a compromise between the two dates already mentioned, but rather dictated by the requirement of minimum launch energy, which allows encounters only in the ecliptic plane, to which Halley's orbit is inclined by 18°. The comet will cross the ecliptic twice, first on 9 November 1985 (possibility of pre-perihelion encounter, distance to the sun 1.8 AU), and again on 11 March 1986 (possibility of post-perihelion encounter, distance to the sun 0.85 AU). It turns out that the launch energy required for the post-perihelion encounter is considerably lower than for the pre-perihelion encounter. Also, the comet will be much more active during the post-perihelion period. It is for these two reasons that a post-perihelion encounter is preferred.

Although comets are the most active members of our solar system, very little is yet known about them. Near-earth observations (ground-based or from space) are limited in that they can only provide line-of-sight integrations. Only molecules with strong emission lines in suitable wavelength ranges can be observed by remote-sensing. Nevertheless, it is known now that what appears as the 'comet' is actually a very thin atmosphere consisting of neutral and ionised gas molecules and tiny dust particles that reflect sunlight. It is believed that at the centre of the cometary atmosphere there is a solid nucleus, perhaps a few kilometres in diameter and thought to consist of a mixture of snows and ices of condensed gases together with solid particles. This mixture is best described as a dirty snowball.

As the comet approaches the sun, the surface of the nucleus is heated up and

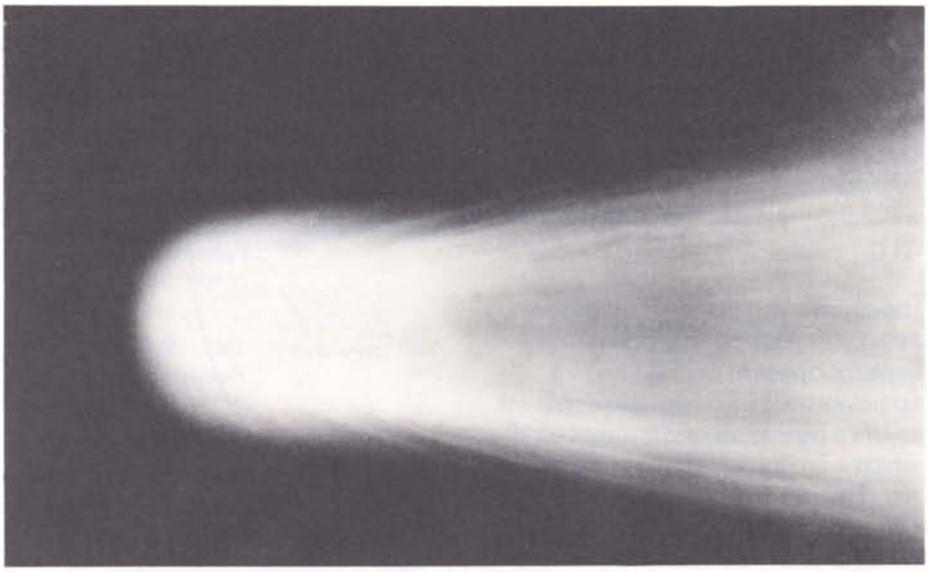


Figure 1 – Head of Comet Halley 1910 II on 8 May 1910 (Mt Wilson and Palomar Observatories)

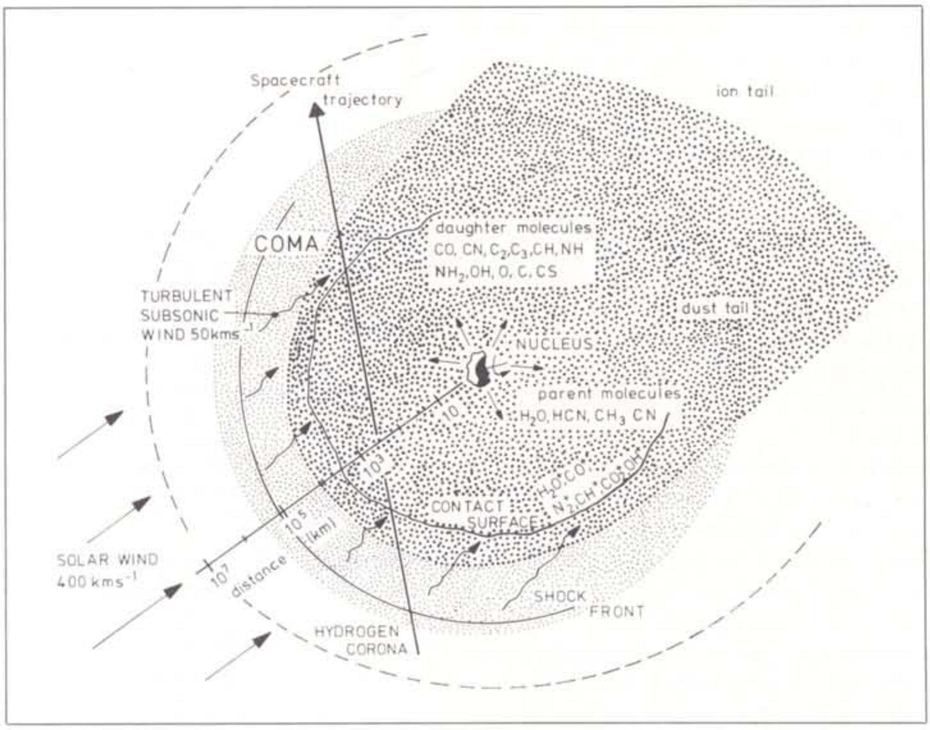


Figure 2 – Model of the cometary coma

the outer layers, perhaps to a depth of a few metres, are sublimated. The gas and dust expand to form the cometary coma visible from earth. The solar-wind plasma sweeps the cometary ions in the anti-solar direction, thus forming a narrow ion tail; the solar radiation pressure also forces the smaller dust particles in the anti-solar direction, forming a broader curved dust tail. The small cometary nucleus is able to produce a coma up to 4×10^5 km across, a hydrogen corona many times larger than the sun, and a tail up to 0.3 AU long.

Up to now, approximately 630 different comets have been recorded – so why, apart from its fame, has Halley been selected for this first cometary mission?

About 10^{11} comets (which together have about the mass of the earth) are believed to orbit the sun at a distance of 50 000 AU in the so-called Oort/Öpik cloud. Each year, some 100 comets are newly deflected into the jovian capture region (4–6 AU from the sun) as a result of chance gravitational perturbations occurring in the distant reaches of the solar system. Occasionally, the orbit of such a comet is perturbed into a short-periodic orbit by the gravitational field of one of the major planets.

Based on their orbital periods, comets can be categorised as short-periodic (with periods between 3 and 25 yr), intermediate-periodic (25–200 yr), long-periodic (200–10^6 yr), and 'new' comets. Halley, with its 76 yr period, is a member of the intermediate-periodic comets. The most active and therefore brightest comets are the new ones, comets that have never previously approached the sun. Ideally, then, one would like to rendezvous with a new comet, but this is presently impossible. Firstly, such a rendezvous calls for a continuous low-thrust propulsion system, e.g. solar electric propulsion, and no such system is currently under development. Secondly, to plan a mission to a comet, its orbit must be well known, which means that the comet must have returned at least a few times. This rules out new comets and leaves only the short-periodic and a few intermediate-periodic comets as candidates.

Comets that have returned to the inner solar system several times build up dust layers on their surface because the dust carried away by the gases is pushed back by solar-radiation pressure. This simplified mechanism could explain why comets decrease in brightness with each return. All short-periodic comets are considerably less bright than new comets, and they produce two orders of magnitude less gas and dust. There is only one comet among the 630 whose orbit is well known and which still has a gas and dust production rate comparable to that of new comets, and that is Halley. Moreover, the launch energy required to encounter Halley is one of the lowest for all cometary missions. Table 1 lists the observed characteristics of Comet Halley.

One disadvantage to the Comet Halley mission is that Halley's orbit is retrograde, which means that its direction is opposite to that of the earth. This has the consequence that the relative flyby velocity is very high (68 km/s). The spacecraft will traverse the whole coma, the extent of which is greater than the distance from the earth to the moon, in only about 1.5 h. In some respects, however, a fast flyby is not necessarily a disadvantage, since the number of events that will be registered by the experiments on-board the spacecraft will be the same, whether the flyby is fast or slow; these events will just occur faster and this can be compensated for by using a high data rate. A rate of the order of 40 kbit/s over a distance of about 1 AU is foreseen. This requires transmission in the X-band and a spacecraft dish antenna of 1.5 m diameter.

The dust particles emitted by the comet nucleus have velocities of the order of 100 m/s. Because of the high flyby velocity, however, they will strike the spacecraft with a velocity of 68 km/s, fifty times faster than a bullet from a gun. A 0.1 g particle with that velocity can penetrate an aluminium wall 8 cm thick! To protect the spacecraft against such dust particles with a single sheet of 8 cm aluminium would involve a mass penalty of 600 kg, which is prohibitive. Fortunately, there is an ingenious solution to the problem available in the dual-sheet bumper shield, which consists of a thin (1 mm) front sheet and a somewhat thicker rear sheet with a space of about 25 cm between. When a dust particle impacts on the front sheet, an enormous amount of energy is released which completely vapourises and even partly ionises the dust particle. The gas cloud formed expands into the space between the two sheets and impacts on the rear sheet where the impact momentum is distributed over a large area. It is estimated that a 60 kg shield can withstand the impacts of particles up to 0.1 g.

Having defeated the dust particles we are faced with yet another problem. The impact of the dust particles and the cometary neutrals on the spacecraft will create a plasma around the spacecraft which is orders of magnitude denser than the cometary ions to be measured. Fortunately, these artificially created ions will be at rest in the spacecraft frame of reference while the cometary ions will have velocities of $\sim$68 km/s. It will therefore be possible on the basis of this velocity difference to separate the cometary ions unambiguously from the artificially created ions, allowing undisturbed measurements to be made.

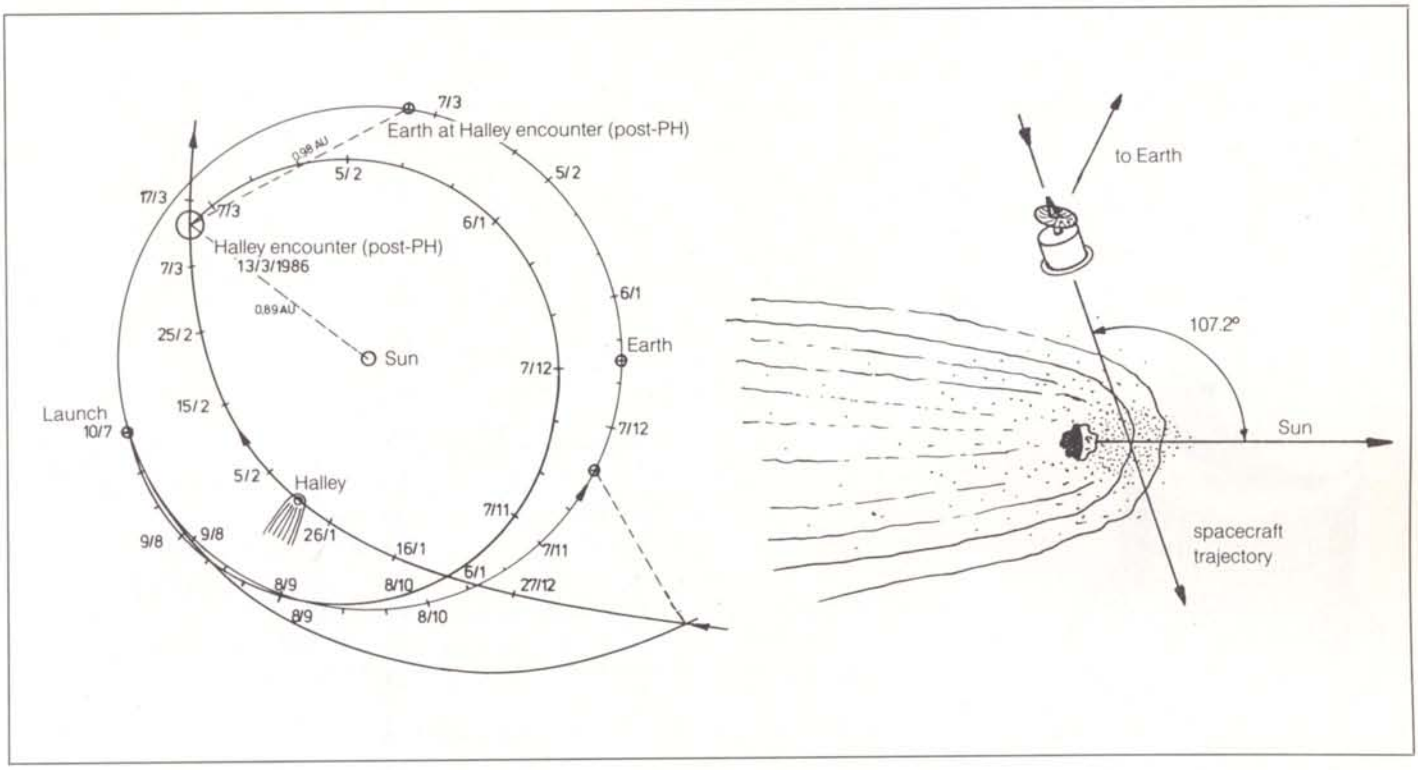
The nominal orbit of the Giotto spacecraft from its launch on 10 July 1985 up to the encounter with Halley on 13 March 1986 is shown in Figure 3, together with details of the encounter geometry. The spacecraft will approach Halley at an angle of 107° with respect to the sun – comet line, i.e. from behind. Up to the point of closest approach, the dust fluxes encountered will be very small. In particular, no large particles are expected because the comet emits dust particles predominantly into the sunward hemisphere. As soon as the spacecraft enters the sunward hemisphere the dust densities will become very high and the spacecraft will be hit instantaneously by a great number of large particles, possibly larger than 0.1 g. Spacecraft survival beyond that moment cannot be guaranteed and Giotto has therefore been designed to transmit all scientific data in real time. Giotto's power budget and thermal control concept are such that it will be active for 4 h between experiment switch-on and the point of closest approach. The power will, of course, not be switched off should the

Table 1 — Observed characteristics of Comet Halley

Earliest recorded appearance	239 BC, possibly 1057 BC
Latest appearance	August 1909 – June 1911 Perihelion passage: 20 April 1910
Next appearance	1984 – 1987 Perihelion passage: 9 February 1986
Period	76 yr (approximately)
Perihelion distance	0.59 AU
Aphelion distance	35 AU
Orbital inclination (with respect to ecliptic)	162°
Absolute total magnitude	5
Photometric behaviour	– Brighter post-perihelion – Fountain effect from nucleus sunward – Spherical halos expanding from nucleus (0.1 to several km/s) – Jets and streamers showing evidence for directed ejection – Sudden outbursts – Maximum visual coma diameter $\sim 4 \times 10^5$ km
Tail structure	– Dust tail and ion tail present – Motion of fine streamers and disconnection phenomena in ion tail – Numerous envelopes showing 'closing umbrella' phenomena – Maximum visual tail length $\sim$0.75 AU reached 5 to 6 weeks post-perihelion Ion tail begins to form $\sim$1.5 AU pre-perihelion. Dust tail begins to form near perihelion
Meteor shower attributed to cometary debris	η Aquarid (early May) Orionid (late October)

Figure 3 – Left: reference trajectory for Giotto from launch on 10 July 1985 to post-perihelion Halley encounter on 13 March 1986

Right: Geometry at Halley encounter. The spacecraft trajectory shown here is not representative as Giotto will probably be targetted to pass north or south of the nucleus



spacecraft survive the large-particle impacts and any remaining power and thermal margins will be exploited.

The encounter geometry (Fig. 3) also shows that the angle between the spacecraft spin axis, which is aligned with the relative-velocity vector, and the earth is 45°. Since the spacecraft's antenna has to point permanently at the earth during encounter, it is inclined and despun.

Giotto will be launched by an Ariane-2 in tandem configuration using the SYLDA (système de lancement double Ariane*) during a 15-day nominal launch window in July 1986. The two spacecraft will initially be put into a geostationary transfer orbit where they will be separated. After a number of revolutions in this parking orbit, Giotto's solid-propellant motor will be fired close to perigee to inject the spacecraft into the comet transfer trajectory (Fig. 3).

During the cruise phase about ten mid-course manoeuvres are foreseen to target the spacecraft at the comet nucleus, using the on-board hydrazine system. Nevertheless, there is a residual targetting uncertainty which is essentially due to insufficient knowledge of the nucleus' position within the coma. It is estimated that a miss distance of less than 500 km from Halley's nucleus can be achieved with a 50% probability.

During cruise the spacecraft will be

Major milestones for Giotto

Project approval	8 July 1980	Experiment delivery dates:	
Experiment proposals due	15 October 1980	Structural model	December 1982
Announcement of experiment selection	January 1981	Engineering model	June 1983
Start of definition phase (Phase-B)	June 1981	Flight model	January 1984
Start main development phase (Phase-C/D)	February/March 1982	Launch	10 July 1985
		Comet Halley encounter	13 March 1986

* See ESA Bulletin No. 15 (page 28) for further information.

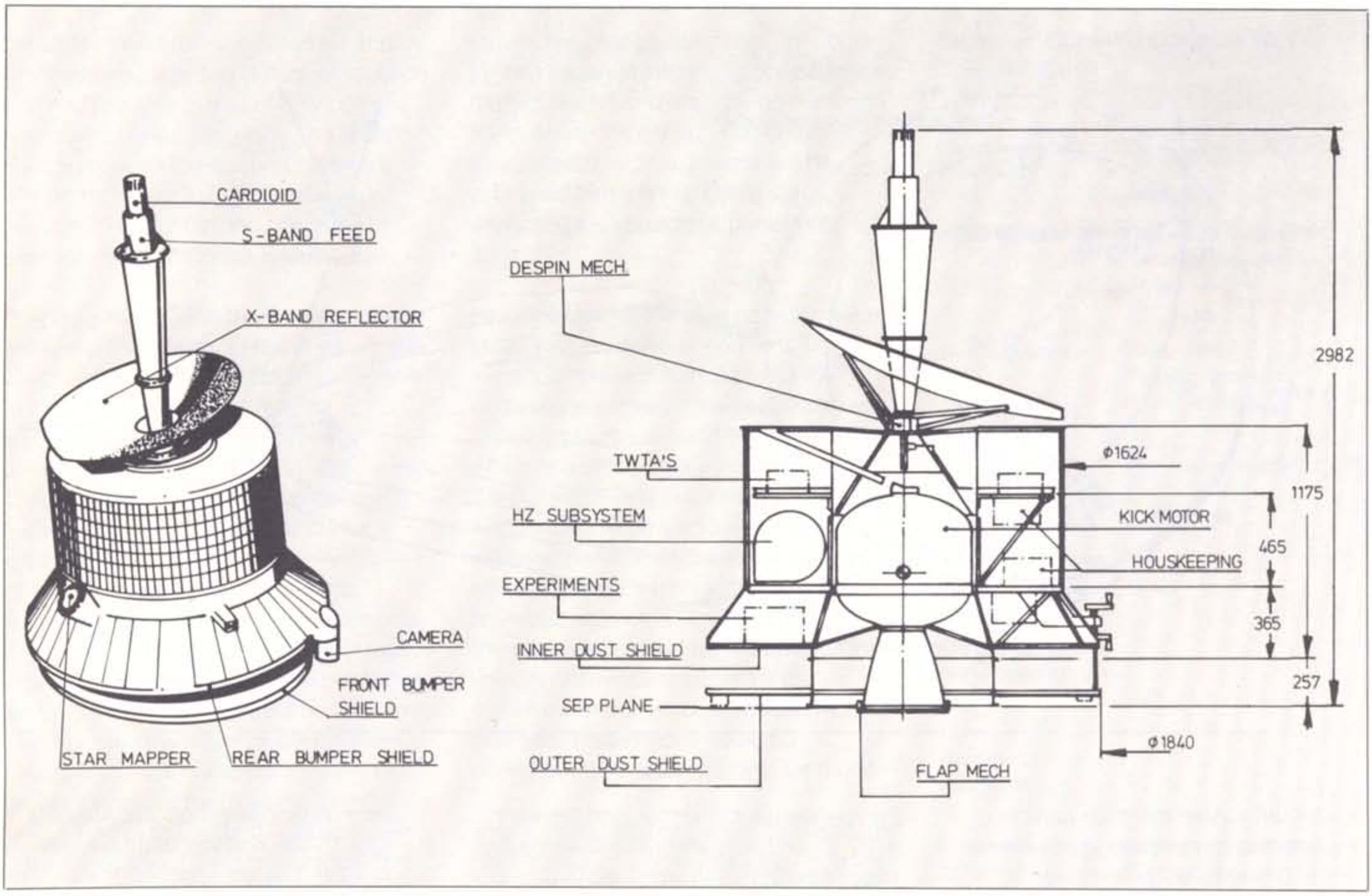


Figure 4 — The Giotto spacecraft. The scientific experiments will be accommodated between the lower platform (right-hand figure) and the rear bumper shield

controlled from the European Space Operations Centre (ESOC) in Darmstadt, Germany, using the 30 m antenna at Weilheim. For the 4 h Halley encounter, the Australian CSIRO Institute has offered the use of its 64 m Parkes antenna, which is normally used for radio astronomy. This antenna can be linked via satellite to ESOC for the encounter period.

In summary, then, the major spacecraft features are:

- a 1.5 m dish antenna, inclined and despun
- a dual-sheet bumper shield
- a solid-propellant injection motor
- an active attitude and orbit control system using hydrazine
- a power budget and thermal concept that guarantees 4 h of active scientific data taking.

The Giotto design (Fig. 4) is based as far as possible on the existing Geos spacecraft with a view to containing mission costs. Giotto will be spin-stabilised (15 rpm) and will have a total mass of 750 kg at launch, reducing to 430 kg by the time of comet encounter. The scientific payload will consist of some eight experiments, with a total mass of 53 kg.

One of the prime scientific objectives of the mission is to detect the comet nucleus (if it exists), which is too small to be seen from earth even with the best telescopes, including the Space Telescope to be put into orbit in late 1983. Giotto will be equipped with a camera able to provide colour photographs of the surface of the comet nucleus with a resolution down to 50 m from a distance of 1000 km. It will also be equipped with several other instruments to carry out fundamental investigations of the cometary atmosphere. Neutral, ion and dust mass-spectrometers will measure the elemental and isotopic composition of the cometary gas and dust particles. The interaction of the solar wind with the cometary ions leads to a variety of plasma physical processes (formation of a contact surface and a bow shock, acceleration of charged particles, tail rays) which will be investigated by charged-particle analysers and a magnetometer. Finally, the impact of dust particles on the spacecraft will be registered, and the spectral lines emitted by the gaseous coma in the ultraviolet range will be measured by a UV spectrometer.

Table 2 summarises the design characteristics for the European Giotto mission to Comet Halley. As Table 2 also shows ESA is not the only space agency

*Table 2 — Design characteristics for potential Comet Halley missions**

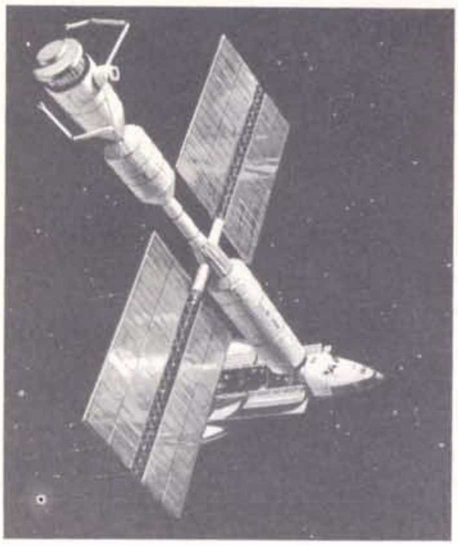
	ESA	USA	Japan	USSR
Launch date	July 1985	July 1985	August 1985	December 1984
Launch vehicle	Ariane	Shuttle	Impr. Mu-3S	Proton
Spacecraft mass	750 kg	1500 kg	120 kg	~1000 kg
Spacecraft type	Spin	Three-axis	Spin/despin	Three-axis
Communication rate	53 kbit/s	120 kbit/s	128 bit/s	10 kbit/s
Encounter date	13 March 1986	26 March 1986	9 March 1986	March 1986
Encounter speed	68 km/s	60 km/s	70 km/s	70–80 km/s
Targetted miss distance	0 km	800 km	10^5 km	10^4 km
1 σ aiming accuracy	90 km	90 km	10^5 km	10^4 km
Nucleus position knowledge	500 km	0 km**	500 km	500 km
Payload mass	53 kg	126 kg	10 kg	50 kg
Science payload	Neutral mass-spectrometer Ion mass-spectrometer Dust impact mass-spec. Dust impact detector Electron/ion analyser Magnetometer Narrow-angle imaging UV spectrometer	Wide-angle imaging Narrow-angle imaging Neutral mass-spectrometer Ion mass/velocity spec. Dust comp. Magnetometer	UV camera Magnetometer	Vidicon camera Plasma instr. Dust counter (neutral mass-spectrometer) (ion mass-spectrometer)

* Adopted with minor modifications from Friedman L D, The International Halley Watch (IAF paper 80 G 287), *Proc 31st IAF Congress*, Tokyo, 22–28 September 1980, to be published

** On-board optical navigation

planning a mission to Halley. The Japanese are planning to launch their first deep-space probe called 'Planet A' to make large-scale observations of the comet. The Soviet mission may use one or two Venus spacecraft to be launched in late-1984. After carrying the Venus entry probes to the vicinity of Venus, the spacecraft would be retargetted to intercept Halley in March 1986. The spacecraft would have a fixed antenna pointing to the earth, thus precluding the possibility of efficient shielding against impacting dust particles. Consequently, the spacecraft would be targetted to pass no closer than 10 000 to 50 000 km from the nucleus.

Only two of the four missions, ESA's and Japan's, are already approved. They are the cornerstones of the International Halley Watch (IHW) programme* which is a global effort to capitalise on this novel scientific opportunity in order to extract as much information as possible during Halley's 1986 appearance and to provide for the distribution of that information to both the scientific community and the public.



Spacelab Follow-On Development*

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With Spacelab approaching operational status in 1983, it is time to reflect on a Spacelab follow-on development programme in Europe. From the ESA-sponsored studies carried out so far, it is clear that Spacelab, with all the advantages inherent in its modular design, provides growth potential that lends itself to cost-effective application in any future evolutionary space-platform programme.

The Spacelab Programme, initiated in 1973 as the first cooperative venture by Europe and the United States in manned spaceflight, has the demonstration of the usefulness and economic viability of manned operations in space, and the advancement of European technological knowhow and capabilities as its main objectives. As an integral part of NASA's Space Transportation System, Spacelab is presently the only manned Shuttle payload in the US inventory for the 1980s. It is therefore only logical to consider the role Europe could play in future cooperative programmes utilising Spacelab and Spacelab derivatives as building blocks for larger and more complex entities.

In January of this year the ESA Council approved the execution of the initial phase of a three-step evolutionary Spacelab development programme leading from the present sortie-mode concept for a Shuttle-attached Spacelab, to free-flying and Spacelab-derived elements as building blocks for future space stations.

Evolving user needs

Through their coordinating organisation the Joint User Requirements Group (JURG), ESA and NASA have examined the most desirable extensions for Spacelab's capabilities for the near, medium and far term (Table 1), on the basis of known major user requirements for advanced space systems.

For the near future, the highest priority needs are:

- increased electrical-power and heat-rejection capabilities for payloads
- extension of mission durations beyond seven days
- increased flexibility in payload servicing.

The simultaneous increase in electrical-power and heat-rejection capabilities, particularly for space-processing and space-physics missions, is needed to achieve a better balance between physical accommodation (mass, volume) and experiment resources.

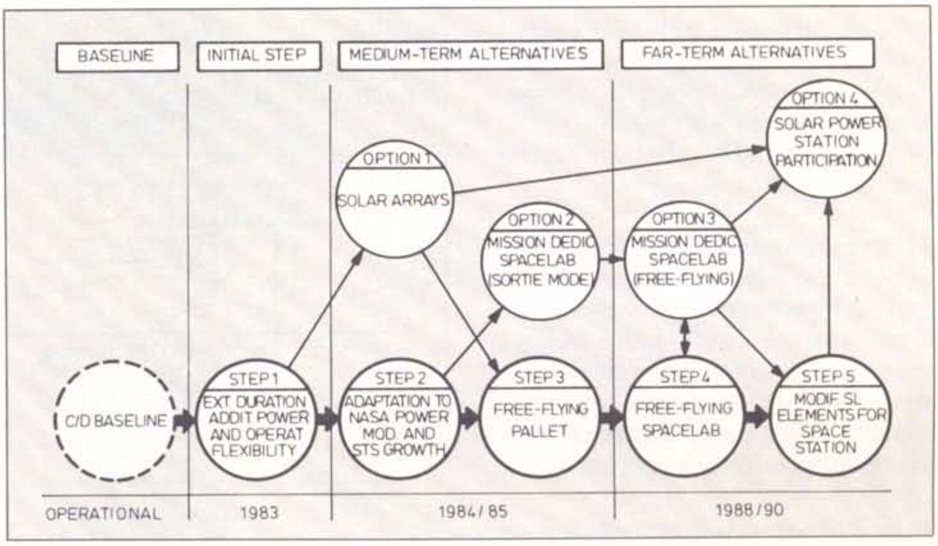
The need for longer missions is well supported by the majority of Spacelab users, not least because extended missions will lead to improved mission cost-effectiveness, since considerably more data/results are obtainable for what is a small increase in operational costs compared with the launch costs.

For astronomical missions in particular, the scientific return is almost directly proportional to mission duration. Some disciplines have specific requirements for prolonged missions; certain crystal-growth processes (materials science), for example, require about two weeks of continuous operation, while studies of cardio-vascular or metabolic problems (life sciences) require up to four weeks of observations.

Calls for greater operational flexibility are aimed at increased access to standard Spacelab services: more power outlets, increased computer memory, short pallets, small pointing systems, etc.

* Based on a presentation to the Third DGLR/AAS Symposium, Hanover, 28–30 April 1980

Figure 1 – Spacelab follow-on development (FOD) approach



For the medium- and long-term future, there is a demand for even more electrical power (up to 40 kW for 1988–1990) and for practically unlimited orbital stay time for nearly all disciplines.

There is also a lobby for free-flying Spacelab elements, particularly for pallets, in order to minimise man-motion and Shuttle environmental effects on mission performance.

Newly required Spacelab capabilities and proposed programme evolution

The increased user demands that have been discussed will either necessitate adaptations of or extensions to the present Spacelab system, or will require costly new development work. In order to employ the existing Spacelab hardware production capabilities most economically, as well as the technological knowhow and the operational experience to be gained from the first Spacelab flights, ESA has proposed a phased Spacelab development programme involving a sequence of discrete development steps and options that provide three major capability increments (Fig. 1): the 'initial step', the 'medium-term' and the 'far-term' alternatives.

The 'initial step' relies on the provision of more power from an Orbiter augmented by a solar array, and satisfies the need for increased electrical-power and heat-rejection capabilities for experiments, as well as providing increased operational flexibility in resource utilisation and through prolonged stay-times in orbit.

The medium- and long-term proposals are aimed at increasing the autonomy of Spacelab in Shuttle-tended or autonomous free-flying modes and at providing dedicated modules and pallets that could serve as building blocks for future space stations or service platforms.

Relationship between European and American efforts

Compatibility between ESA's Spacelab follow-on development plans and NASA's overall planning for the future of the Space Transportation System (STS) was a major consideration in screening and

Table 1 – User requirements for extended Spacelab capabilities

	Near-term			Far-term	
Disciplines	Augmented power/ heat rejection	Mission extension	Operational flexibility	Manned orbital platforms	Unmanned orbital platforms
Life sciences	Desirable	Essential	–	Essential	–
Materials science and processing	Essential	Desirable	–	Essential	Essential
Solar physics	Desirable	Desirable	Desirable	–	Essential
Astronomy	Desirable	Essential	Desirable	–	Essential
Magnetospheric/ plasma physics	Essential	Desirable	Desirable	–	Desirable
Atmospheric physics	Essential	Desirable	Desirable	Desirable	Desirable
Earth observation	Desirable	Essential	Desirable	Desirable	Desirable
Space technology demonstrations	–	–	–	Desirable	Desirable

selecting the options for the European programme. Figure 2 summarises the projected evolution of the STS as far as launcher development, servicing provisions and orbiting-platform facilities are concerned.

For Spacelab's evolution, the platform sector of this projection is of particular interest. Here the present seven-day Spacelab is projected to evolve via mission duration and power increases for the sortie mode towards free-flying unmanned and manned experimental and then operational space platforms.

In this framework, Europe presently finds itself with the unique role of providing the only early platform in NASA's overall STS inventory. By assuming responsibility for the design and development of Spacelab, therefore, Europe has acquired a privileged position as regards the future evolution of the STS. In this context, Spacelab is not seen by ESA as an end in itself, but rather as Europe's first step into the future market for space platforms. Capitalisation on this lead will require a well-phased but continuous effort to ensure Europe's participation in the further development and exploitation of the inherent potential of today's Spacelab.

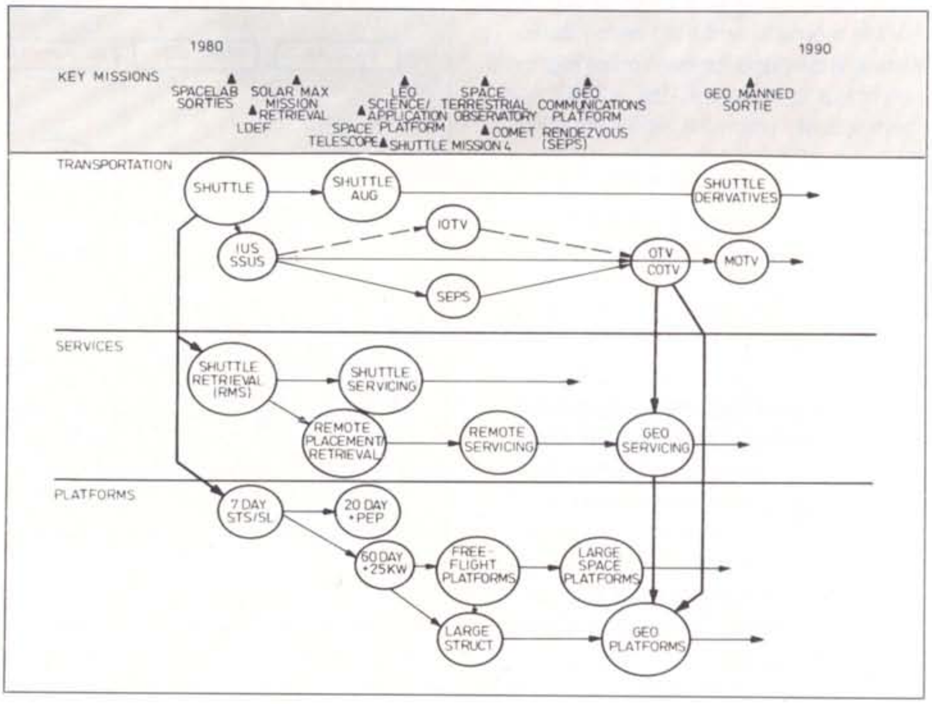
To assure close coordination of future efforts, ESA and NASA have formed a joint working group to refine the ESA-proposed 'initial step' improvements and to pursue full interface compatibility with the Orbiter Power Extension Package and Power System presently being studied by NASA.

Beyond the first step of augmenting Shuttle resources by the addition of the Power Extension Package or Power System for prolonged flights, NASA is studying a variety of concepts for space platforms or space operation centres (SOC), as illustrated in Figure 3.

All of these concepts, whether manned or unmanned, depend on NASA's Power System as the service element, and on

Figure 2 — Projected evolution in space transportation systems (from NASA/OSTS, June 1979)

IUS/SSUS = Inertial Upper Stage/Spinning Solid Upper Stage
SEPS = Solar Electrical Propulsion System
OTV = Orbital Transfer Vehicle
COTV = Cargo OTV
MOTV = Manned OTV
IOTV = Interim OTV



Spacelab-like pallets or modules as payload-support elements. As shown in Figure 4, the building blocks for these facilities are of similar modular design and of similar size to Spacelab, as a result of the cargo-bay limitations of the Space Shuttle.

Unmanned space platforms will be used predominantly for scientific-research applications that require clean electromagnetic and particle environments with no man-made disturbances.

Proposed improvements for the 'initial step' and industrial initiatives

In response to user requirements and NASA's plans to augment the Shuttle's electrical power-generation capabilities for prolonged flights, ESA has performed detailed studies to substantiate the feasibility of cost-effective Spacelab improvements for the proposed 'initial step'.

(a) All modifications to Spacelab needed to extend mission duration to 30 days by providing
- additional nitrogen storage tanks (Fig. 5)
- storage for additional cartridges for carbon-dioxide removal
- an in-flight exchange system for critical equipment to maintain a high probability of mission success.

(b) All modifications to Spacelab that make it compatible with an Orbiter that provides an additional 4 kW of electrical power to the experiments by
- addition of a Spacelab radiator to allow heat rejection (Fig. 5)
- increased Spacelab water-flow rates to facilitate greater heat transportation
- modification of the Spacelab power feeder to allow peak powers of up to 18 kW.

(c) Selected modifications to increase the operational flexibility of Spacelab by
- provision of low-power modes for energy saving
- extension of the computer memory and simplification of data-bus interface units
- provision of shorter pallets and pallet-

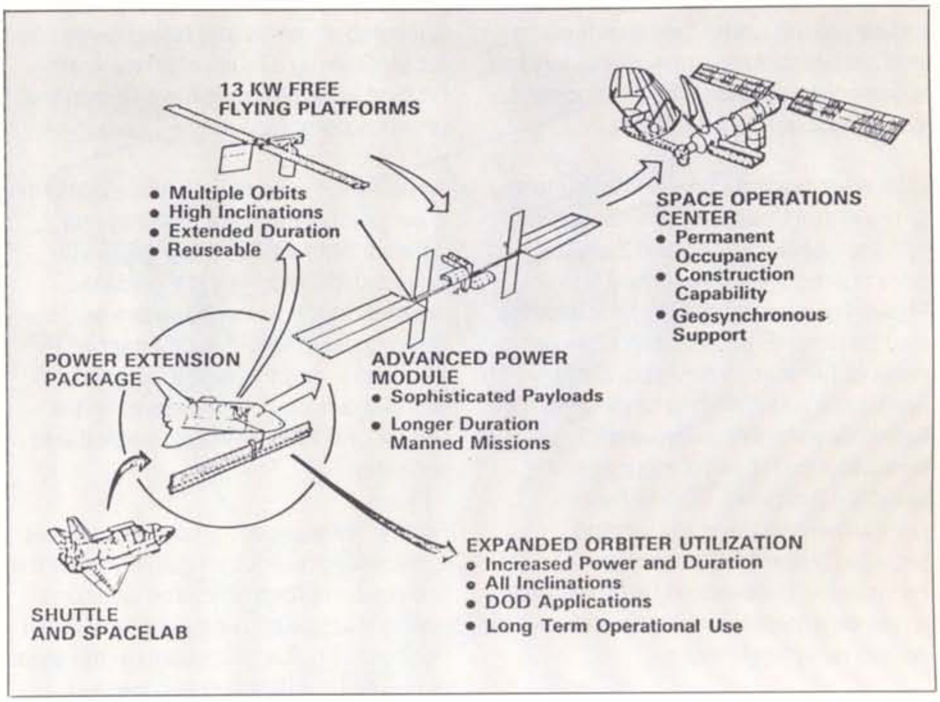
Figure 3 — NASA concept for the evolution of space platforms

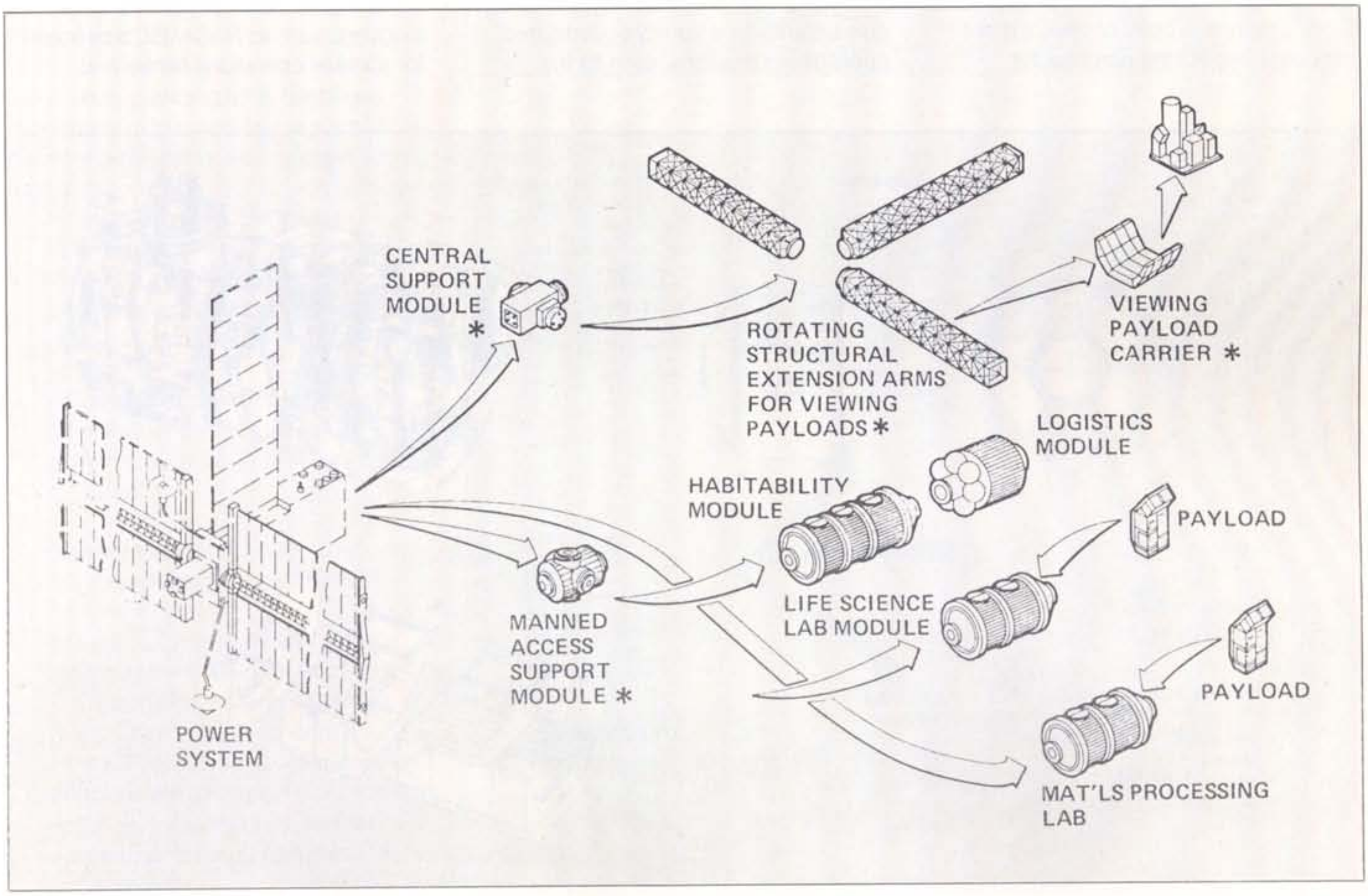
Figure 4 — Modular building elements for future space platforms

support structures (Fig. 5)
- provision of small pointing mounts.

The recently completed joint ESA/NASA cost/benefit analyses for the above options, have confirmed that the improvements listed under (a) and (b) will lead to savings in operating costs of more than eight times the initial investment needed. These improvements therefore rank highest in the implementation priorities. ESA is currently seeking approval from its Member States to commence a detailed definition phase (Phase B) for these items.

Encouraged by ESA's follow-on development efforts, which have been supported by and elaborated jointly with industry, and encouraged by the market prospects for applications of Spacelab hardware in future US projects, European





industry, partly under their own funding and partly subsidised by national funding, is presently advancing the development status of Spacelab equipment.

CIMSA for example, has performed tests to prove that Spacelab's computer can operate under vacuum and therefore does not require a pressurised housing. This will give greater flexibility by allowing the computer to be accommodated on a pallet rather than in the igloo. British Aerospace has obtained funding from the British Government to derive and qualify a new pallet that is half the length of the standard 3 m pallet. Dornier System, complementing the study funding provided by the ESA technology programme, is developing a prototype for a new drive assembly for a small two-axis position and hold mount.

The potential of Spacelab and its derivatives for future development

From a technical point of view, it is not difficult to predict the potential for Spacelab elements and future derivatives for an evolving STS and for new earth-orbiting systems, as we have seen in the previous paragraphs.

As far as the evolution of space platforms is concerned, there are basically two different flight modes offering growth potential for Spacelab: the so-called 'sortie mode' in which Spacelab or Spacelab elements remain attached to the Orbiter, and the 'free-flying mode' in which space platforms depend on the Orbiter only for placement, retrieval and servicing.

For the 'sortie mode', an obvious market is created for European industry by all the Spacelab improvements and additions needed to maintain compatibility with an upgraded Shuttle, particularly in the areas of power, heat rejection and mission duration. There will also be a growing market for pallets or pallet-type structures and systems for a variety of dedicated applications missions, such as the Materials Experiment Carrier (Fig. 6). Generally, there will be a strong trend towards less complex Orbiter payload units requiring shorter integration times and allowing easier access for particular payload disciplines at reduced cost. Short (half) pallets might well constitute building blocks for more autonomous 'pallets of opportunity', aiming at reduced Orbiter/payload integration complexity and time.

For the 'free-flying mode', Europe's already qualified pallets or pallet-type structures provide building blocks for unmanned instrument platforms, ranging from small single units with a high degree of autonomy to clusters of experiment carriers depending on a central facility like the 25 kW Power System, for basic resources (Fig. 7).

For the next step to larger platforms, including habitable modules and service modules, such as NASA/JSC's concept for a space operations centre and

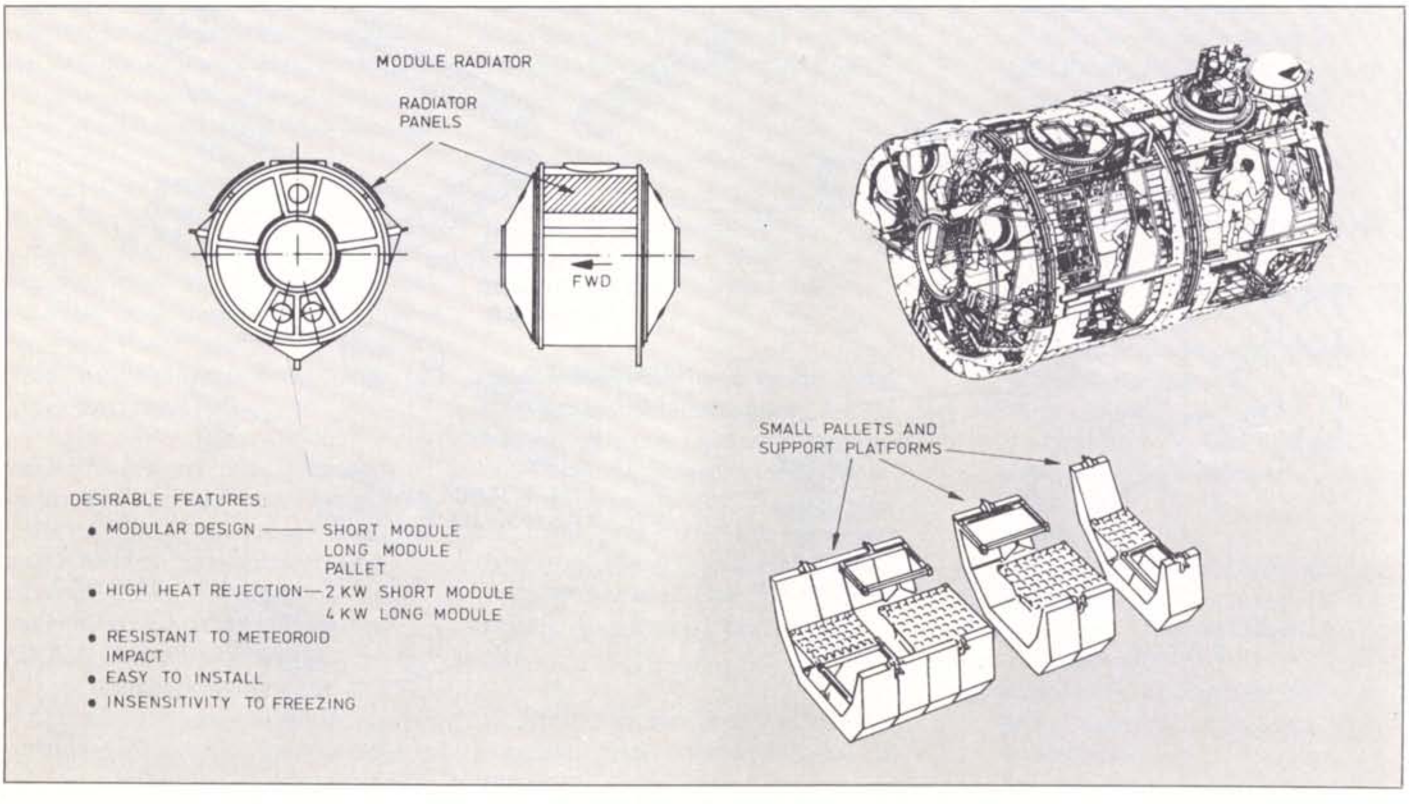


Figure 5 — Examples of potential Spacelab near-term improvements

Figure 6 – Pallet-based Materials Experiment Carriers (MECs) with their own radiators, intended for attachment to space platforms

Figure 7 – Examples of possible pallet derivatives

NASA/MSFC's concepts for initial space platforms (Fig. 8), adapted Spacelab-like modules are considered to be key elements.

Long-term prospects for Europe's involvement in the development of manned space systems

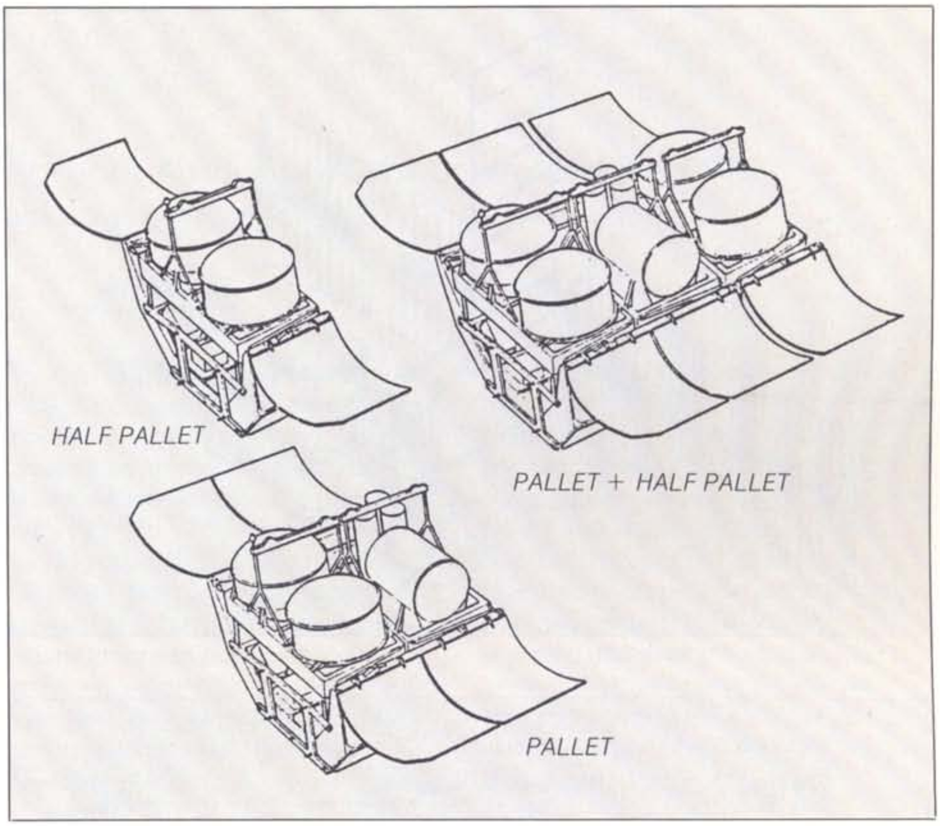
The original Post-Apollo Programme postulated 'manned planetary exploration of Mars before the end of the twentieth century' as the desirable goal, or as a driver for new developments. Now, ten years later, one can conclude that this original objective has given way to the more practical approach of using man in space only if he can contribute more effectively to our knowledge and well-being than 'space robots'. This change in emphasis is evident in the trend towards more sophisticated research apparatus, increasing demands for automated space service systems, and economic pressures towards obtaining improved service at reduced cost.

ESA's future planning for a continued involvement in manned space systems will therefore be influenced by answers to such questions as:

- Will man's presence in space operations grow or diminish?
- Will research into materials and the physics of space processes lead to increased commercial involvement in space?
- Will strong motivations be found for other manned space research activities, such as life sciences and medicine?

But European decisions will also be strongly influenced by the answers to such questions as:

- Will political trends among nations lead to greater collaboration?
- Will Europe strive towards a more autonomous space concept?
- How will social and political interests affect the distribution of resources for space exploration, basic science, applied science and social welfare programmes?



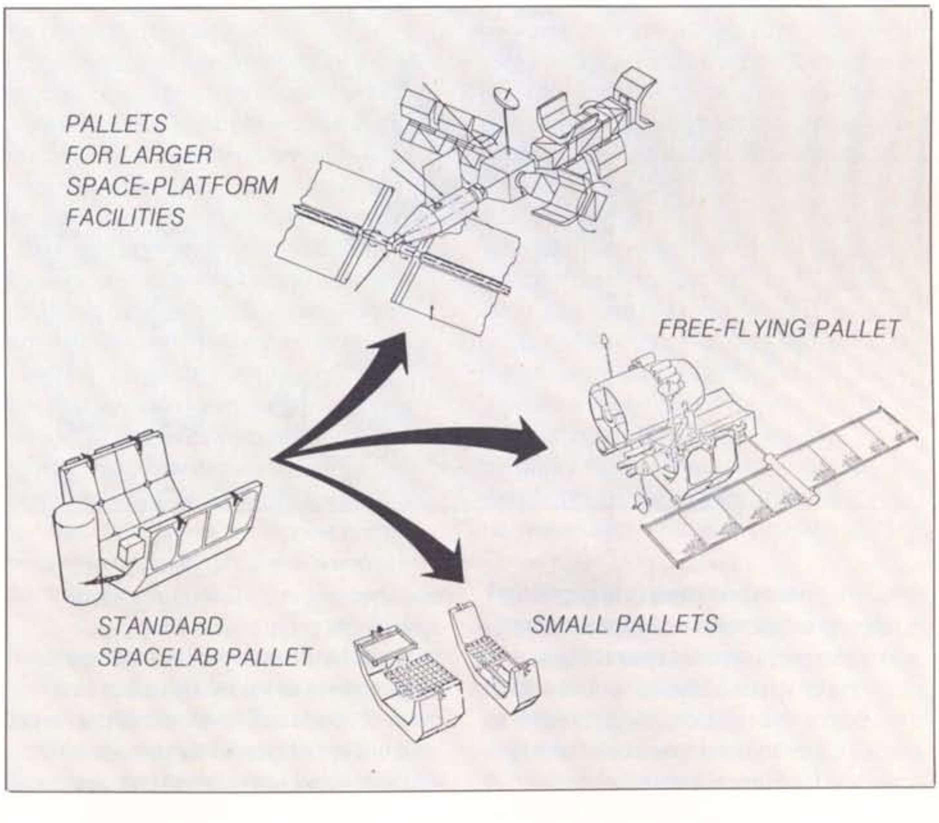


Figure 8 — NASA concept for a manned space platform

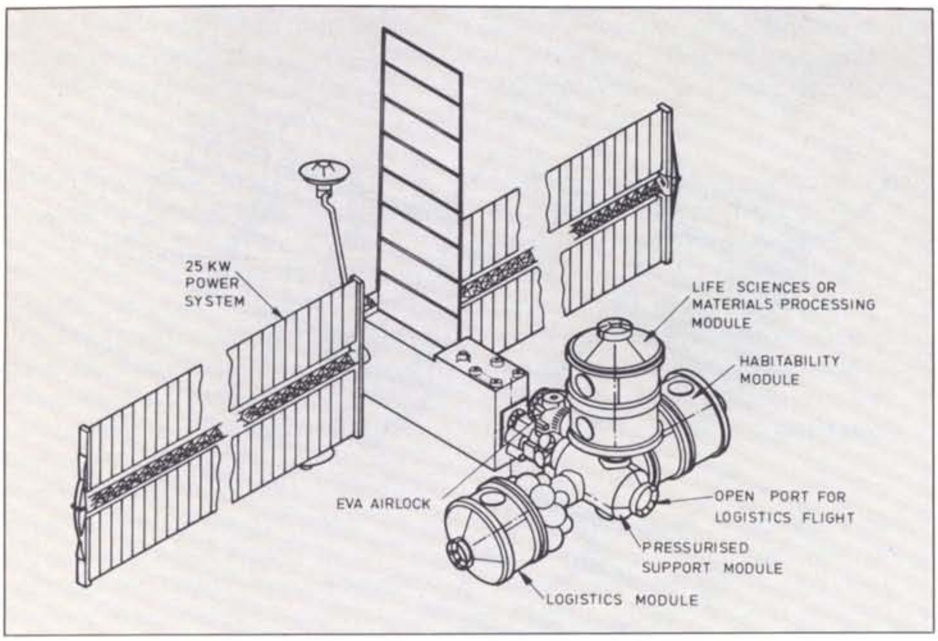
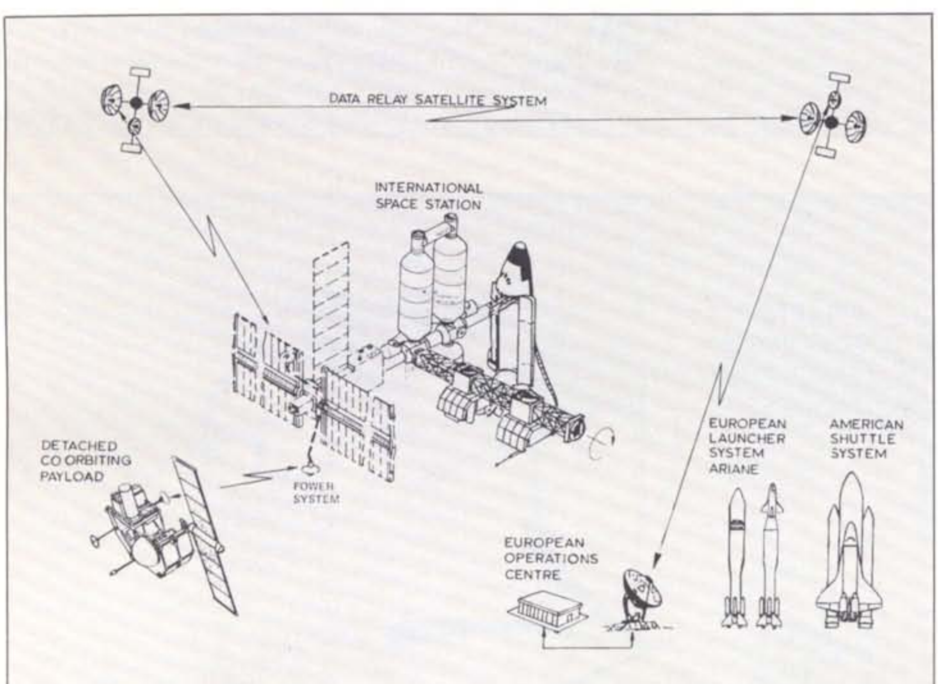


Figure 9 — Possible European space-system developments

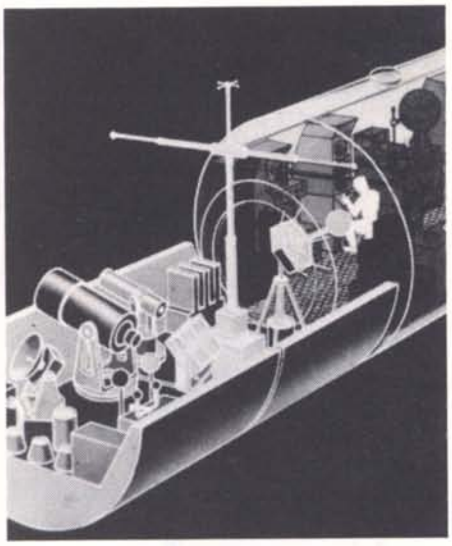


Different answers to these and similar questions will generate different scenarios and these scenarios will shape the planning of space activities for the end of the century. It is not possible at present to predict either the exact nature of or any schedule for Europe's continued engagement in a far-term manned spaceflight programme. One can, however, reasonably expect the space programmes of the 1990s to aim at a class of space activities intended to add an extra dimension to earth-bound systems, to provide goods and services on a macro-economic scale. Typical examples might be large space-based power stations, and manufacturing facilities for products of high intrinsic value (high quality crystals, medicines, etc.).

Such systems will inevitably require the presence of man for construction, maintenance and repair activities, leading to a need for safe shelters and work areas.

If programmes evolve in the direction indicated above, a number of new techniques and capabilities relevant to a Spacelab-like follow-on development will be required. Notable among these will be habitation modules compatible with a stabilised platform, logistics modules, laboratory modules, production modules, and manned or unmanned platform elements that can be released from and re-attached to the central platform supply base. It is therefore important that Europe recognises these trends and establishes goals and the associated planning, which must be as responsive as possible to today's environment but sufficiently bold and creative to warrant serious study in the interests of advancing European technological knowhow and capabilities. The latter are vital for the advancement of a society whose prosperity is based largely on its leading role in technology.

Figure 9 illustrates a scenario in which a space platform that could in large part be of European Spacelab descent (modules, pallets) is shown as part of a future European system consisting of Ariane resupply capability, data relay systems and a centralised European operations centre.



A Position and Hold Mount for Smaller Spacelab Experiments

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The need for a small facility giving low to medium pointing stability for Spacelab experiments weighing up to 200 kg became evident in 1977 from surveys of potential European Spacelab payloads. The position and hold mount (PHM), which covers the low stability range, can satisfy approximately 30% of all European experiment requirements. It combines the advantages of low development and flight-hardware fabrication costs with that of lowest user cost for this group of experiments.

A re-usable, multiple-payload carrier like the STS/Spacelab combination has to be able to provide a wide variety of services to satisfy the differing requirements of the individual experimenters. The fact that many Spacelab experiments need pointing capabilities exceeding those of the Shuttle itself has been emphasised again recently by NASA's order for a second European-manufactured instrument pointing system (IPS). The IPS is presently the only pointing mount to have reached the flight hardware development stage.

Development of the IPS was started originally with the intention of satisfying the pointing and payload-accommodation requirements of the majority of all Spacelab experiments. This broad mandate naturally led to the design of a large and complex, very high accuracy pointing mount. Such a facility would impose unduly high pallet-area, pallet-load and power penalties on very small experiments in cases where these could not be assembled into sufficiently large clusters, whether for integration, interface or operational reasons. The need for smaller experiment pointing mounts to improve Spacelab's operational flexibility was therefore recognised by ESA early on, and a number of studies of smaller experiment mounts to complement the IPS were started.

The technical requirements that the Agency formulated for these studies were based on the results of Spacelab-experiment surveys conducted within the European user community. Evaluation of pointing and payload-accommodation requirements indicated a need for both a small pointing mount with medium pointing stability (20–30 arcsec), and a position and hold mount (PHM). The PHM did not need to provide greater stability than the Orbiter, but it had to make the experiments independent of the Orbiter's attitude control for target tracking, scanning and slewing from one target to another. The load-carrying capability needed by both types of mounts was identified to be of the order of 200 kg (Fig. 1).

Because of the PHM's comparatively low mass and power consumption, and because the PHM and its payload take up only a small area on the pallet, the cost to users for small PHM-mounted payloads with low pointing stability requirements will be lower than on any other pointing mount.

Whereas the development of a small, medium pointing stability mount eventually had to be postponed because of lack of funding, the PHM concept had the advantage of system simplicity and low development costs (less than 10% of the cost of the IPS). ESA initiated a feasibility study of the PHM in 1978 and decided in 1979 to continue with a hardware demonstration phase (Fig. 2).

Pointing and accommodation requirements of smaller experiments

The service requirements of experiments to be accommodated on a pointing mount can be expressed in terms of attitude-control and payload-accommodation requirements:

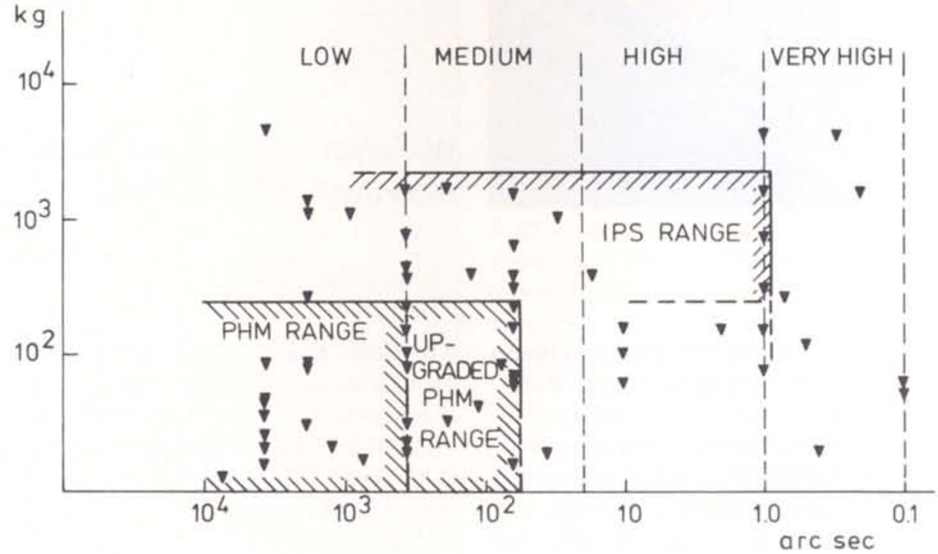

Figure 1 – Payload mass as a function of pointing stability for potential European Spacelab experiments

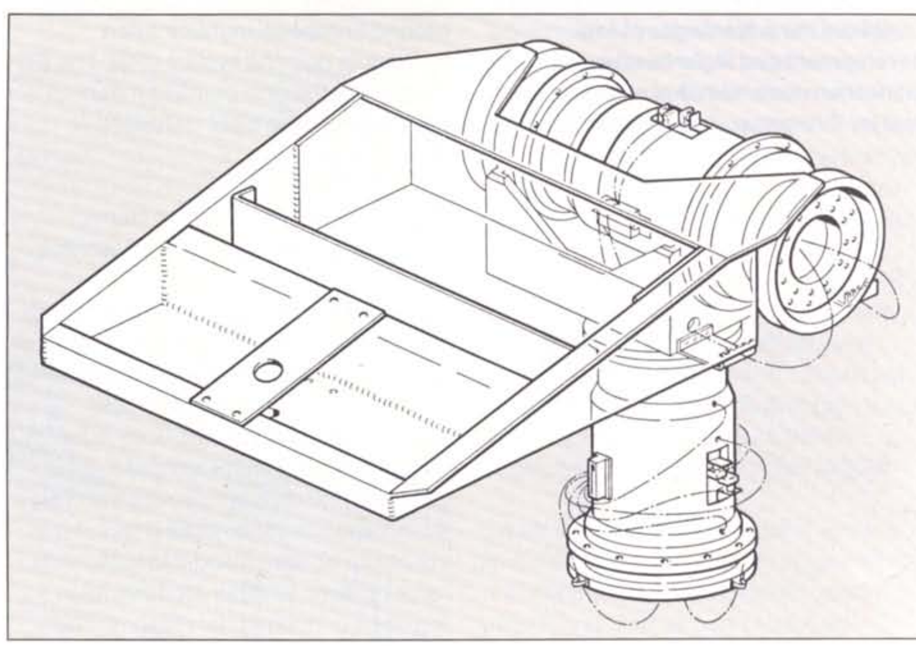

Figure 2 – Schematic of the demonstration model of the Spacelab position and hold mount (PHM)

- Attitude control: pointing performance, expressed in terms of pointing stability, pointing accuracy and number of controlled axes and the operational modes such as tracking, scanning and position holding
- Payload accommodation: payload mass and volume, data-transfer requirements, and power requirements.

Pointing stability and accommodatable payload mass have been identified as the most important design drivers in the above lists. Before investigating the services to be provided by a new pointing mount, therefore, the scope of these two features has to be defined.

Figure 1 is a plot for potential European Spacelab experiments of mass as a function of stability field. Four different ranges of pointing stability can be identified:
- Low range: stability equal to or worse than 0.1 deg (Orbiter stability)
- Medium range: stability better than 0.1 deg up to 20–30 arcsec
- High range: stability better than 20 arcsec up to 1 arcsec
- Very high range: stability better than 1 arcsec.

There are clearly a large number of potential European Spacelab experiments that call for medium and low pointing stabilities, particularly the group with a stability requirement of around 1 arcmin and another requiring just Orbiter stability (0.1 deg) or less. The high and very high stability ranges are catered for by or are even beyond the capabilities of the IPS and are not discussed further here.

Figure 1 also shows a concentration of experiments in the lower mass range, but as there are no pronounced groupings it is hard to define an upper mass limit.

In addition to potential-payload mass/stability considerations, three other facts need to be considered:

- the lower mass limit of the IPS for a single payload
- the fact that operational constraints and integration complexity increase with the number of payloads to be clustered
- the additional mass for the payload integration structure.

Based on the above a 'small' mount able to carry between 150 and 300 kg would ideally complement the IPS. The concentration of potential experiments in the low mass/stability region means that nearly a third of all European experiments can be satisfied by a 200 kg PHM.

Attitude control motions like slewing, scanning, and tracking are required in all pointing stability ranges. The minimum angular rate that the PHM should be capable of is the orbital rate of the Orbiter

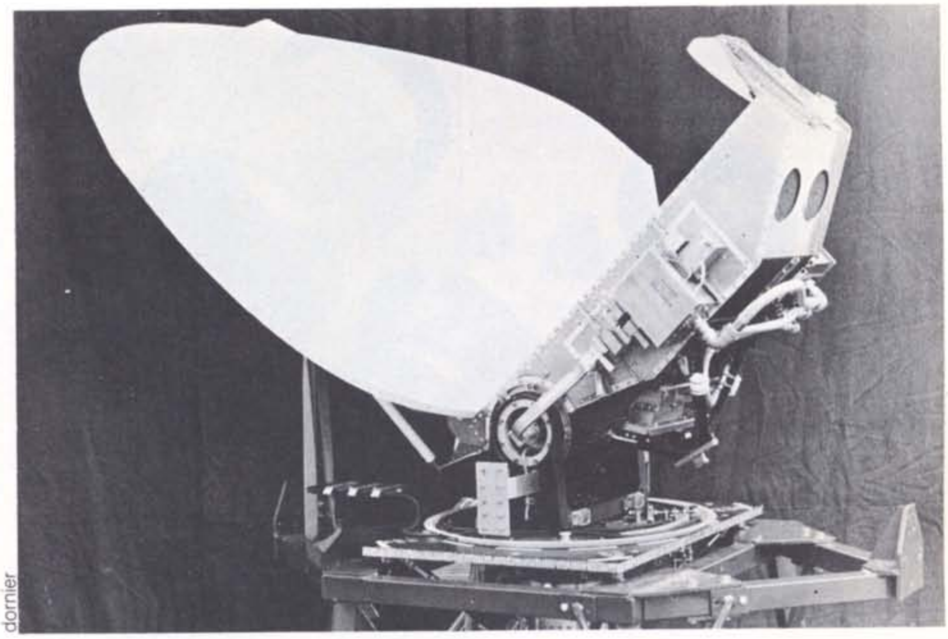

Figure 3 – The Microwave Remote Sensing Experiment (MRSE)

(4 deg/min) plus some margin for fast reset in order to maximise observation time; this total comes to approximately 10 deg/min.

For medium- or low-stability experiments, only two controlled axes perpendicular to the line of sight are usually necessary. Control about the line of sight is necessary only for polarimetric experiments, and in such cases the control facility may be provided within the experiment.

Because of the differing geometries and volumes of the various payloads, a gimbal configuration (side-mounted or end-mounted) for the PHM that imposes a minimum of constraints on experiment dimensions is needed.

Technical characteristics of the PHM
By closing the attitude control loop between the angular resolvers and the torque motors of the gimbal system, the PHM's pointing is based on the coordinate frame of the vehicle on which it is mounted. It differs in this respect from an autonomous pointing mount, which operates under gyro and optical-sensor control as an inertially stabilised platform.

The PHM has the operational capabilities of gimbal hold (i.e. locking the gimbal angles at any desired position), of slewing to predetermined positions, of following variable position and velocity commands, and of programmed pattern scanning.

The designs for the PHM's drive unit, control system and payload locking mechanism presently being studied by Dornier System are based on the pointing system of the Microwave Remote Sensing Experiment (MRSE) developed under DFVLR funding to fly on Spacelab 1 (Fig. 3). They have had to be modified and further developed to comply with the higher loadings and increased mechanical and electrical requirements of multiple payloads and with the reliability and safety requirements for a general-purpose Spacelab facility. Some elements of the MRSE pointer design from which the PHM design is derived are shown in Figures 4 and 5.

The basic PHM subassemblies are: the drive units, the payload locking device, the power electronics, and the data electronics (Fig. 6). Like the MRSE mount, the PHM will be controlled by a digital processor.

The payload can be mounted on top, on either side of, or on the end of the PHM gimbal system. The PHM itself can then be mounted on a Spacelab element like the proposed European experiment bridge (Fig. 7) or on a bracket on the side wall of a pallet. The degree to which the PHM's maximum loading of 200 kg can be used in any given situation will depend on the eccentricity of the payload's centre of mass with respect to the gimbal axes.

The PHM will be operated via the displays and keyboards of the command and data management system (CDMS) in the Spacelab module or from the Orbiter aft flight deck. It will normally be powered from Spacelab's main experiment power bus. As a contingency for, for example, emergency retraction in the case of a main bus failure, it will also be connected to the essential power bus.

As safety is one of the overriding requirements in manned spaceflight, the PHM must have a contingency mode that locks both mount and payload in a safe landing configuration in the case of PHM-component or Spacelab electrical system failure.

PHM performance improvements
The modularity of the PHM data electronics allows incorporation of additional coupling modules, which provide the interface for attitude signals generated by additional sensors or by the experiment itself. This additional attitude information can be used to:

- improve PHM pointing accuracy
- extend the PHM into an autonomous stabilised pointing mount.

The PHM's initial pointing accuracy may be no better than 1 or 2 deg, due to the unavoidable alignment tolerances and shifts between the Orbiter navigation base and the pallet location where the PHM is mounted. The additional attitude signals

Figure 4 – Drive unit components of the MRSE mount

dornier

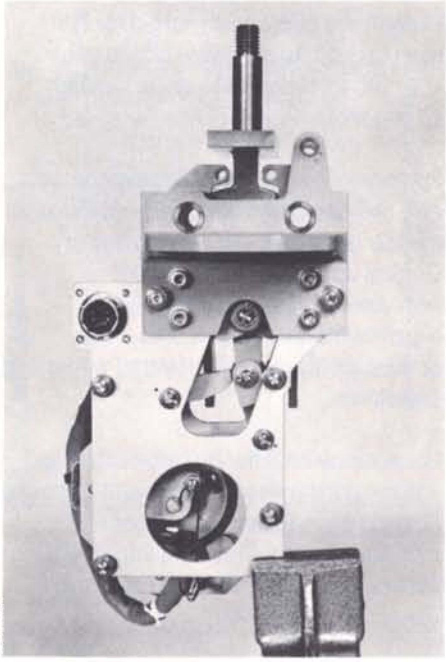

Figure 5 – Payload locking device of the MRSE mount

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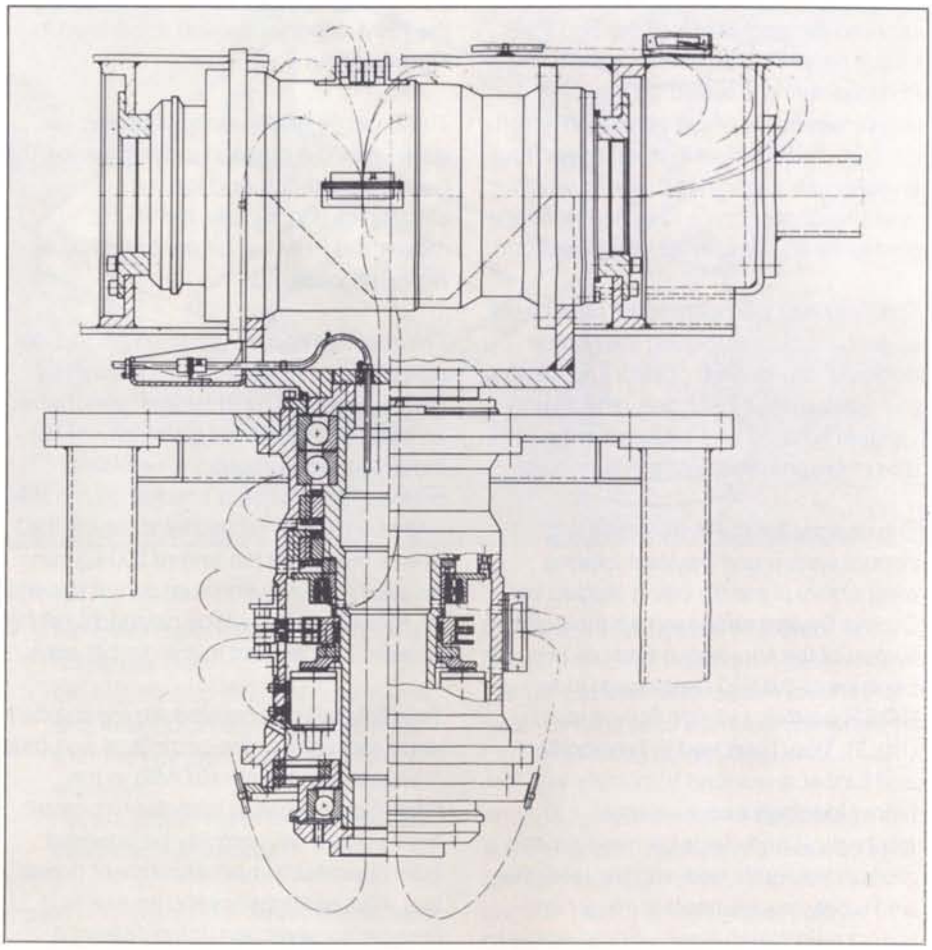


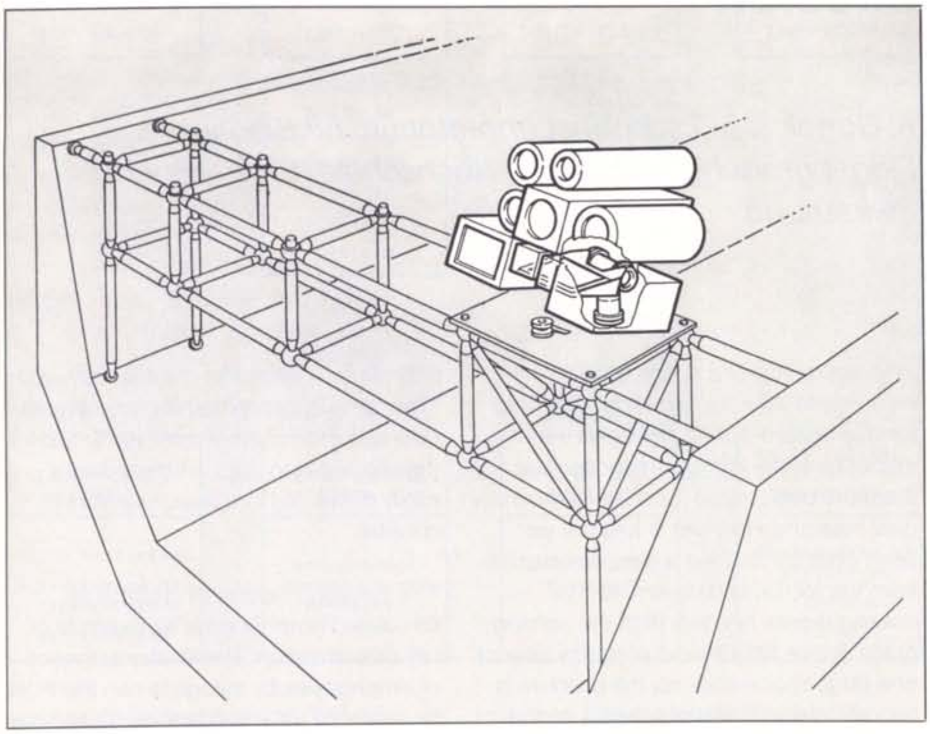
Figure 6 – Schematic of the PHM gimbal system

can be used for misalignment compensation by adding them as bias values into the position command calculation. In this way the pointing accuracy of the PHM can match the attitude stability of the Orbiter, namely 0.1 deg.

To extend the PHM into an autonomous, stabilised pointing mount, the attitude signals of the resolvers must be replaced by those of the experiment, gyros, and/or optical sensors. The necessary modifications are confined to software changes and the addition of standard hardware modules. The wiring necessary to accommodate an optical sensor (e.g. sun sensor) is already included in the basic PHM.

Such a stabilised pointing mount controlled by a sun sensor is expected to have a pointing stability of 30 arcsec or better and a pointing accuracy of approximately 1 arcmin. The distribution of potential experiments (Fig. 1) shows that approximately 50% of all European needs could be satisfied optimally if a pointing mount with this performance and a PHM were available.

Figure 7 — The PHM shown mounted on the proposed European experiment bridge for a Spacelab pallet



PHM development philosophy
To minimise development cost and risk it was decided to make as much use as possible of previous development experience and existing hardware designs developed for space and other applications, but bearing in mind the need for a certain growth potential towards a stabilised pointing mount.

In space programmes, where the development phase and the flight-hardware production phase are combined in a single (C/D phase) contract, the late resolution of technological and design problems can prove very expensive because of schedule constraints. It was therefore considered that manufacture and testing of a hardware demonstration model of a PHM made from commercial quality components and materials early in the programme could considerably reduce cost and schedule risks, by verifying the attitude control modes and performances, the payload capabilities, the accommodation of payload cables and the operation of the emergency mode.

This first hardware phase will be followed at the beginning of 1981 by an analytical study phase, in which all the systems analyses needed to guarantee both compatibility with Spacelab and safe and reliable operation in orbit will be performed. The availability at that stage of inputs from already tested hardware will be a considerable advantage. Moreover, if design modifications turn out to be needed as a result of the systems analyses, these can still be incorporated without the constraints of a flight-hardware phase.

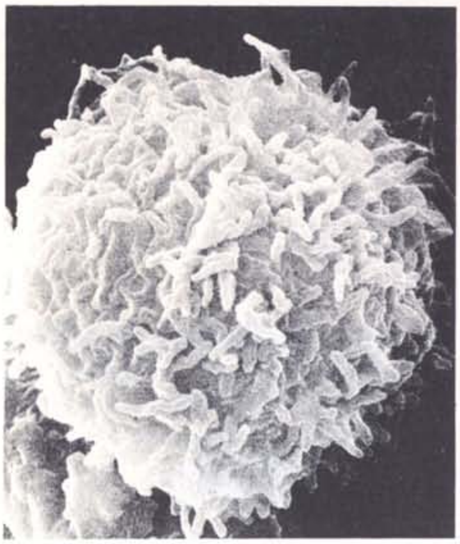
Finally, it will be possible to perform the last phase, i.e. the final development to flightworthy design, the qualification for flight and the manufacture of flight hardware on reliable and safe systems design, on already tested hardware, and on verified interfaces.

Current development status
For the first stage of PHM development, namely the design adaptation and preliminary payload-accommodation studies, two proposals from Saab-Scania (Sweden) and Dornier System (Germany), were selected. The study results from both companies successfully demonstrated the suitability of their designs for the PHM. This first phase was concluded in June 1979.

The Dornier System design was selected for the demonstration model phase, which was begun in late 1979. A design review of the detailed design of the PHM and its test equipment, and of the performance-demonstration plan, was successfully conducted in July. Fabrication of the demonstration model is presently underway and will be completed later this year. Environmental and performance testing will take place at the contractor's site before the end of the year and an operational demonstration of the hardware at ESTEC is planned for 1981.

The ESA funding for this study is complemented by Dornier-sponsored effort, particularly as regards completeness of the demonstration hardware and its extension to an autonomous, stabilised pointing mount. The demonstration at ESTEC will include operation of the mount in stabilised pointing mode under sun-sensor control, as well as in the PHM mode.

Because of the PHM's inherent growth capability, with the experience gained in its manufacture, testing and operation it will be possible to uprate it in the future into a fully stabilised pointing mount comparatively inexpensively.



White Blood Cells in Space – An Experiment for the First Spacelab Mission

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Post-flight biomedical studies of the crews of American and Soviet space missions have revealed diminished lymphocyte reactivity. Lymphocytes constitute approximately 30% of the white cells in human blood and play an important role in maintaining immunity against infection. The objective of the European experiment, titled 'the effect of weightlessness on lymphocyte proliferation' (experiment number 1 ES 031), is to test the reactivity of human lymphocytes in-vitro during the first Spacelab mission.

Any weakening of a space crew's immunity to infection would represent a serious hazard during flight and the efficiency of the immune response has therefore been tested for crew members of past missions. However, it has not yet been possible to draw a clear conclusion from the available data and further investigation is needed. With the coming of the Space Shuttle and probably later of new large space stations, the problem is becoming a very real one, because the opportunity to work and to stay in space will be offered to a broader community of scientists and technicians than hitherto.

What are lymphocytes?

Lymphocytes are the cells in our blood responsible for the immune response, which reacts to body-foreign substances called 'antigens'. Structures (receptors) that specifically recognise the antigens are localised on the cell surface. The interaction between antigens and receptors triggers lymphocytes to proliferate and to produce antigen-specific antibodies. The diameter of resting cells, which is about 5 μm, increases in activated lymphocytes to 15 μm. Infectious bacteria are typical antigens recognised by lymphocytes.

A similar reaction can be triggered in-vitro when lymphocytes are exposed to a number of substances called mitogens. Maximum activation is usually observed on the third day of culture. The activation can be accurately measured by incubating the cultures with a radioactive constituent of the cell. Tritiated thymidine is a component of desoxiribonucleic acid, a kind of biological software in which all information needed by the cell is stored. Thymidine is incorporated into activated cells at a much higher rate (100 to 200×) than into resting cells. ^{3}H-thymidine is easily measured in a liquid scintillation counter.

The transition from resting status to stimulated lymphocyte is an example of cell differentiation. The in-vitro activation of lymphocytes by mitogens can therefore be regarded as a good model for testing the efficiency of the immune response and for the study of the mechanism of cell differentiation, the latter being one of the most interesting topics in biology today.

Scientific background

It was disclosed in 1973 that lymphocytes taken from the blood of cosmonauts on the Soyuz-6, 7 and 8 flights were less reactive to mitogens than before their flights. This finding was confirmed by experiments on lymphocytes from the crews of all three Skylab missions and from the Apollo-Soyuz Test Project. However, no such effect was apparent after the Apollo missions. Experiments performed with rats on the Soviet biosatellite Cosmos 782 by US scientists showed little or no effect of the space environment on the immune system.

Any analysis of these partially contradictory results must take into account whether the exposure to zero gravity occurred with isolated cells in-vitro or directly in-vivo, since only in-vitro systems allow the identification of gravity or weightlessness effects per se. We, therefore, started our laboratory investigations with a series of tests on

Figure 1 – The logistics of Spacelab experiment 1 ES 031

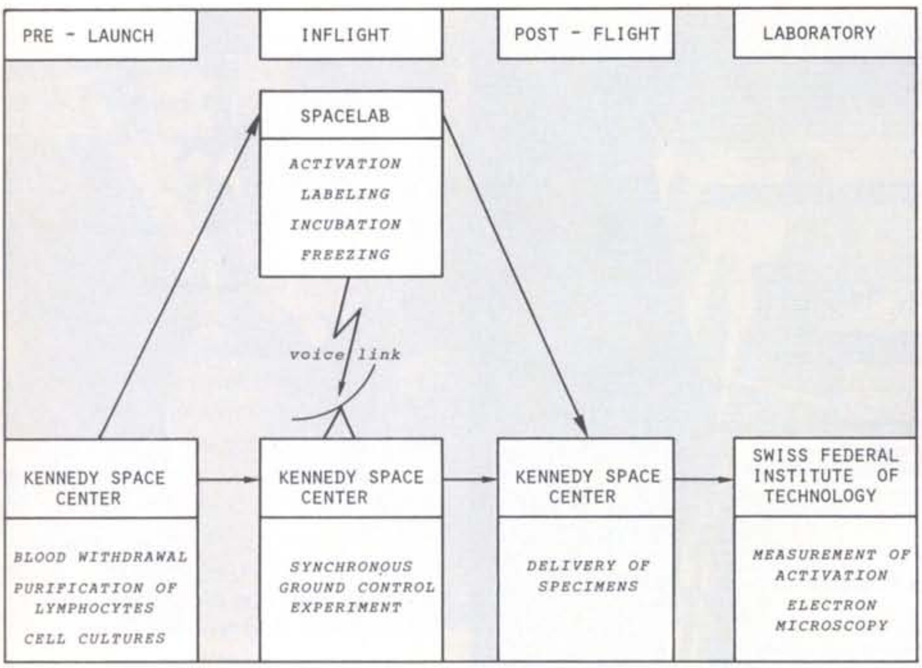


Figure 2 – The cell-culture chambers and chamber block

lymphocytes cultured in-vitro. The programme involves ground-based simulations at high and low gravity, as well as experiments to be performed aboard Spacelab. We used concanavalin A (Con A), a protein extracted from the jack bean (canavalia ensiformis) as mitogen.

High-gravity conditions (2, 4 and 8 g) were generated using a centrifuge and low gravity was simulated in a fast-rotating clinostat (the clinostat does not generate true zero-gravity conditions, but it does provide useful indications of the possible effects of microgravity on living systems).

We found that rat and human lymphocytes react remarkably faster towards Con A at high gravity than in the 1 g controls. Maximum activation was observed on the second day of culture, instead of on the third as usually observed at 1 g. In addition, the level of activation was often higher at high gravity than at 1 g. When cells were cultured in the clinostat, we found that Con A activation was depressed by 50%. Ultrastructural analysis by electron microscopy suggests that the gravity environment interferes with some still unknown biological cycles in the cell. High gravitation seems to accelerate certain cell processes, including cell death, whereas low gravity appears to stop cell development at an early stage.

The phenomena observed can be related to changes in the cell shape, to an altered distribution of cell organelles, or to a change in the rate of cytoplasmic streaming. We are still far from explaining the effect observed and we hope to gain more information through experiments on Spacelab.

Experimental approach

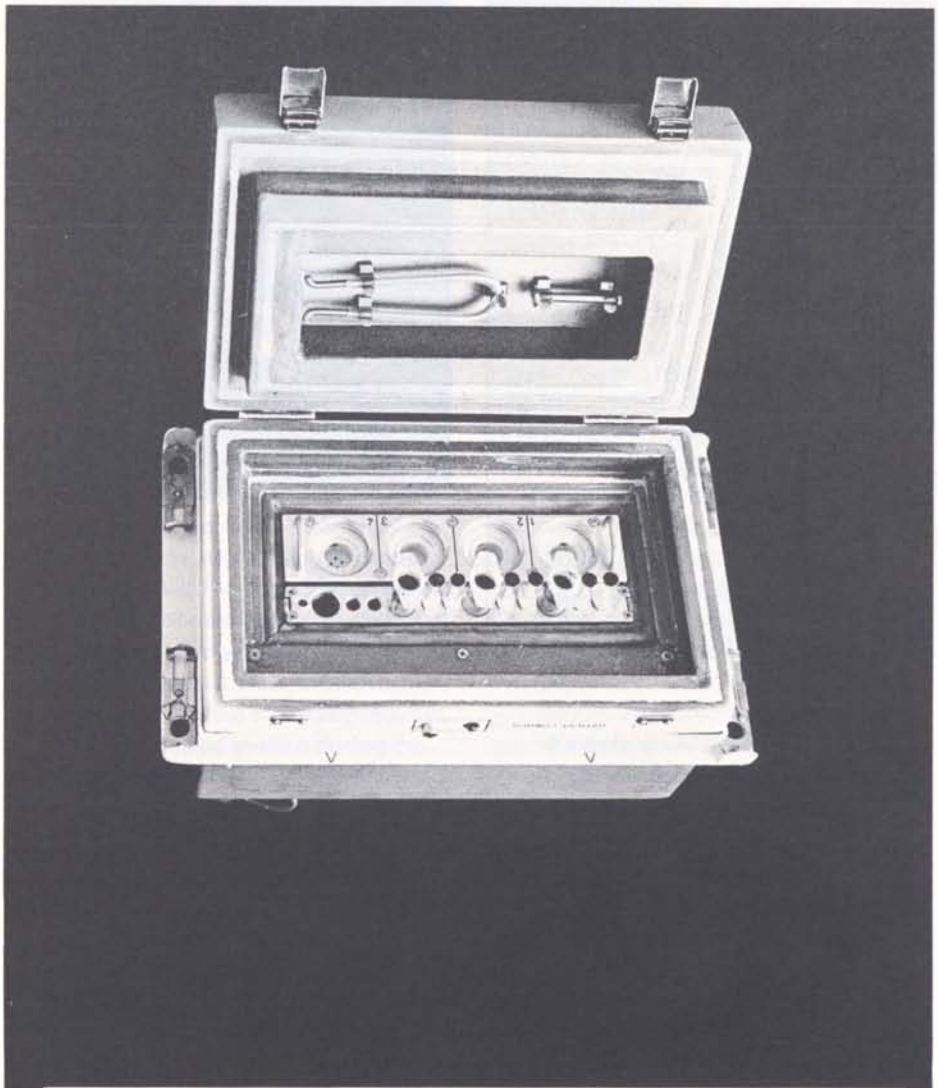
The essential operations of Spacelab experiment 1 ES 031 are outlined in Figure 1. Our team will be responsible for all ground operations at Kennedy Space Center, at a biological laboratory provided by NASA. On launch day venous blood will be taken from a healthy donor. The lymphocytes will be purified by standard procedures and set in cultures, i.e. in a medium containing all the substances necessary to keep cells alive (salts, aminoacids, blood serum, vitamins). One portion of the culture will be retained for a ground-control experiment, the other portion will be sealed into four cell-culture chambers (Fig. 2). The cultures are to be placed in a carry-on incubator (Fig. 3) kept at 37°C, which will be stowed in the Shuttle Orbiter cabin 8 h before take-off (late access).

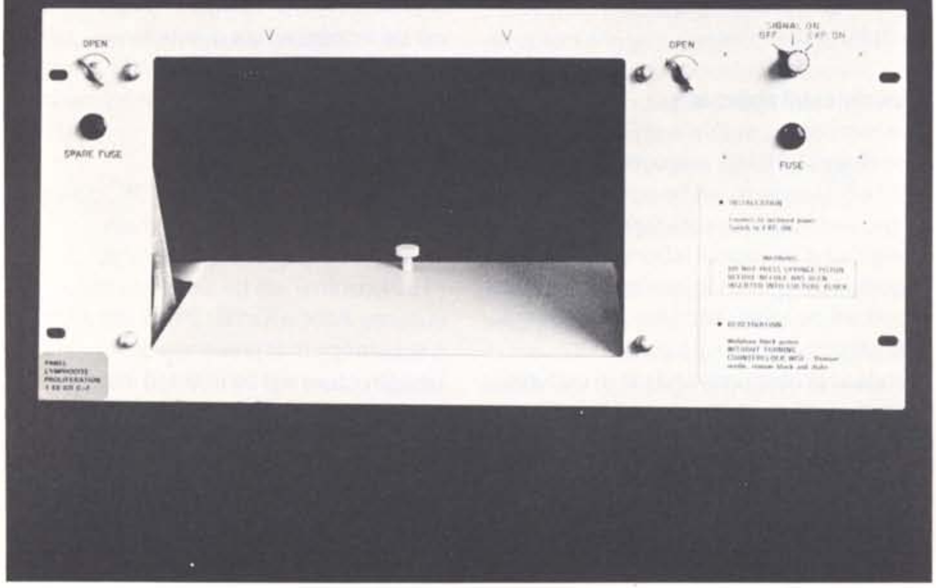
Once the Shuttle/Spacelab are in orbit, a crew member will activate the experiment by injecting the mitogen Con A into the four chambers using the syringes contained in the incubator (Fig. 3). When the Spacelab module becomes accessible, about 12 h after launch, the incubator will be transferred to the module, fixed to its front panel (Fig. 4), mounted into rack no. 4 and connected with the on-board power. Temperature will be monitored via a remote acquisition unit (RAU) connection in the Payload Operations Control Center at Johnson Space Center in Houston.

After 70 h of incubation at 37°C, during which the experiment will remain unattended, the radioactive label (^{3}H-thymidine) will be added to the cultures. After a further 2 h of incubation, a substance that preserves cell ultrastructure will be injected into the cultures. The culture block will then be removed from the incubator and stowed in a freezer precooled by liquid nitrogen. The biological specimens will be handed out to the respective investigators within 24 h of the Shuttle's landing.

Figure 3 – Incubator with cell culture block, syringes and other instruments

Figure 4 – Front panel which fits into a single rack in the Spacelab module





The parallel ground control experiment will be run with a 1 h delay, coordinated by a voice link with the Spacelab crew, to allow for possible blackouts and contingencies.

The frozen cells will be transported to our laboratory in Zürich. After careful thawing, cell activation will be determined by measuring the amount of radioactivity incorporated into each cell culture. Ultrastructure will be analysed by thin section, freeze fracture, and scanning electron microscopy. We will also recover some viable cells and try to culture them further in-vitro.

Comparison of the data from the Spacelab flight and the ground experiment should provide valuable information on the efficiency of the immune system in space.

The hardware

The flight equipment consists of three main items:

- The front panel (Fig. 4), which carries the electronic box with the connector to the remote acquisition unit and to Spacelab's powerbus.
- The incubator (Fig. 3), consisting of a carry-on box (26 × 17 × 17 cm^3, and weighing 3.5 kg) in which the temperature can be kept at 37°C, with either battery power (up to 24 h) or Spacelab power (28 V DC).
- The cell-culture chambers and the chamber block (Fig. 2), which were the most critical items to develop.

Lymphocytes are cells that need particular material and surface properties for survival in-vitro. In addition, the shape of the vessel plays an important role in lymphocyte activation. About 40 materials (metals and plastics) were tested for compatibility with the ESA/NASA safety requirements and with the biological properties of the cells. The injections of mitogen, radioactive label and freezing preservative are to be made through a silicon rubber disk in the piston of the culture chamber. The piston's movement

Figure 5 – Shuttle/Spacelab crew members training at ETH-Zürich. From left to right: W Ockels, A Cogoli, U Merbold, M Lampton, O Garriott, B Parker, B Lichtenberg and C Nicollier

compensates for any volume change in the chamber without generating over- or underpressure.

The syringes are set in a rack fixed in the incubator (Fig. 3). The whole experiment weighs 5.5 kg, the total power consumption is 0.6 kW/h, and 57 min of crew time are needed for experiment operation.

Conclusion

The ETH experiment should represent the first step in a programme of biomedical investigations using Spacelab. A more complicated experiment based on the study of lymphocytes from crew members before, during and after flight has already been selected by NASA as a candidate for a subsequent dedicated life-sciences mission.

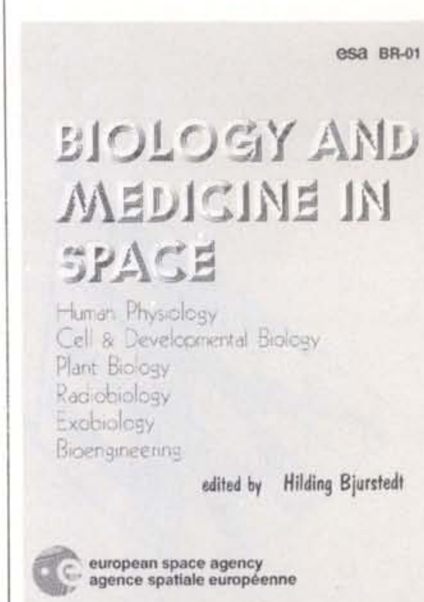
The data collected on the first and subsequent Spacelab missions should provide conclusive evidence regarding the efficiency of the human immune system during and after spaceflight. The use of cultures in-vitro will allow us to discriminate between any indirect effects of stress during the flight and the effects of zero-gravity itself on the lymphocytes.

Acknowledgement

The project is supported financially by the Swiss National Science Foundation. The experiments in the clinostat were performed in collaboration with W. Briegleb of DFVLR (Bonn) and the electron microscopy studies with M. Müller of ETH.

Some vibration and load tests were conducted by the Swiss Federal Laboratory for Materials Testing and Research (EMPA), Dübendorf. A number of qualification tests have been and will be performed by ESTEC (Noordwijk). All experiment activities are being coordinated in collaboration with ESA's SPICE (Spacelab Payload Integration and Coordination in Europe) office in Porz-Wahn (Germany).

Recent documentation from ESA Scientific & Technical Publications Branch



The Role of the L-Sat Programme in the Evolution of European Communications Satellites

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With the current rapid growth in satellite-based communications on a global scale, it is comparatively difficult to predict the future evolution of individual market sectors with accuracy although the general positive trend is clear. Nevertheless, any forward-looking applications-satellite development activities must be justified by the best possible evaluation of future prospects and guided by the best possible prediction of future technical and commercial requirements.

In 1979 the European Space Agency undertook a study the objectives of which were fundamentally to take stock of the implications of the dynamic growth situation on the future market for communications satellites of European origin, and hence to derive the correct orientations for any near-term development programmes to be sponsored by the Agency in this domain. It was as a result of this study last year that ESA Member States decided to embark on the definition phase of the L-Sat programme. The technical orientation of the programme originated from the results of the study, but more work has been done since and details of the programme's technical direction are continuously being adapted in the light of more recent inputs and developments in the user community. This article reports briefly on the L-Sat programme origins and objectives, provides an outline of the satellite design, and explains the role of the ESA L-Sat development programme in equipping European space industry to satisfy the future demand for communications satellites to meet a variety of foreseeable needs.

Study of market prospects

Investigations of the future global telecommunications satellite market have been regularly undertaken by various organisations and there is a general consensus that a dramatic growth can be expected in the use of satellites for various communications and broadcasting applications over the next decade or so. The survey undertaken within ESA in 1979 differed somewhat from the majority of recent surveys of predominantly American origin in that the objective was to consider the future possible market for (civilian) satellites of European origin, and in particular to establish the proportion of this potential market that would lead to requirements for a larger class of satellite. It was decided to exclude from the survey those domestic markets apparently not open to European industry. In the execution of the survey, use was made of previous market surveys, available literature, ESA files on recent contacts with user organisations and governments, and consultancy support.

Since the ESA work in the first half of 1979, and the start of the L-Sat definition phase in the autumn of the same year, the Agency has continued to look at near-term and medium-term market prospects and also at the long-term prospects which were not really covered in the above study. With particular relevance to the L-Sat programme, certain nearer term specific missions and applications have been the subject of more detailed investigations and this more pointed type of work will continue in association with the programme implementation. In addition British Aerospace, the L-Sat prime contractor, has been further assessing the satellite's market potential from a more commercial angle and this has provided inputs on satellite design requirements and will help to establish the necessary strategy for industrial marketing of L-Sat derivatives.

In summary, the market sectors that appear relevant for L-Sat derivatives are the following:

– European fixed services including the

Figure 1 – Exploded view of L-Sat, highlighting the modularity of its design

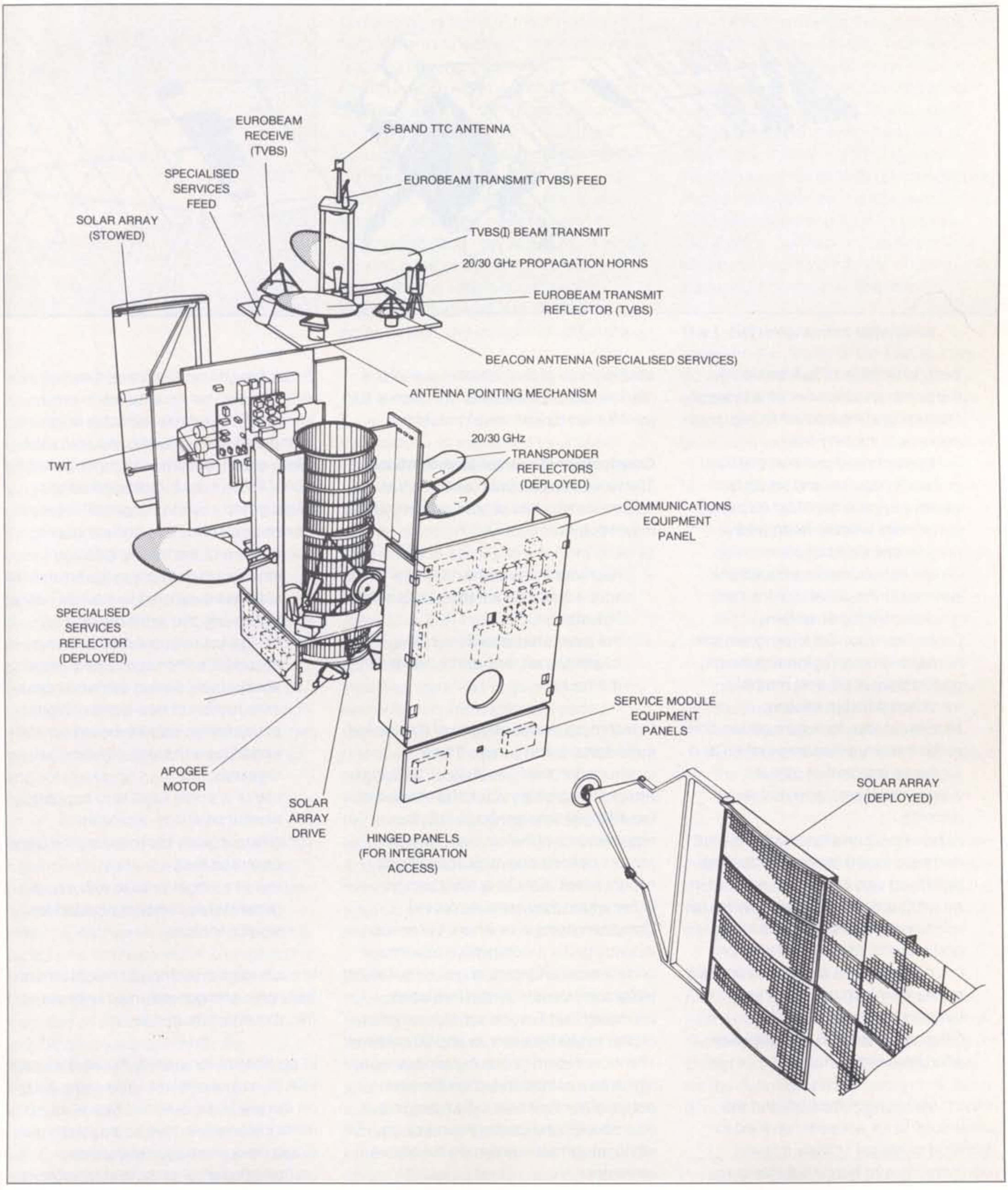
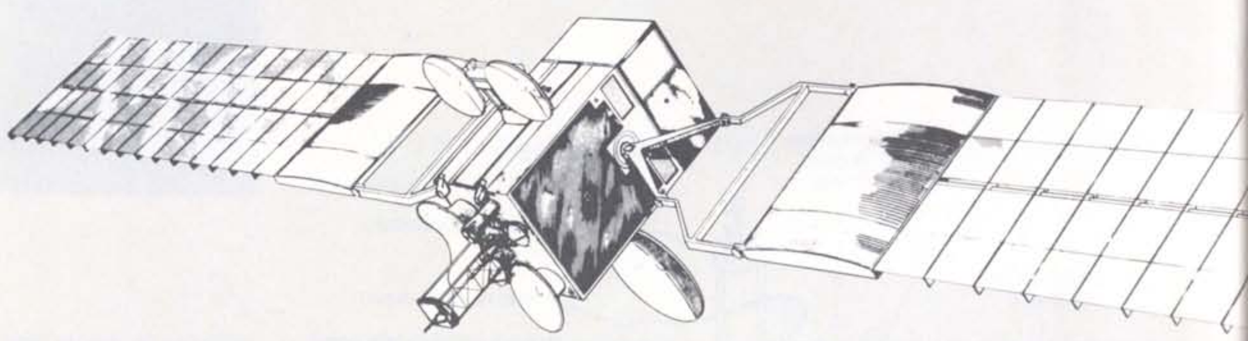


Figure 2 – L-Sat in orbital, three-axis-stabilised configuration



next generation of Eutelsat trunk telecommunications service systems (including video-conferencing), and national trunk services,
- European broadcast services that embrace national and (in certain cases) regional direct broadcasting, community broadcasting and programme distribution,
- Global telecommunications trunk services in the context of the next-generation Intelsat system,
- Global transponder leasing services for national and regional domestic application, at present mainly furnished through Intelsat,
- Mobile services for future generations of the Inmarsat maritime system and for future regional or global aeronautical and land mobile systems,
- Future non-European regional and domestic mixed services, including both fixed and broadcast services in an integrated fashion, with particular reference to developing countries and regions, as well as developed countries not in a position to entirely satisfy their own needs on an economic basis,
- Other services such as data relay and data dissemination.

In each sector, both the ESA and the prime-contractor activities have led to definition of typical or likely mission requirements and hence satellite class, assessments of the potential size of the market, and assessments of potential for penetration by European industry.

Conclusions of market investigations

The work that has been outlined has led to a series of conclusions concerning two major points:

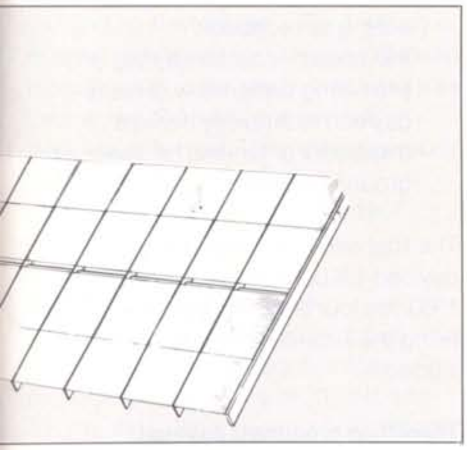
- the magnitude of the market and the scope for its penetration by European industry
- the main characteristics of the satellite types that will be needed in the future.

Concerning the magnitude of the market considered in the survey, it was concluded in the ESA study of 1979 that about 150 satellites would be needed in the 1983–94 time period to fulfil the requirements of the six main market sectors defined above. Europe could expect to sell in these market sectors either where they are a protected European domain or where European industry gains a competitive advantage on technical and/or cost grounds. Taking all factors into account, it has been estimated that Europe could reasonably expect to sell between 35 and 60 satellites. The more recent British Aerospace work, which has concentrated on the sales potential for their own L-Sat design but also covered the same ground as the ESA work, has largely confirmed the above estimates.

As for the characteristics and size of satellites that will be required to meet identified market requirements, it was found that the medium-sized, so-called 'Delta-class', satellite will be insufficient for about 85% of the future applications investigated and that larger satellites will be needed. This is due in each case to one or more of the following factors:
- increase in capacity requirements for satellites dedicated to a single service
- increasing demands on satellite design sophistication to find ways around the shortage of frequency spectrum as service demands grow
- introduction of new types of higher performance satellite-based service operating with small ground terminals
- use of a single satellite to support several payloads dedicated to different types of service for the same coverage area
- use of a single satellite with a general-purpose-type payload for several services.

In each market sector it turns out that at least one, and generally two or three, of the above factors apply.

In an attempt to quantify the situation, the ESA investigations went into some detail on the predicted needs of typical future missions and how they could relate to a single class of 'large' multipurpose platform design. A sample of ten specific



missions were selected from those fields covered by the market survey and a calculation was made in each case of specific typical payload parameters and demands, together with an estimate of the range of likely variations about this projection. The result of this exercise was the generation of a plot of payload mass versus payload power demand for the various typical cases considered, and hence derivation of the envelope of desirable payload-carrying capacity for a single multipurpose class of large platform. It was found to be possible in fact to derive two curves which envelope practically all foreseen required payload mass/power combinations, the two curves corresponding to the two extremes of full and zero payload operation during eclipse.

The conclusions of the exercise were that a platform sized to support an effective payload mass of about 530 kg would be able to support most of the foreseen missions, with some well-defined possible exceptions, and also with the exception of some multiple-mission combinations. Effective payload mass is defined here as including all effective contributors, including repeater and antenna hardware, the proportion of solar array, battery and power-conditioning electronics relevant to payload, and all other payload-specific elements. In addition to mass and power generation, communications payloads tend to be demanding in terms of thermal control requirements and these, which also have a strong bearing on satellite configuration, were quantified. Finally, the technical studies highlighted the severe requirements on flexibility of antenna accommodation which must be met. For the range of missions considered it was concluded that between one and six principal antennas would have to be accommodated. They would be of widely varying sizes and differing mechanical constructions, which could involve reflectors being rigid and fixed to the body, hinged, deployable, or unfurlable.

The above conclusions were employed to define the initial specifications for the L-Sat definition phase. The prime contractor was requested to analyse critically the results of the ESA work, to update the market survey conclusions as outlined earlier, and to elaborate in much greater detail on the requirements of a wide range of sample missions in order to check – and if necessary revise – the basic programme specifications. At the same time, ESA has pursued its own investigations of the requirements for some specific missions. Finally, the industrial team was requested to elaborate the implications of each requirement on the satellite design. The conclusions of these activities, which were largely executed during the first six months of 1980, are broadly speaking that the above defined multipurpose platform requirements are correct and realisable, and that they do correspond to a reasonable upper envelope for the majority of near/medium-term mission requirements that can be predicted today.

However, certain possibly important missions and mission combinations seem likely to exceed the above envelope in terms of mass/power combination, and the general recent evolution in the telecommunications satellite business makes it seem worthwhile considering the incorporation of some further growth potential in the L-Sat design. In practical terms, this would imply ensuring from the outset that the satellite design could grow to match increased levels of demand with the minimum of modifications. Work is in progress to quantify and investigate all the implications of such an increased design capability, paying particular attention to Ariane-4 and US Space Transportation System (STS) compatibility and to the impact on the less demanding mission of designing now for greater capabilities. Conclusions from this work will be incorporated into the ongoing study effort during the next months.

The L-Sat programme objectives

Based on the results of the ESA studies during the first half of 1979, and taking account of the conclusions of the three-year study of the larger class of direct-broadcast satellite (H-Sat), it was decided in July 1979 to propose to the ESA Member States the start-up of the L-Sat programme, with two main objectives:

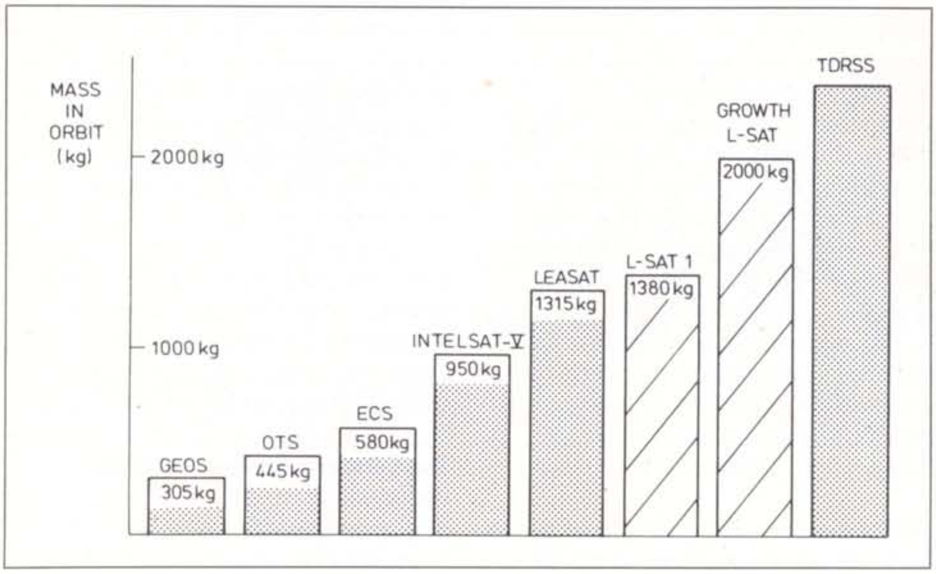
- development and in-orbit demonstration of a large multipurpose platform able to satisfy the range of foreseen future mission requirements on a cost-competitive basis
- development of communications-payload hardware related to future mission needs and in-orbit demonstration of new types of communications systems to stimulate the introduction of new satellite-based services and techniques.

The work that has been performed since certain Member States approved the start of the definition phase has confirmed the validity of these objectives and the strong interest in their continued pursuit.

There are now nine countries participating in the L-Sat programme: Austria, Belgium, Canada, Denmark, Italy, Netherlands, Spain, Switzerland and the United Kingdom. The approved budget for the definition phase is about 15 million account units* and this phase is

* 1 accounting unit = ± 1.2 US $

Figure 3 — In-orbit mass of L-Sat compared with those of other telecommunications satellites



scheduled to continue until early spring 1981, when the decision to proceed to the development phase has to be taken. A launch date towards the end of 1984 is presently predicted, although precise definition of the target launch date depends to some extent on payload definition, the launch vehicle, and the availability of a launch opportunity.

Satellite design outline

It is beyond the scope of this paper to do more than trace a general outline of L-Sat's design, which is conceived to meet the multipurpose objectives of accommodating a range of future missions. The platform is able to provide basic service functions for communications payloads with sunlight DC power demands in the range 2–7 kW, with eclipse power demands of up to 3.5 kW, and with radiating-area requirements of up to 9 m^2. The configuration geometry will permit the accommodation of all foreseen types of antenna farm while still remaining compatible with launch by Ariane and by the Shuttle. The platform is of an advanced mass- and cost-effective design, with new technologies introduced wherever these have proved to be of fundamental benefit in improving payload-carrying capacity, reliability and/or flexibility at a reasonable price. Figure 1 is an exploded view of the satellite, which illustrates the design modularity rather clearly, while Figure 2 shows L-Sat in orbital, three-axis-stabilised configuration. To put the L-Sat class of satellite into perspective, Figure 3 shows its synchronous-orbit mass in relation to that of some other past and current programmes. Figure 4 shows the L-Sat solar array dimensions compared to those of other programmes.

In the case of an Ariane launch, L-Sat is to be matched for the first launch to the Ariane-3 capacity of 2420 kg at injection, but it will also be adaptable to the capabilities of Ariane-2 and Ariane-4 (single- and dual-launch cases). The satellite is equally designed to be cost optimised for launch by the Shuttle where, for the equivalent to the Ariane-3 case, the total mass in the cargo bay would be around 8800 kg – including satellite, perigee stage and support equipment. This launch flexibility is a further example of the satellite's built-in design flexibility.

A multiple-element payload will be carried by the platform for the first demonstration flight, the choice of payload elements being based on:

– the strength of market predictions for each type of mission
– the interest in demonstrating and promoting certain new services
– payload technology benefits
– availability of funding for space and ground segments.

The final selection of the demonstration payload will take place before the end of 1980, the four elements described below being the subject of the current definition studies.

Television broadcast payload

It is envisaged that L-Sat will carry a two-channel TV payload suitable for high-power, direct-to-home broadcasting in the 11.7 – 12.5 GHz band. One channel would be employed for pre-operational services in Italy, while the other would be steerable to support experiments and demonstrations throughout Europe. A single 'European' programme for reception over the whole of Europe by community/cable-head installations could also be transmitted.

Specialised services payload

The term 'specialised services' is employed here to describe the range of types of service primarily adapted to business and industrial users, including data transmission, facsimile, electronic mail and videoconference applications. Use of L-Sat to provide specialised services employing advanced concepts and covering the whole European zone is foreseen, operating with small terminals on private or public premises and with antenna diameters of 3 m or less. Uplinking will be in the 14.0 – 14.25 GHz band and downlinking in the 12.5 – 12.75 GHz band, using a multibeam antenna. This concept is intended to prefigure the second generation of European systems (Telecom-1 and possibly ECS representing the first generation) and to prove the key technologies and systems that will be needed.

20/30 GHz communications payload

In view of the predicted future use of the 20/30 GHz bands for the more bandwidth-demanding services, an L-Sat payload to develop techniques for utilisation of these frequencies is under study. It incorporates three active channels and two fully steerable antennas. The primary missions to be satisfied would be video-conferencing and communications-system trials.

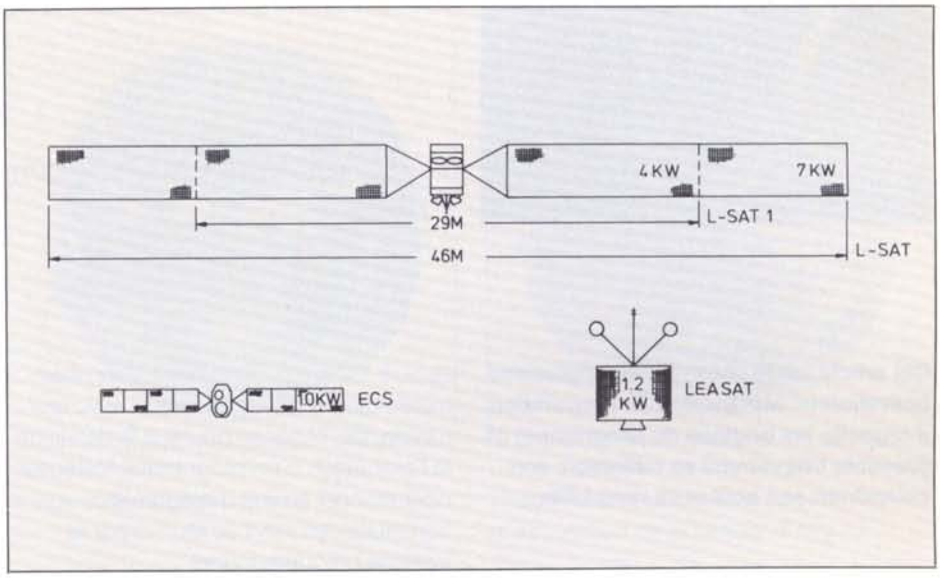
20/30 GHz beacon payload
To obtain the data needed for future satellite system design concerning propagation conditions at 20 GHz and 30 GHz, the L-Sat payload would include a beacon package giving Europe-wide coverage and supporting the range of required types of measurements.

Future role for the L-Sat platform
As already emphasised, the L-Sat platform is being designed not for the requirements of the first demonstration mission outlined above, but for those of the full range of missions that could be satisfied by European space industry over the next decade and beyond. This range would span the complete panoply of service types and of potential customer organisations. As explained earlier, the current challenge is to ensure that the platform design finally adopted at the beginning of next year for the development phase is optimised for those applications that have the best 'sales prospects'.

Once this has been settled and the programme approved, the energy of the ESA and industrial teams will be devoted to the development programme proper with a view to an early launch and follow-up test and demonstration programme, striving for cost-effectiveness without sacrificing programme objectives or technical quality.

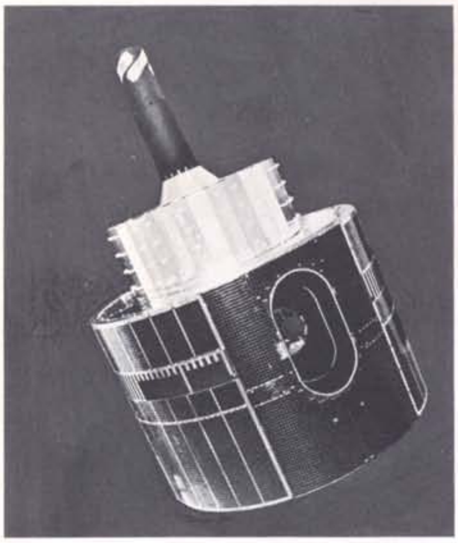
Thereafter, the scenario that ESA has in mind would be that, in the course of the development programme and beyond, a series of applications for the L-Sat system/platform design would be identified and would present bidding opportunities for the industrial team.

Figure 4 — Array dimensions and power figures for L-Sat and other satellites



Bidding would normally be direct by industry to the customer organisation although ESA might in some cases play a positive role as consultant to the customer organisation and/or as procurement authority on behalf of a customer organisation, drawing on experience acquired during the L-Sat development phase as well as in other programmes. In addition certain future 'ESA' missions may be identified which could be effectively carried by derivatives of the L-Sat platform, either 'piggy back' on a platform primarily dedicated to a paying outside customer or on a dedicated ESA flight justified in terms of a further group of new missions meriting promotion and requiring in-orbit technology and systems demonstration. However, one would expect such dedicated ESA missions to be rather infrequent and indeed perhaps associated with simultaneous upgrading of the platform capabilities and technologies if this proves to be worthwhile in the longer term.

Future relevance of the first L-Sat mission
As mentioned earlier, it is planned to include four demonstration missions on the first L-Sat to be launched. Details are yet to be finalised, but the principle is that each of the missions supported by L-Sat 1 would permit tests and demonstrations that would prepare the ground for future dedicated operational missions. It is therefore envisaged that the L-Sat demonstration would give rise in the not-too-distant-future to operational satellite broadcasting missions for certain countries, to the next generation European specialised service and trunk service missions, and to operational application of the new 20/30 GHz bands, all re-using the L-Sat platform if this proves to be the best solution from a technical and cost viewpoint. There are, moreover, several other candidate demonstration missions to be accommodated either on L-Sat 1 or on a near-term successor, designated L-Sat 2, which would similarly give rise to dedicated derivatives. In the broader context, the Agency sees the L-Sat programme as a key step in the development and promotion of telecommunications and broadcasting by satellite, to the ultimate benefit of both the participating European space industries and the user communities.



Le programme opérationnel Météosat

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Cet article fait le point sur le programme opérationnel Météosat et sa préparation. Il rappelle les origines du programme et présente brièvement sa définition, son calendrier, son coût et sa rentabilité.

Depuis 1979, à la demande de services météorologiques européens et avec leur assistance, l'Agence poursuit la définition et l'évaluation d'un programme Météosat opérationnel en vue d'assurer la continuité des services fournis par le système préopérationnel.

Ces activités préparatoires ont consisté principalement à:

- établir en mars 1979 des projets d'accord et de protocole entre l'Agence et les services météorologiques concernés;
- obtenir en février 1980 une proposition technique et financière de la SNIAS, maître d'oeuvre du consortium COSMOS pour la réalisation des satellites préopérationnels Météosat 1 et Météosat 2, portant sur la fourniture d'une série de satellites opérationnels;
- procéder à des études internes jusqu'en mars 1980 portant principalement sur la fourniture du segment terrien et l'exécution des opérations en utilisant les services de consultant de la firme canadienne Macdonald Dettwiler and Associates pour le système de calcul au sol;
- passer un contrat d'étude avec EUROSAT pour estimer la rentabilité d'un tel programme dans les années 1980;
- remettre en janvier 1980 aux services météorologiques intéressés une estimation préliminaire du coût du programme opérationnel et en août 1980 une proposition finale.

Cet article propose une synthèse de la situation concernant ce programme en août 1980: genèse, définition de base et options, calendrier, coût et rentabilité. Il suppose que les différents aspects du programme préopérationnel déjà présentés dans les précédents bulletins ESA sont connus (en particulier les numéros 11, 16, 21).

Genèse du programme

En 1972 le programme de développement Météosat lancé par les autorités spatiales et météorologiques françaises était 'européanisé' grâce à des arrangements juridiques conclus par l'ESA (ESRO à l'époque) avec huit de ses Etats membres (Allemagne, Belgique, Danemark, France, Italie, Royaume-Uni, Suède et Suisse) et le CNES.

En 1973, l'Agence confiait à la SNIAS (Cannes) le développement et la réalisation de deux satellites préopérationnels, Météosat 1 et Météosat 2, et passait avec l'industrie européenne les premiers contrats pour le développement et l'installation des divers éléments du segment terrien.

L'année 1975 voyait la mise au point par le Conseil directeur du programme de la version définitive du Protocole Météosat assignant à l'Agence la responsabilité de l'exploitation du système pendant les trois années suivant le premier lancement réussi du satellite. Tous les Etats membres participants, à l'exception de la Suède, ratifiaient ce Protocole.

Au début de 1977, le Conseil directeur du programme approuvait le lancement de Météosat 2 en tant que passager principal

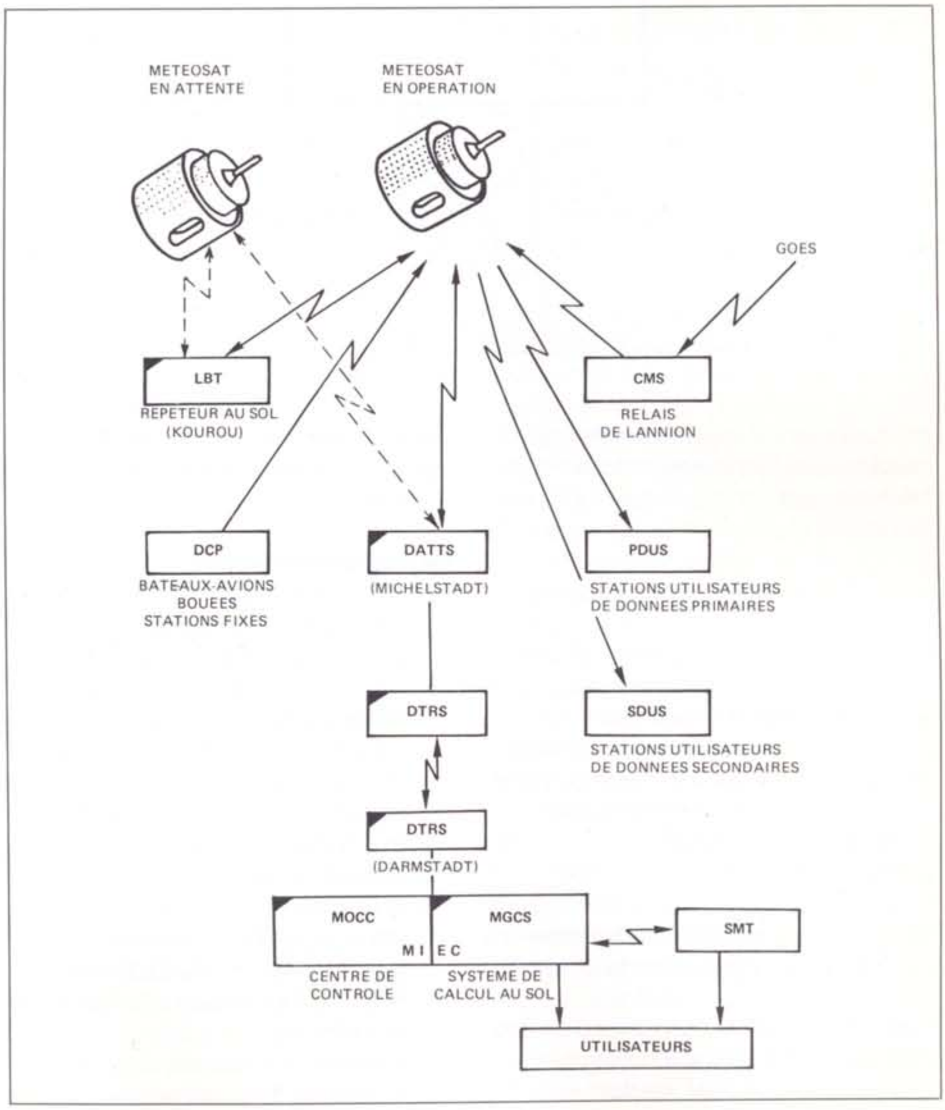
Figure 1 — Les trois images transmises chaque demi-heure par Météosat

Image dans le spectre visible

Image infrarouge thermique

Image infrarouge dans la bande d'absorption de la vapeur d'eau

Figure 2 — Organisation du système Météosat

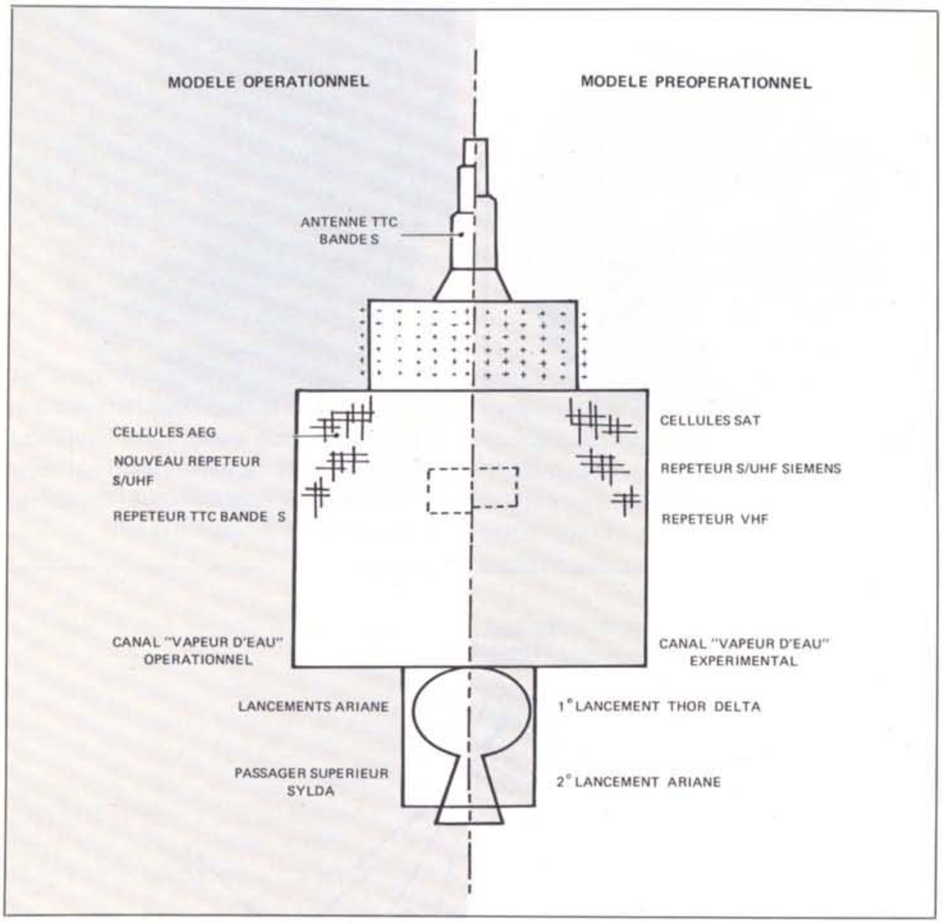


du troisième tir expérimental de la fusée Ariane (L03).

Le 23 novembre 1977, Météosat 1, premier satellite météorologique européen, était lancé par une fusée Thor-Delta de Cap Canaveral. Durant deux années, au fur et à mesure que le segment terrien parvenait à la maîtrise du traitement des images et des informations météorologiques, les différentes missions du système Météosat s'avéraient très réussies.
Malheureusement, le 24 novembre 1979, à la suite d'une panne dans ses circuits d'alimentation, Météosat 1 cessait de transmettre les images brutes du globe terrestre (mission no. 1) et de diffuser les images traitées au sol (mission no. 2) alors qu'il continuait à assurer la collecte des données (mission no. 3).

Météosat 1 avait transmis plus de 63 000 images d'excellente qualité, prises dans trois domaines du spectre: la fenêtre infrarouge thermique, le visible et la bande d'absorption de la vapeur d'eau (Fig. 1). A la fin de 1979, le système (Fig. 2) permettait mensuellement la diffusion de plus de 13 000 formats d'images, l'extraction de 30 000 vents et 56 000 températures de surface des océans, l'archivage de 7000 produits sur bandes magnétiques et de 2000 négatifs photographiques ainsi que la collecte, le traitement et la distribution des données

Figure 3 — Les différences principales entre satellites préopérationnels et satellites opérationnels



en provenance d'une quarantaine de plates-formes. Les images diffusées par Météosat 1 étaient reçues par une dizaine de stations d'utilisateurs de données primaires et par plus de 150 stations d'utilisateurs de données secondaires.

De décembre 1978 à novembre 1979, Météosat 1 participait également au succès de la Première expérience mondiale du Programme de recherches sur l'atmosphère globale (FGGE), comme élément du système international des satellites météorologiques géostationnaires. Ce succès a incité récemment l'Organisation météorologique mondiale à recommander fortement le maintien de ce système international.

Météosat 2 devrait être lancé au début de 1981 avec Ariane L03 et fonctionner jusqu'au début de 1984. Au-delà, les services Météosat devraient être assurés par le programme opérationnel, présenté ci-après.

Le programme de base

Le programme de base a été défini en fonction des objectifs suivants:
- bénéficier au maximum de l'expérience acquise au cours du programme préopérationnel;
- assurer la continuité des services fournis en période préopérationnelle en maintenant notamment des interfaces entièrement compatibles avec les installations utilisatrices existantes;
- offrir une grande souplesse d'exploitation pour la gestion des satellites, l'acquisition et le traitement des données;
- parvenir à un coût minimum en procédant uniquement aux changements rendus strictement nécessaires par le caractère opérationnel du programme ou conduisant à des économies.

Le programme opérationnel couvre une période de 14 années, soit une période préparatoire de quatre ans et une période d'exploitation et de prestation de service de dix ans; avec l'hypothèse d'une approbation au début de 1981, le premier lancement intervient au début de 1985 et l'objectif est la fourniture d'un service opérationnel jusqu'à la fin de 1994.

L'hypothèse de base est le lancement de cinq satellites par Ariane aux dates suivantes:

M01 – février 1985
M02 – mars 1986
M03 – juillet 1988
M04 – février 1991
M05 – février 1993

Tous les satellites du programme de base sont identiques et semblables au second modèle de vol du programme préopérationnel déjà modifié pour éviter la panne rencontrée sur Météosat 1 – à l'exception des changements principaux suivants (Fig. 3):
- le canal vapeur d'eau acquiert le statut opérationnel et bénéficie de la calibration 'corps noir' comme le canal infrarouge;
- le répéteur en bande S doit être redéveloppé selon les spécifications du modèle préopérationnel que Siemens ne souhaite plus fabriquer. Il sera en outre capable de retransmettre 16 canaux à 2400 bit/s;
- la fonction interrogation des DCP est supprimée; le sous-système de télémesure et télécommande en VHF utilisé en orbite de transfert est remplacé par un sous-système en bande S compatible avec le nouveau réseau de poursuite de l'ESA;
- les satellites sont lancés par Ariane, trois d'entre eux en passagers supérieurs du Sylda (système de lancement double d'Ariane).

Le segment terrien conserve globalement son architecture actuelle. Toutefois, certains aménagements sont prévus de 1981 à 1984 pour tenir compte du caractère opérationnel du programme exigeant en particulier la gestion d'un satellite de secours, la surveillance des produits diffusés et la réduction des coûts d'exploitation. Les aménagements principaux concernent, d'une part, la Station d'acquisition des données, de télémétrie et de télécommande (DATTS) et le Système de transmission (DTRS) et, d'autre part, le Centre de contrôle des opérations (MOCC) et le Système de calcul de Météosat (MGCS).

Pour la DATTS et le DTRS, ces aménagements portent sur:

- l'installation d'une antenne supplémentaire de 6 m de diamètre permettant la gestion du satellite de secours en orbite;
- le remplacement du calculateur assurant la gestion de la DATTS afin d'améliorer les performances et les conditions de maintenance du système;
- le rénovation du DTRS entre la DATTS et l'ESOC pour les mêmes raisons que ci-dessus;
- l'installation d'une PDUS et d'un système d'archivage approprié nécessaires à la surveillance de la diffusion des images.

Pour le MOCC et le MGCS, ils portent sur:

- la redistribution des fonctions individuelles entre les différents éléments du centre de calcul;
- l'utilisation d'interfaces micro-programmables entre certains de ces éléments pour augmenter la souplesse du système;
- le remplacement des deux unités centrales ICL 2980;
- le remplacement des calculateurs périphériques Siemens 330;
- le remplacement du sous-système de visualisation;
- la simplification du sous-système d'archivage;
- l'adaptation du logiciel aux aménagements précédents.

Les options

Le programme de base est complété par trois options facultatives:
L'option no. 1 prévoit la réalisation et le lancement de trois satellites de base ainsi qu'un lot de rechanges complet permettant d'assembler, si nécessaire, un quatrième satellite.

L'option no. 2 prévoit la réalisation et le lancement de trois satellites 'améliorés' ainsi qu'un lot de rechanges complet permettant d'assembler, si nécessaire, un quatrième satellite. Les améliorations techniques sont les suivantes:

- augmentation de la fiabilité du radiomètre entraînant une augmentation globale de fiabilité pour le satellite d'environ 0,46 à 0,56 sur trois ans;
- accroissement de l'autonomie des satellites due aux consommables (puissance électrique et fluide propulsif): la durée de vie passe ainsi de 3-4 ans à 4-5 ans;
- transmission permanente du canal 'vapeur d'eau', en mode nominal, sans dégradation des autres canaux, avec maintien en particulier de la résolution 'visible' à 2,5 km au point sous satellite;
- diminution des bruits parasites sur ce canal 'vapeur d'eau';
- amélioration de la calibration des voies IR et UV par régulation de la température du corps noir de référence embarqué à une valeur voisine de 305 K.

L'option no. 3 prévoit de compléter le programme de base par la mission Distribution de données météorologiques (MDD) exécutée à titre expérimental par le satellite Sirio 2 de 1981 à 1983. Le but de la mission MDD est d'établir des liaisons bilatérales entre les petits terminaux au sol de deux réseaux interconnectés: les Centres météorologiques nationaux (NMC) et les Centres régionaux de télécommunications (RTH) en Afrique, et entre ceux-ci et certaines stations de liaison du réseau principal du Système mondial de télécommunications (SMT).

Des études récentes montrent que la mission MDD peut être remplie par 16 canaux séparés opérant à 2400 bit/s et qu'un des canaux de diffusion en bande S de Météosat peut être adapté, avec des modifications minimes, à la retransmission de ces canaux.

Les principaux attraits de cette nouvelle solution sont:

- impact minimal au niveau des interfaces satellite, surtout en ce qui concerne les besoins en puissance électrique;
- faible risque de développement, résultant de la réutilisation de fonctions Météosat existantes;
- compatibilité avec le segment terrien actuellement développé dans le cadre du programme Sirio 2/MDD.

Cette nouvelle solution est rendue possible grâce aux marges de liaisons confortables obtenues sur les canaux de diffusion de Météosat. La réserve de puissance RF existante dans Météosat est suffisante pour alimenter la mission MDD sans altérer la performance de la mission de base.

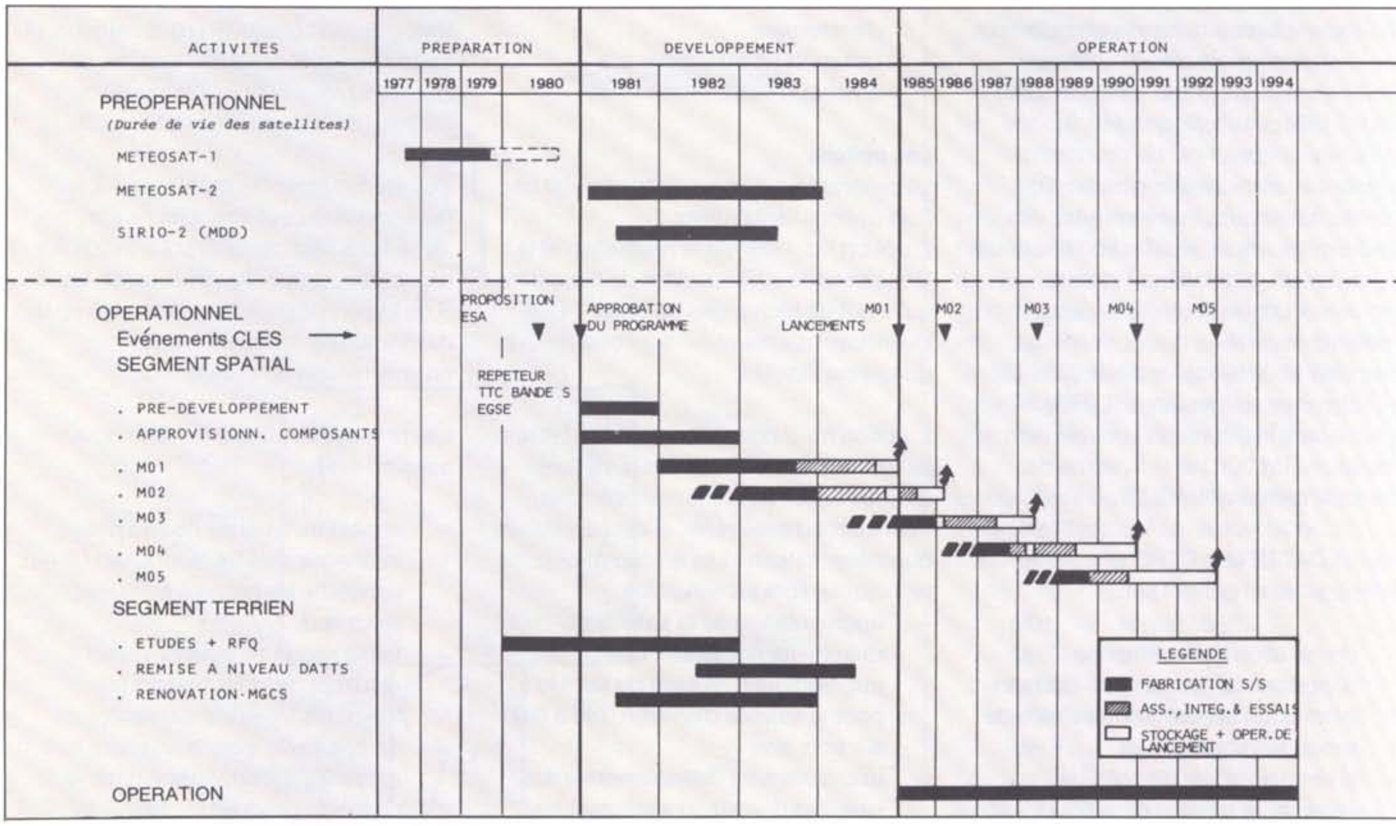
Compte tenu de la modification très minime exigée à bord des satellites pour préserver la possibilité d'exécuter cette mission, cette modification est incluse dans le programme de base. Par contre, les investissements 'sol' et les frais d'exploitation de cette mission font l'objet de la présente option. Ils pourront être approuvés plus tard avec un préavis de 15 mois.

Calendrier d'exécution

L'année 1979 a été mise à profit par l'Agence pour la définition technique et l'évaluation financière du programme au moyen d'une consultation industrielle et d'études internes.

Figure 4 — Calendrier du programme de base

Figure 5 — Synthèse des calendriers et des coûts



Programme	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	COUT TOTAL
Référence (cinq satellites de référence) Profil de paiement	10.1	43.4	39.3	32.6	36.1	30.5	21.9	25.7	16.5	20.5	19.9	16.9	11.0	10.00	334,4 MUC
Lancements/exploitation (simple-double-simple-double-simple)															
Option 1 (trois satellites de référence)	10.1														239,0 MUC
Lancements/exploitation															
Option 2 (trois satellites améliorés)	10.1														260,8 MUC
Lancements/exploitation															
Option 3 MDD Investissement sol Exploitation	Investissement sol, préavis de 15 mois: 0.595 MUC; Exploitation: 0.305 MUC/an														

L'année 1980 a débuté par l'envoi en janvier aux directeurs des services météorologiques des Etats membres d'une estimation préliminaire du coût du programme, suivi, cet été, par l'envoi d'une proposition officielle. Nous entrons maintenant dans une phase de concertation entre les gouvernements des Etats intéressés, leurs services météorologiques et l'Agence afin de mettre en place ce programme et finalement l'approuver.

On prévoit que l'exécution du programme de base ou des options pourrait se dérouler selon les calendriers présentés à la Figure 4. Il apparaît dès maintenant une solution de continuité minimum de l'ordre d'une année entre le dernier satellite préopérationnel, Météosat 2, et le premier satellite opérationnel.

Coût et rentabilité

Le coût du programme de base s'élève à 334 millions d'unité de compte (MUC, prix mi-79, taux de change 80), répartis approximativement comme suit:

Cinq satellites avec rechanges	114
Cinq lancements dont deux avec Sylda	124
Modifications et maintenance du secteur terrien	9
Opération sur 10 années	60
Gestion du programme	27
Total:	334 MUC

Les coûts du programme de base et des options sont résumés sur la Figure 5.

La rentabilité du programme a été évaluée par EUROSAT pour le compte de l'Agence en 1979 de la manière suivante: on a d'abord estimé l'amélioration des prévisions météorologiques provenant de l'utilisation du système Météosat pendant la décennie opérationnelle; on a ensuite recherché, par une méthode d'échantillonnage et d'extrapolation, les économies potentielles permises par l'amélioration des prévisions dans les principaux secteurs économiques des pays de la zône de couverture.

La rentabilité du programme est alors exprimée par le rapport 'Economies ou Bénéfices Potentiels/Coût du Programme'.

L'étude conduite de façon prudente, avec l'assistance d'experts météorologiques et de responsables des secteurs économiques échantillonnés – l'agriculture en France et la construction en Allemagne – a montré que la rentabilité du programme pourrait être supérieure à 16 pour l'ensemble des secteurs économiques, en Europe/Afrique/Moyen-Orient, pendant la décennie opérationnelle. L'agriculture et la construction à elles seules recueillent les 2/3 des bénéfices. Pour l'Europe seule, cette rentabilité varie de trois à huit selon que l'on utilise le système Météosat avec prudence ou avec pleine confiance. Le tableau hypothétique suivant indique quelles seraient les participations et les rentabilités approximatives pour les pays européens ayant financé le programme préopérationnel, plus les Pays-Bas et l'Espagne, dans le cas d'une utilisation prudente du système.

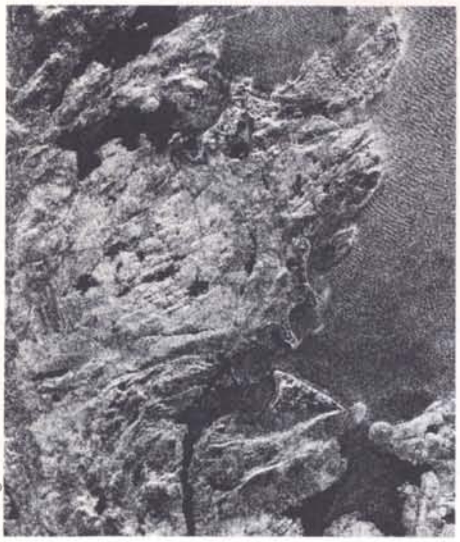
Pays	Participation au programme opérationnel (en %)	Rentabilité potentielle
Allemagne	25,57	2,6
Belgique	4,29	2,3
Danemark	2,29	3,3
Espagne	4,73	7,8
France	21,07	3,4
Italie	12,19	4,3
Pays-Bas	5,60	1,1
Royaume-Uni	15,35	1,6
Suède	4,41	1,7
Suisse	3,96	1,7
Rentabilité globale		2,9

Conclusion

Il convient de retenir au moins trois arguments en faveur du programme opérationnel Météosat. D'abord, le succès du programme préopérationnel. La panne accidentelle de Météosat 1, après deux annés d'excellent fonctionnement, ne doit pas masquer la réussite du programme illustrée par la qualité des produits météorologiques fournis et l'intérêt des utilisateurs qui se sont dotés de plus de 160 stations de réception.

Ensuite, l'indéniable réussite du Programme de recherches sur l'atmosphère globale (GARP) et particulièrement de la Première expérience mondiale du GARP grâce à la contribution du système international des satellites météorologiques géostationnaires. Ce succès a incité récemment l'Organisation météorologique mondiale à fortement recommander le maintien du système international.

Enfin, l'étude de rentabilité du programme opérationnel, conduite de façon prudente, a estimé qu'elle pourrait être supérieure à 16 pour l'ensemble des secteurs économiques de la zône de couverture. Pour l'Europe seule, ce rapport ravie de frois à huit, disons cinq



dfvlr-gsoc

Earthnet's Experience with Seasat SAR Image Processing

J.P. Guignard, Data Handling Division, ESTEC, Noordwijk, Netherlands

A significant amount of synthetic aperture radar (SAR) data transmitted by the Seasat-A spacecraft was acquired in Europe and processed using both optical and digital techniques, and valuable experience has been gained at system level with both hardware and processing algorithms. Delivery of data has been regularly complemented by the organisation of workshops aimed at facilitating the dialogue with the potential users of such data, one of the principal merits of Earthnet's* present activities being the stimulation of European user and applications-oriented initiatives.

As the different and often unexpected applications of SAR images have emerged, optimum extraction of the images' information content has become more and more the crucial issue, not just for the Seasat data but more particularly for future SAR-carrying satellite missions, such as a European earth-resources satellite.

* Earthnet is an ESA programme the long-term aim of which is the creation of a strong and well-structured service capable of acquiring, preprocessing, archiving and disseminating remote-sensing satellite data to the European user community.

Acquisition of data

During its short lifetime, the American Seasat-A satellite provided the first opportunity to acquire, receive, process and disseminate data from a spaceborne SAR. For European reception, the UK station located at Oakhanger was upgraded to cope with Seasat's data. Unfortunately, the early failure of the satellite prevented ESA from undertaking the development of a dedicated SAR processor and alternative approaches have since been developed to process the 53 min of SAR data acquired during the satellite's operation. These 53 min represent a very large volume of data and therefore imply a particularly challenging processing task.

The JASIN experiment, performed in the North Sea just after validation of Seasat's sensors, was supported by ship, aircraft and buoy measurements to provide ground/sea-truth data. The raw Seasat data were recorded on a high-density digital 42 track Martin Marietta (HDDR) recorder (recording at 120 Mbit/s, playback 7.5 Mbit/s). The conversion of the HDDTs (high-density digital tapes, 30 000 bit/inch) to 70 mm signal film for optical processing proved an extremely delicate operation because of the large number of adjustments needed and defects (e.g. drop-outs) in the original tapes that resulted in synchronisation failures.

Conversion of HDDTs to computer-compatible tapes (CCTs, 1600 bit/inch) for digital processing called for the development of dedicated hardware. Again, the multiple corrections needed to ensure sufficient data integrity resulted in a heavy computer load.

SAR processing

Optical processing

Processing of SAR data by optical methods is characterised by the operations required to compress the extended point target histories to points or spots of light at the processor output and additional operations associated with data handling and output image data extraction. A variety of optical-processor configurations are available but we will concentrate here on the tilted-plane processor system used for Seasat-A SAR processing at the Environmental Research Institute of Michigan (ERIM).

This type of processor makes use of two telescopic lens sets in cascade, the first forming a spherical and the second a cylindrical telescope (Fig. 1). The spherical telescope re-images, in the range direction, the light focused by the zone plates of the input radar data to the processor output plane. The cylindrical telescope modifies the imaging process in the azimuth dimension to remove the anamorphic property and adjust relative scale factors. Approximately 12 000 km of 100 km swath width strip map imagery could be generated in one day using a dedicated optical processor and film-development facility.

All ESA recorded data have been optically processed ('survey processing'), the SAR data being provided in the form of strips each representing a quarter swath width 4000 km long (Figs. 2a, b). Over specific

Figure 1a – Schematic of a Seasat synthetic-aperture radar (SAR) optical-processor system

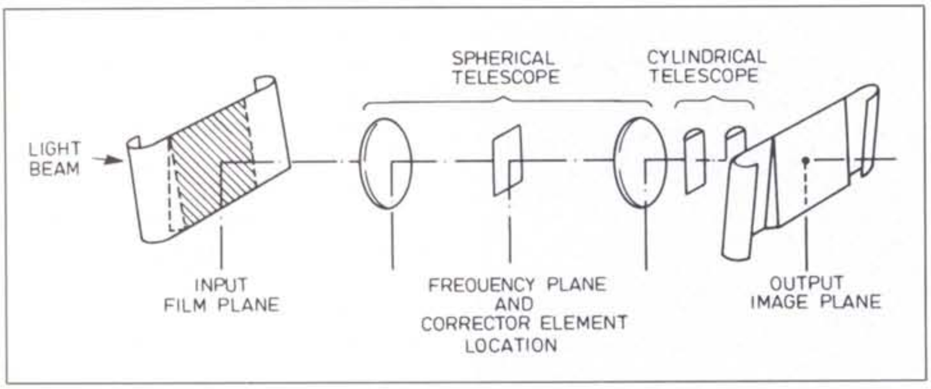
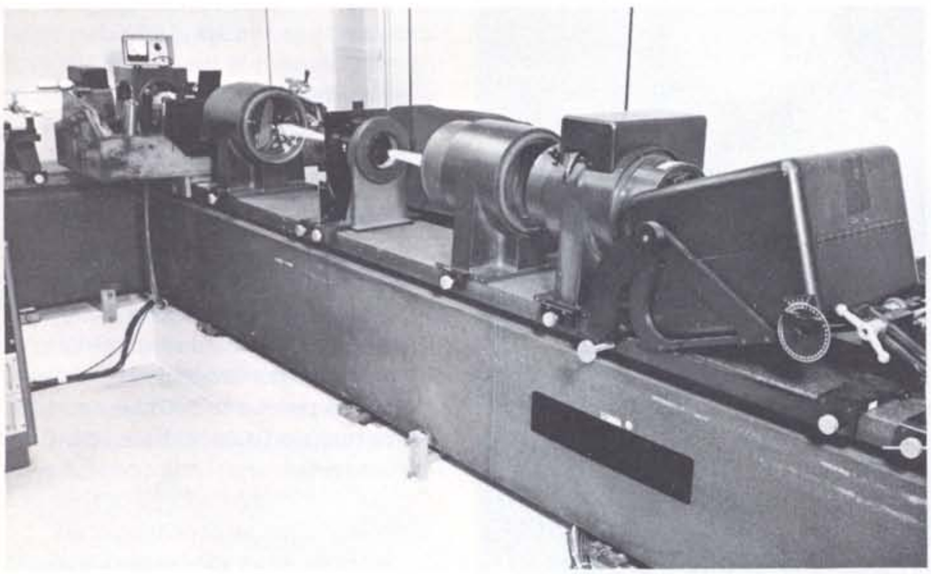


Figure 1b – Tilted-plane SAR optical processor (courtesy of ERIM)



areas, refined lens settings have been used to produce 'precision processed' data (100 – 500 km long strips).

Optical processing has proved to be an efficient data-processing approach that has a significant throughput capability. However, the image quality is difficult to control and it has been thought desirable to provide users with digitally processed data.

Digital processing

The SAR processing consists basically of two deconvolution processes in cascade. The first, range compression, is one-dimensional. Various 'complications', e.g. the Earth's rotation, make the second processing, azimuth compression, two-dimensional. By correcting for the 'complications', through 'range-migration correction', one-dimensional deconvolution algorithms can also be used for azimuth compression.

The range-migration correction can be applied in either the time or the frequency domain and various techniques have been implemented for Seasat processing. One of these variants, spectral analysis, takes advantage of the simplifications, from a mathematical viewpoint, resulting from the characteristics of the SAR signal itself (linear frequency modulation). The fact that existing Seasat processors rely on different algorithms has provided an opportunity to make detailed comparisons of their respective merits in terms of throughput and image quality. ESA has purchased a SAR software processor developed by MacDonald Dettwiler and Associates under the sponsorship of the Canadian Centre for Remote Sensing. This software has been installed at the German Space Operations Centre (DFVLR-GSOC) in Oberpfaffenhofen on an Interdata 8/32 minicomputer (32 bit, floating-point hardware, 80 and 300 Mbyte disks). It has been used to produce the first digital Seasat SAR images, which are notable for their outstanding quality (Figs. 3a–d). The typical digitally-processed products cover an area 50 km × 40 km and provide 25 m resolution (four looks).

The digital-processing software is also being tested on the Itel mainframe computer at ESRIN (Frascati) where a number of experiments are to be undertaken and special products, such as two-dimensional power spectra of SAR images, produced. ESA also has access to an experimental SAR processor facility (ESPF) developed by Systems Designers Limited (UK) under the sponsorship of the Royal Aircraft Establishment (RAE), Farnborough. Samples of RAE imagery are presented in Figures 4a and b.

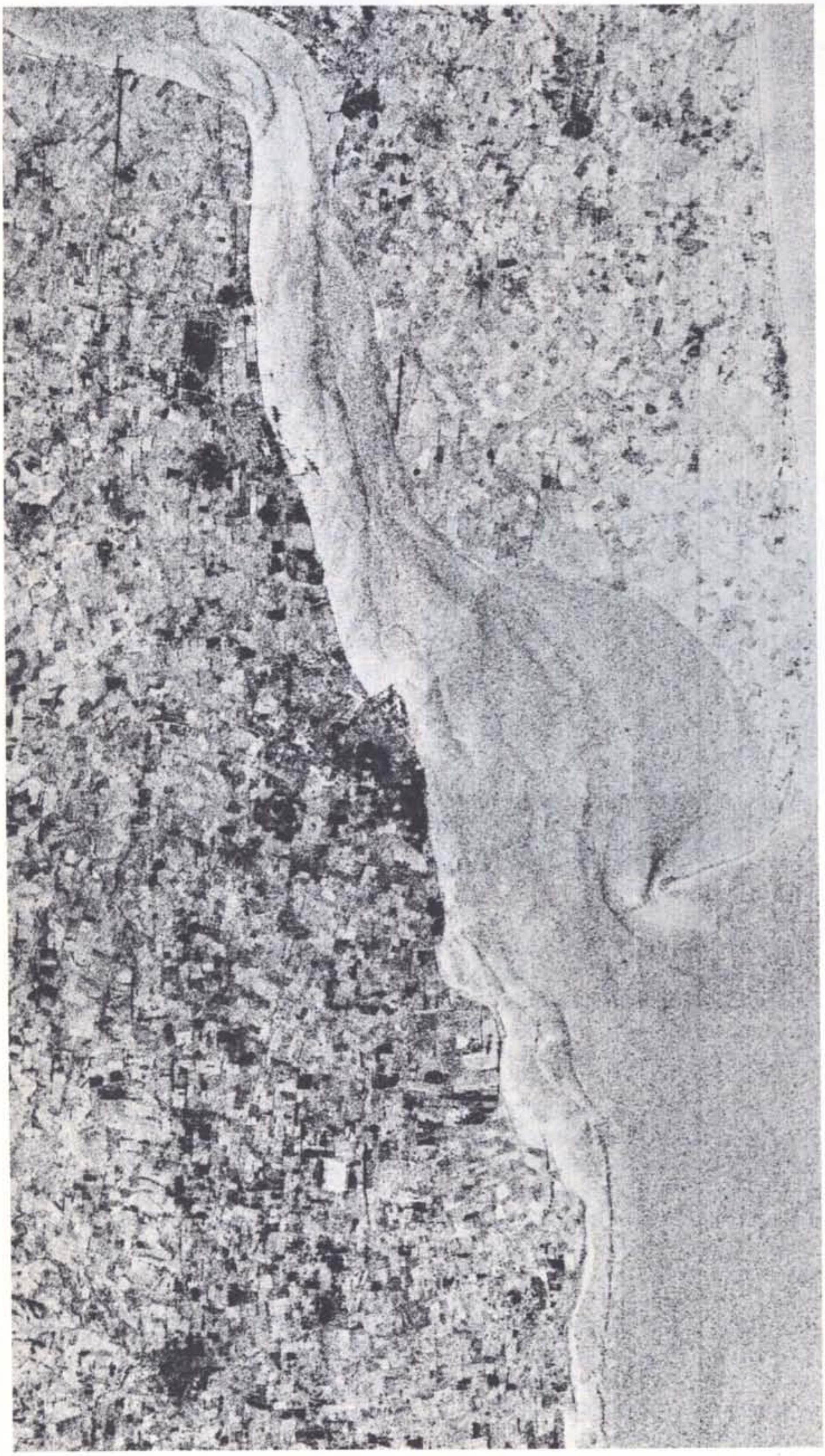
SAR operations

The experience that has been gained in the operational aspects of Seasat data processing is already proving extremely valuable in assessing future ESA systems. It has been demonstrated, for example, that optical processing is efficient but is far from being real time in nature, the processing of very high quality 70 mm films proving an arduous task. The main bottleneck lies in the reproduction of both film and photographic prints, so that there can be a two to three-month delay between processing and delivery.

Digital processing, on the other hand, requires very high precision auxiliary data, such as spacecraft attitude and orbit information, which are not normally available on the day the image data are received. This results in a few weeks delay

Figure 2 – Samples of ERIM (USA) optically processed Seasat SAR imagery

(a) The Wash, UK



(at least) before any data can be processed, and this can be detrimental for the many applications that require near-real-time data delivery, such as ice surveillance.

Another fact that has become clear is that general-purpose computers are unsuited to image processing in general and SAR processing in particular, and the Seasat SAR digital processors now being operated in Europe and the USA consist of minicomputers augmented by array processors. As an example, the production of an image at DFVLR originally required 38 h using the first version of the system. After the addition of an AP-120 B array processor, image production at DFVLR now takes just 7 h.

New computer architectures are needed to cope with the growing processing requirements, which call for the production of between 50 and 100 images per day. Dedicated hardware is likely to be limited in performance and would be extremely expensive to maintain and so today's evolution is rather towards two kinds of system:

- multiprocessors consisting of an assembly of vector-oriented, high-speed processors linked by very fast buses, and
- multiple processors that consist of networks of thousands of elementary processors all of which are performing the same task at any given moment.

Earthnet is currently involved in a SAR benchmark exercise to assess these emerging technologies.

Last but not least, the Seasat image processing has provided sound experience in copying, in cataloguing, archiving and disseminating, and in generating photographic products from CCTs.

SAR data evaluation
RAE, on ESA's behalf, is undertaking

image-quality-oriented experiments both at Farnborough and via subcontracts with industry: Hunting Surveys (objective assessment of geology and land-use applications), Oxford Computer Services (speckle aspects), Marconi Research Laboratories (SAR data statistics, beam-tracking routines, measurability of user-oriented criteria).

SAR data have already been distributed to a large number of laboratories involved in most of its possible applications, including agriculture, geology, renewable resources, cartography, human activities, oceans, ice floes, etc. and the benefits of stimulating information exchange with other international bodies (e.g. NASA, JPL, CCRS (SURSAT), NASDA (Japan), etc.) have been clearly identified.

The experimental nature of the SAR images, which represent the first access for most people to microwave remote-sensing products, means that a close dialogue is needed with users and potential users both to explain the characteristics of the SAR images being disseminated and to obtain feedback concerning requirements.

As already mentioned, Earthnet activities lay emphasis on this kind of dialogue and two three-day workshops have already been organised at Frascati, in July and December 1979. All leading bodies in the field were represented, with participants drawn from Europe, the USA, Canada and Japan.

To tackle the more technical problems, a two-day meeting of the SAR Working Group of the International Society of Photogrammetry was arranged to follow the December Workshop (the Proceedings of all three meetings have been published by and are available from ESA Publications Branch).

Follow-on activities

Despite its short lifetime, Seasat prompted a wide range of analysis activities from which it has been possible to recognise

(b) Dunkirk, France

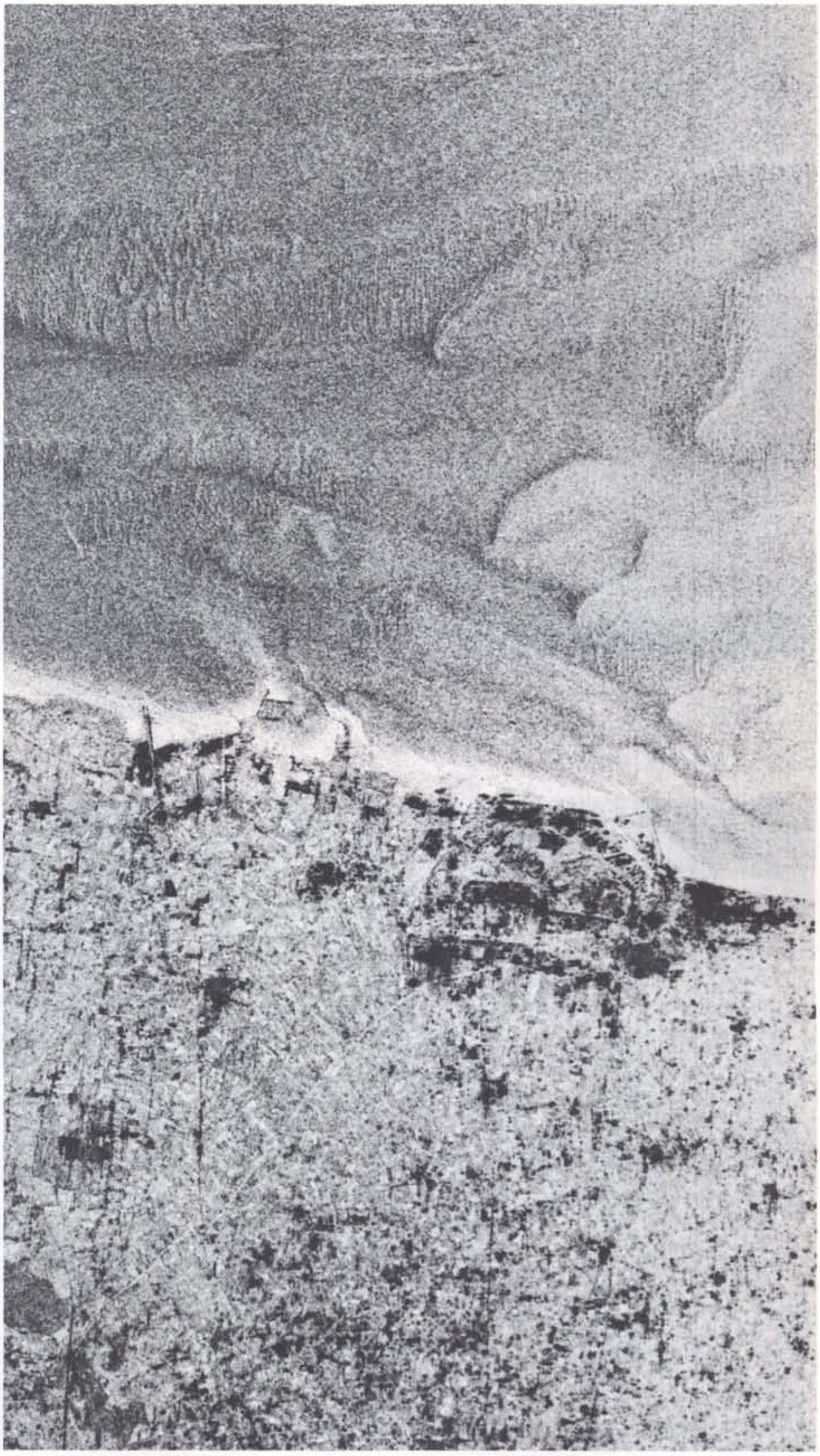
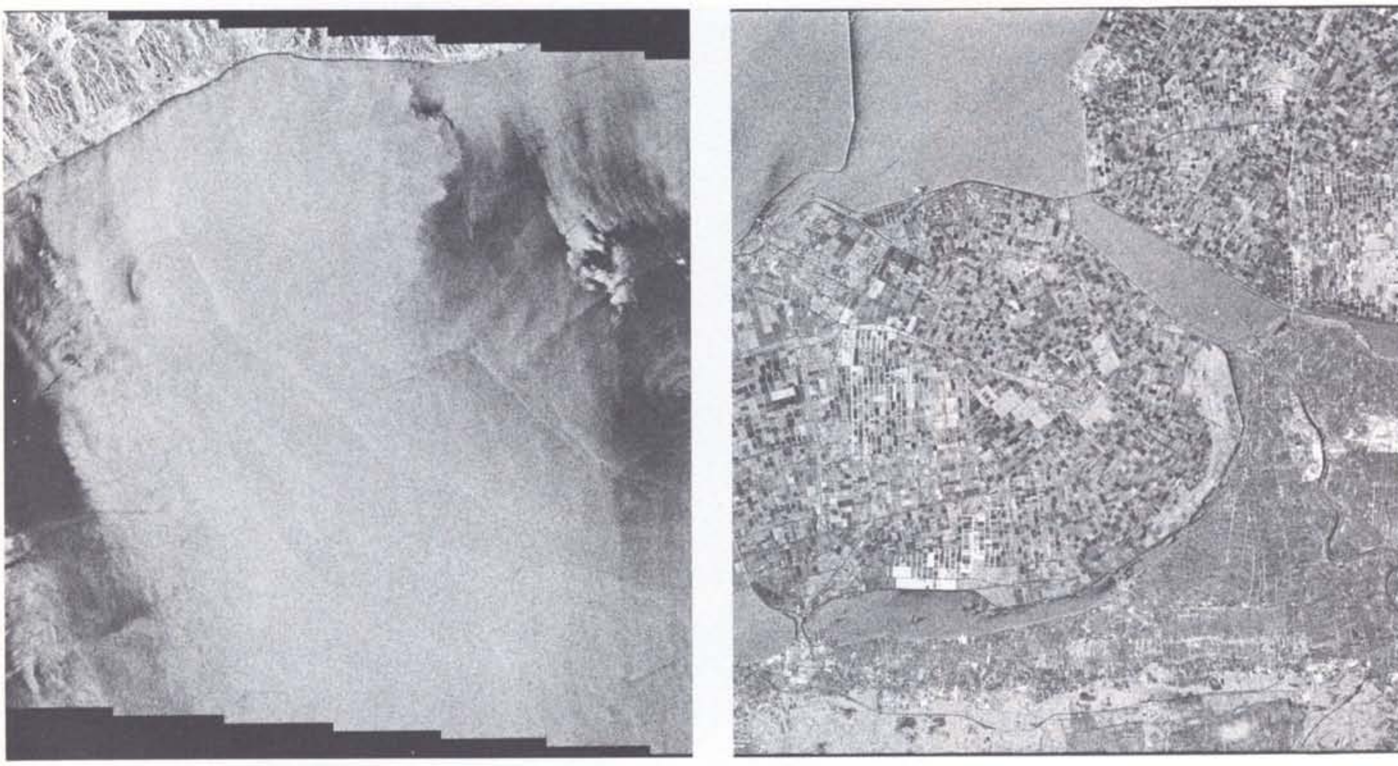


Figure 3 – Samples of DFVLR (Germany) digitally processed Seasat SAR imagery



(a) Calabria, Italy

(b) East Flevoland, The Netherlands

(c) Mont Blanc, France

(d) Barcelona, Spain

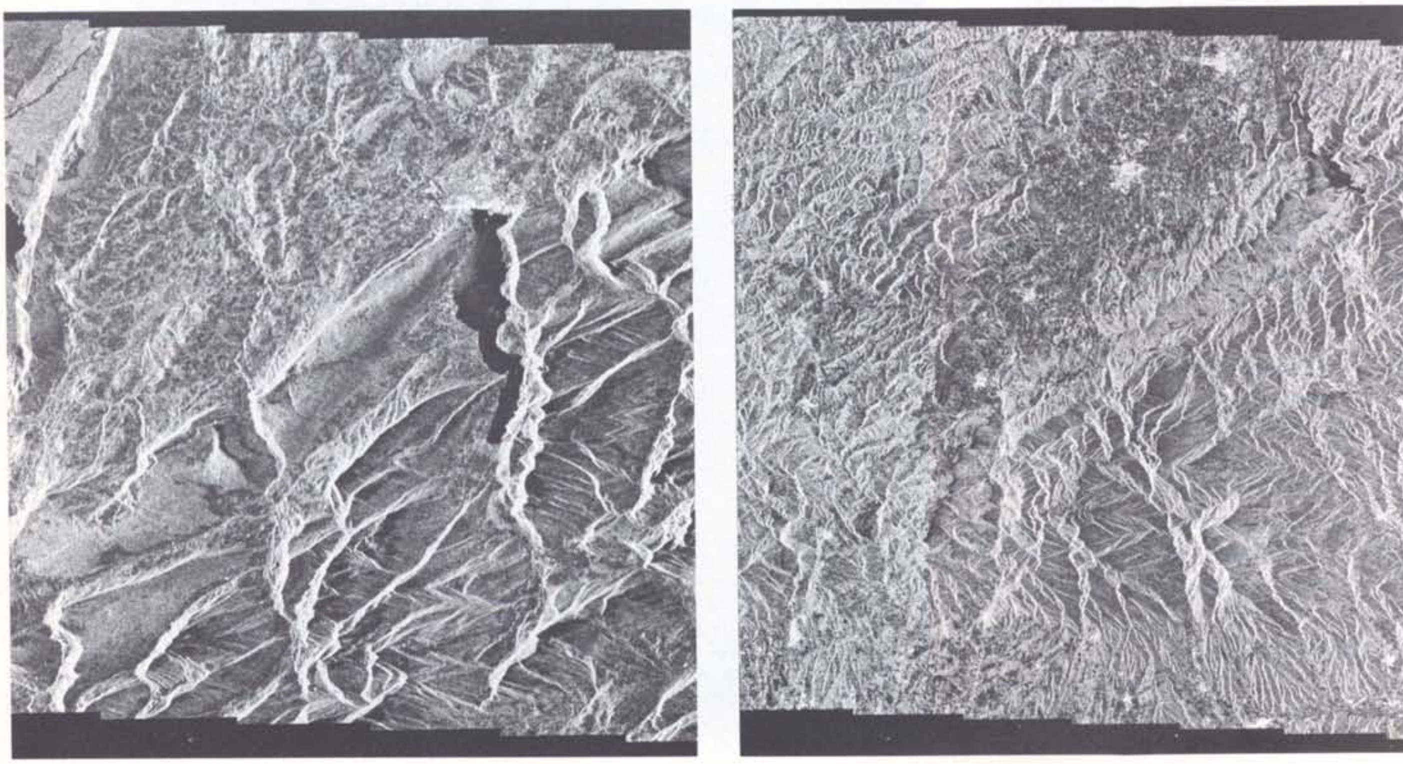
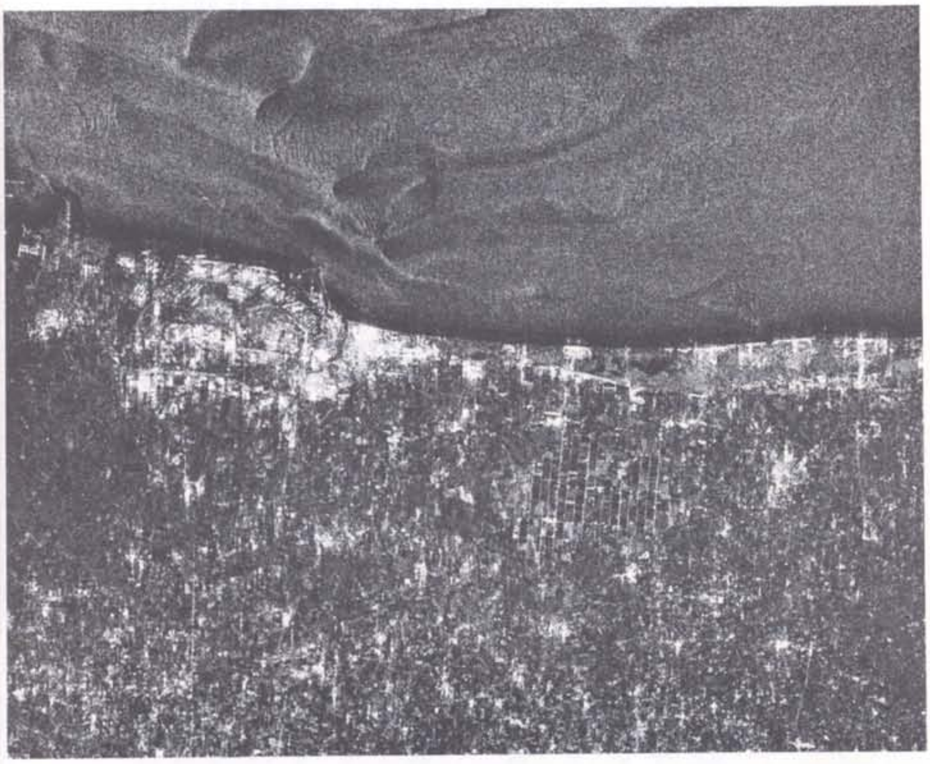
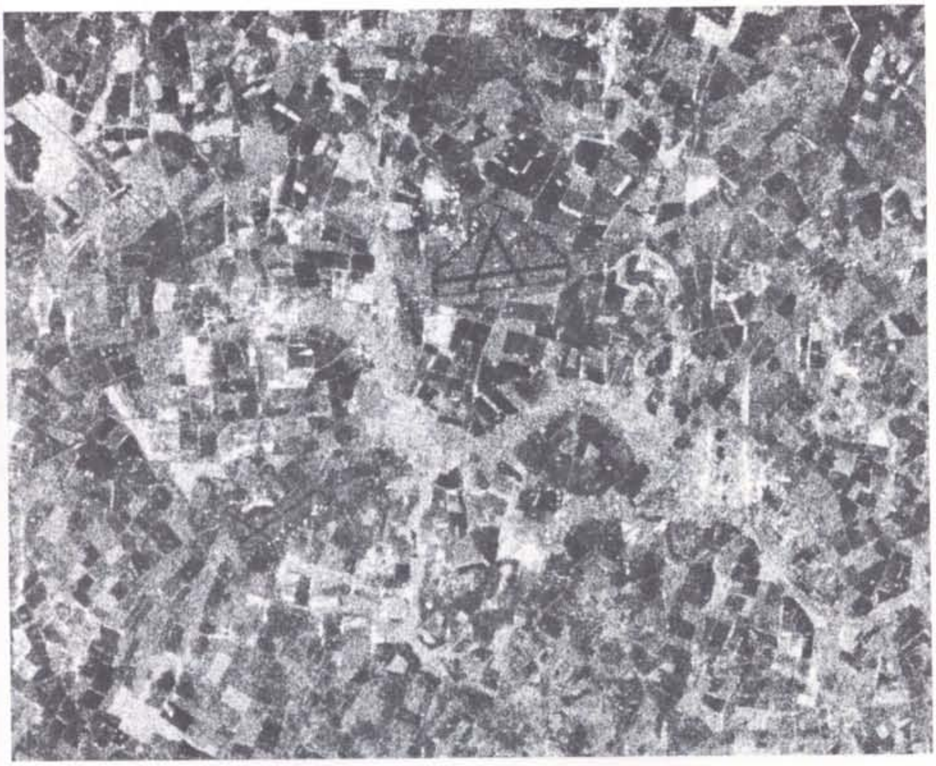


Figure 4 – Samples of RAE (UK) digitally processed Seasat SAR imagery



(a) Dunkirk, France

(b) East Anglia, UK



that potential users of SAR images are still far from being in a position to assess the data's capabilities and that further scientific studies are necessary of such aspects as the wave imaging mechanism. The Seasat data have proved extremely valuable in assessing future systems, such as the Convair 580 aircraft with X, L, and C-band radars and the European Spacelab Microwave Remote-Sensing Experiment, in the X-band. Two major lines of approach have to be pursued in the context of these and future follow-on missions: firstly, definition of algorithms for optimum extraction of information content, using spatial and speckle-related features as well as radiometric information; secondly, the unique features of the SAR images in a multisensor (scatterometer, multispectral scanner radiometer etc.) and/or multimission (Landsat-D, Spot, NOSS etc.) environment must be assessed. This raises extremely difficult problems, such as the need for an accurate digital terrain model, but the future of SAR systems clearly depends on a comprehensive assessment of these issues.

To promote a wider and deeper appreciation of such problems, Earthnet intends to organise a number of further workshops limited to specific subjects; the first will take place in December 1980 and will be devoted to image-quality characterisation and measurement.

cms-lannion

The Earthnet HCMM Data-Processing System at Lannion

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Within the framework of the Earthnet Programme and the Memorandum of Understanding between ESA and NASA, the French Space Meteorology Centre (CMS) at Lannion in Brittanny is acquiring, archiving and preprocessing data from NASA's Heat-Capacity Mapping Mission (HCMM) spacecraft. The data from the HCMM are supporting scientific investigations to establish the feasibility of using thermal infrared measurements of the Earth's surface to determine soil thermal inertia.

The HCMM spacecraft was launched on 26 April 1978 into a circular, sun-synchronous orbit with a 97.6° inclination. A 2 pm local-time ascending node places the satellite over northern mid-latitudes at 1.30 pm and 2.30 am local time, allowing measurements to be made with a 12 h interval at times when the temperature variation is a maximum. This day/night temperature difference can be used to determine the thermal inertia of the ground surface scanned.

Table 1 – Heat capacity mapping radiometer (HCMR) summary data sheet

Orbital altitude	620 km
Angular resolution	0.83 mrad
Resolution	0.6 km × 0.6 km at nadir (infrared) 0.5 km × 0.5 km at nadir (visible)
Scan angle	60° (full angle)
Scan rate	14 rev/s
Sample rate	1.19 samples/resolution element at nadir
Sampling interval	9.2 μs
Swath width	716 km
Information bandwidth	53 kHz/channel
Thermal channel	10.5 – 12.5 μm; NEDT = 0.4 K at 280 K
Usable range	260 – 340 K
Visible channel	0.55 – 1.1 μm; SNR = 10 at ~ 1% albedo
Dynamic range	0 – 100% albedo
Scan mirror	45° elliptical flat
Nominal telescope optics diameter	20 cm
Calibration:	
Infrared	View of space, seven-step staircase electronic calibration, and black-body once per scan
Visible	Pre-flight calibration assumed valid

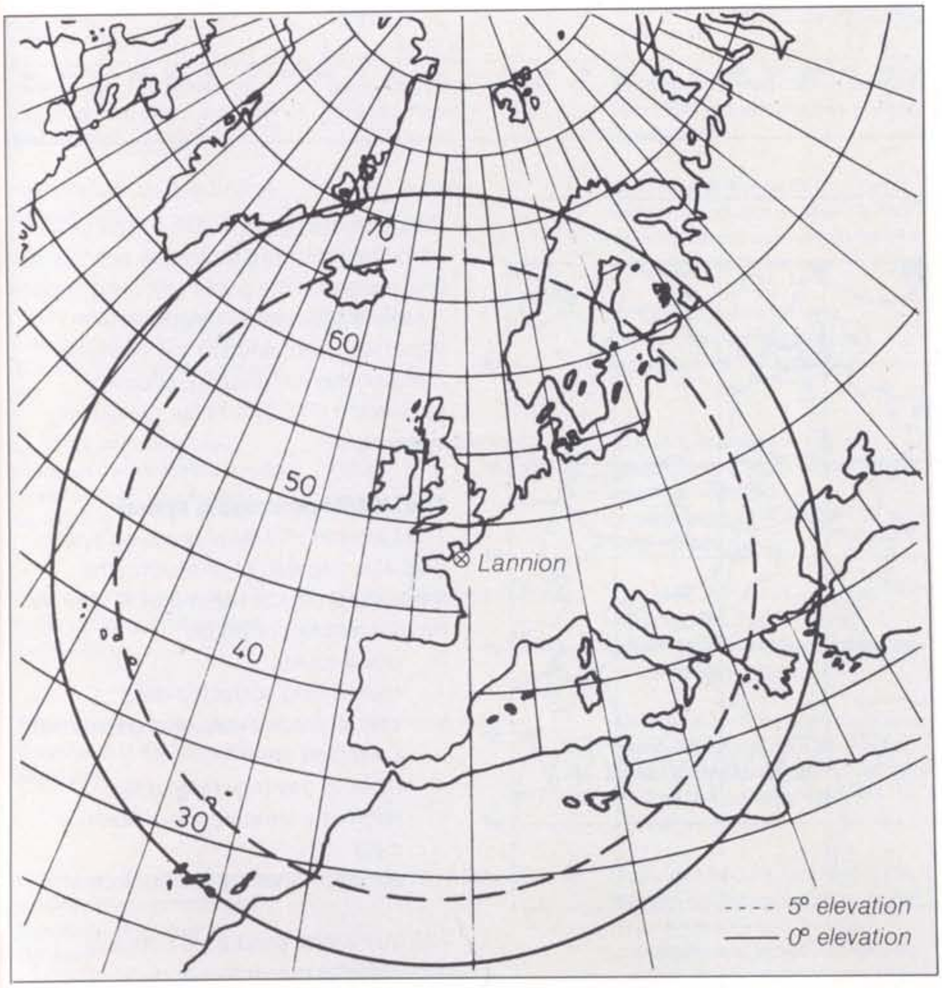
Figure 1 — Lannion coverage area for the HCMM spacecraft

HCMM data acquisition at Lannion started on 11 July 1978 and over 1500 spacecraft orbits have already been archived at the station, with one day pass and one night pass per 24 h. Coverage includes the whole of western Europe and some parts of North Africa (Fig. 1).

The spacecraft and its orbit

Data are acquired by a two-channel scanning radiometer – the heat capacity mapping radiometer or HCMR – which is a modified version of an instrument already flown on the Nimbus-5 satellite (Table 1). One spectral channel covers the visible and near-infrared band between 0.5 and 1.1 μm, the other the thermal infrared band between 10.5 and 12.5 μm. The spacecraft orbit provides coverage of the earth's surface between 85° N and 85° S with a 16-day repeat cycle over a given track.

From the HCMM's nominal orbital altitude of 620 km, the spatial resolution in the infrared is approximately 600 by 600 m at nadir, and 500 by 500 m in the visible. These values are masked by data processing, which generates registered data with a 481.5 m pixel size. Registration between channels is to 0.2 resolution elements. The ground swath of about 700 km (compared to the 185 km of Landsat) with the resulting large overlap between adjacent tracks permits coverage of any given point on six consecutive days and nights, every 16 days. The particular orbit results in satellite night/day coverage patterns at least once every 16 days at approximately 12 h intervals for all latitudes polewards of 35° and all latitudes equatorwards of 20° (Fig. 2a). The typical coverage pattern for a combined 12 h night/day pass across Europe is shown in Figure 2b.



The investigation programme

The main objectives of the HCMM programme are to conduct research into the feasibility of using day/night thermal infrared remote-sensing data for:

- rock-type discrimination and mineral-resource location
- measuring plant-canopy temperatures at frequent intervals to determine evapotranspiration and plant stress
- measuring and monitoring soil-moisture changes
- mapping thermal affluents, both natural and man-made, and the measuring effects of urban heat centres
- mapping and monitoring snow fields for water-run-off prediction.

Table 2 provides a review of the European HCMM investigations that are currently under way.

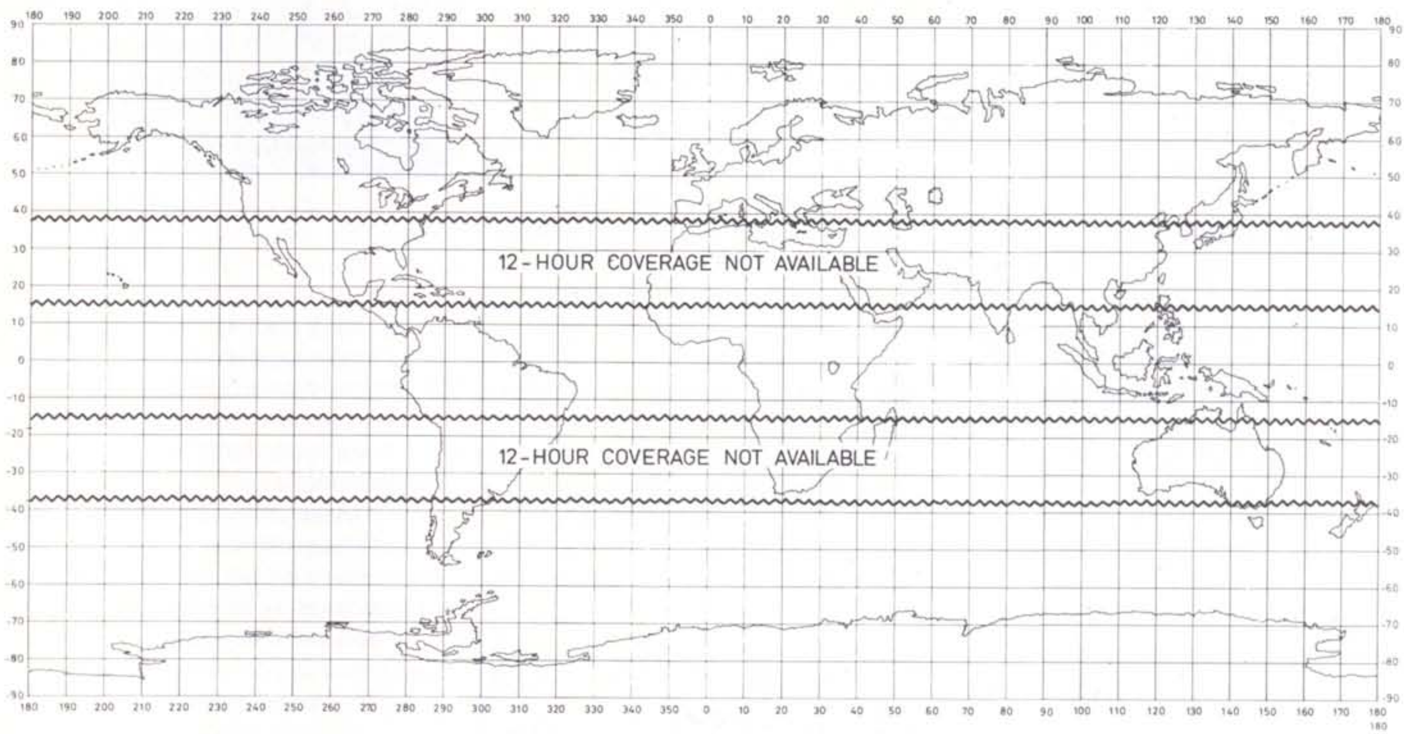
The Lannion HCMM acquisition station

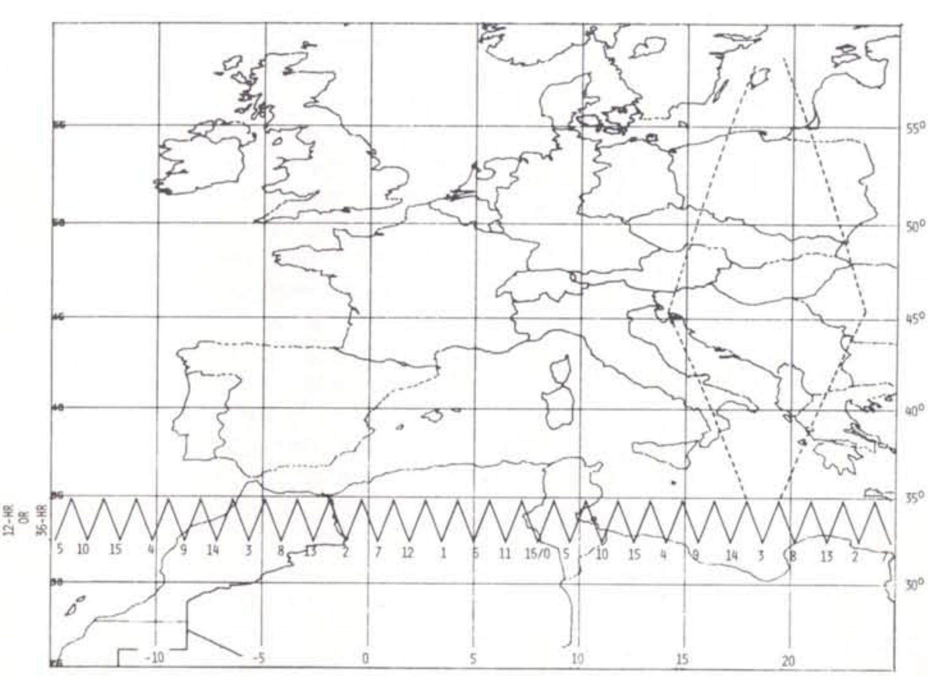
The Lannion HCMM station includes a radio-frequency receiving chain and a digitising and magnetic recording device, controlled by a minicomputer. The radio-frequency circuitry receives the multiplexed data from the satellite and delivers two baseband video signals along with telemetry data, in three different channels (visible, infrared and telemetry). Lannion relies on a pedestal-mounted paraboloid-shaped reflector antenna (10 m diameter) which can be either computer-controlled or autotrack-driven, depending on the satellite signal strength.

The raw data obtained from the spacecraft are temporarily stored on high-density digital tapes (HDDTs), which are subsequently processed to generate computer compatible tapes (CCTs) with re-synchronised lines (traitement de

Figure 2a — Geographical extent of HCMM 12 h day/night coverage

Figure 2b — HCMM 12 h day/night coverage for Europe





recalage des lignes or TRLI). The CCTs carry the raw input for further processing and represent the prime archiving support for the HCMM data. A quick-look capability is provided at the interface between the information receiving equipment (Fig. 3) and the processing system.

The HCMM processing system

The Lannion HCMM processing system (Fig. 4) is capable of producing the following products either on CCTs or as transparent film or prints:

- quick-looks
- radiometric corrected data
- system (radiometric and geometric) corrected data
- night to day registered data
- day/night temperature-difference data
- apparent-thermal-inertia data.

The quick-look product is normally generated at the time of acquisition and archiving for the full spacecraft pass within range of the station. This product is distributed to those users who want to check the quality of the raw data, for the presence of cloud-free areas or for data availability for specific test sites. Day-pass quick-looks include visible and infrared data, while for night passes only infrared data are distributed. For the user's convenience and to reduce the amount of processing called for at the station, a 2 min data unit has been chosen. The units have been defined such that the various European test sites fall within single frames, which are identified by latitude:

Frame 1 from 27.0°N to 34.3°N
Frame 2 from 34.3°N to 41.6°N
Frame 3 from 38.7°N to 46.0°N
Frame 4 from 43.7°N to 51.0°N
Frame 5 from 48.7°N to 56.0°N
Frame 6 from 56.0°N to 63.1°N
Frame 7 from 63.1°N to 70.0°N

Each processing unit is identified by an orbit number and a frame number to provide users with an easy reference. Examples of quick-look products are shown in Figures 5 and 6.

Table 2 — European HCMM investigations

Principal investigator and affiliation	Test-site location	Objectives
Dr P Y Deschamps, Laboratory of Atmospheric Optics, University of Lille, France	Atlantic coast of France, English Channel, Golfe du Lion	Study thermal gradients in the coastal zone of France and tidal gradients in the English Channel; study the influence of sea-surface diurnal heating on thermal stratification.
Dr J Y Scanvic, Bureau of Geology and Mineral Research, Orleans, France	Central France, western France	Discriminate rock types, thermal anomalies in a volcanic region, and lineaments.
Dr M Winiger, Department of Geography, University of Bern, Switzerland	Swiss Alps, Swiss Plateau, Jura Mountains	Delineate and map cold air masses and fog layers; snow survey (melting conditions).
Prof M M Cole, Bedford College, London, UK	Eastern Australia	Discriminate rock types for mineral exploration; detect geothermal heat sources; assess moisture content for rangeland management.
Dr G Fielder, Lunar and Planetary Unit, Dept. of Environmental Sciences, University of Lancaster, UK	North Sea	Investigate the feasibility of monitoring marine pollutants, particularly oil.
Dr S Galli de Paratesi, Joint Research Centre of the European Communities (Tellus Project), Varese, Italy	Southern Italy, Sardinia, Europe	Consortium of several European investigators (Tellus). Studies of soil moisture, vegetation, evapotranspiration, and nature of the land surface.
Dr R Nunez de las Cuevas, National Geographic Institute, Madrid, Spain	Mediterranean coast of Spain	Use of HCMM data for thermal mapping, geothermal source location, natural effluents detection, and plant-stress identification.
Prof R Cassinis, Institute of Geophysics of the Lithosphere, Milan, Italy	Sicily, Sardinia, Italy	Determine the thermal inertia of rock types, define discontinuities (faults), detect thermal anomalies; investigate coastal and lagoonal water circulation patterns.
Dr R Haydn, Central Laboratory for Geophotogrammetry and Remote Sensing, Munich, Germany	West Germany, Italy, Morocco	Apply HCMM data to studies in the fields of geology, ecology, hydrology and climatology and develop processing and analytical methods.

Radiometrically corrected data

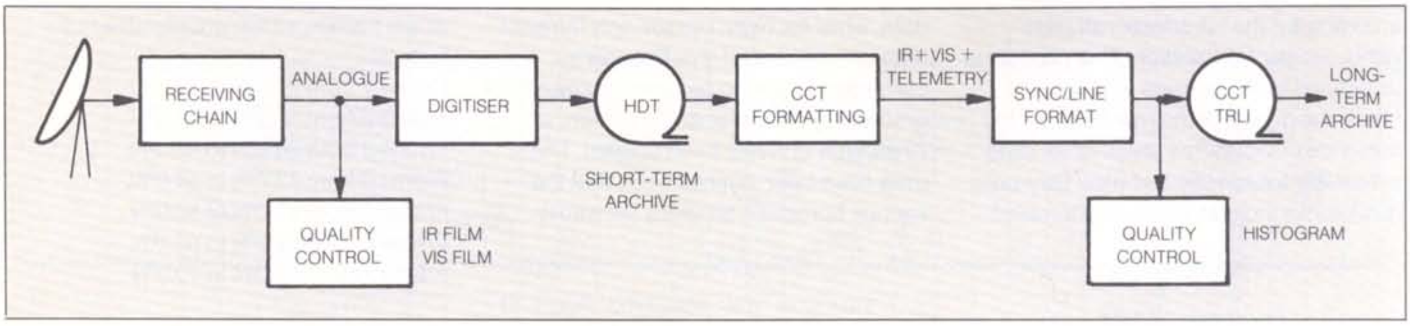
The radiometric corrections are necessary to remove distortions introduced during acquisition and to convert the digitised radiometer scan data to values that can be directly interpreted as physical measurements, such as radiance and brightness. The input for this processing step consists of image data (visible 0.5 − 1.1 μm and infrared 10.5 − 12.5 μm) calibration data, and selected housekeeping parameters. The step from raw to corrected data is made by generating a cubic polynomial function which accounts for the distortion and transformation (radiometric calibration) and then applying that function to each radiometric scan value (radiometric correction).

Two processing steps are required for radiometric calibration of the visible channel. A cubic polynomial, developed by a least-squares interpolation procedure of the calibration staircase, is used to transform scan counts into output sensor voltages and a preflight-specified model is used to transform these voltages to normalised albedos.

The procedure is somewhat more complex for the infrared channel. The calibration data contains a scan of the spacecraft's internal black body source and baseplate black-body temperature readings. These temperature readings are used to compute black-body radiance, via

Figure 3 — Earthnet data acquisition, recording and archiving at CMS Lannion

Figure 4 — Earthnet data processing at CMS Lannion



the Planck equation. The radiance value and black-body scan are then used to define the transformation of sensor voltage output to radiance. A number of smoothing operations are performed to reduce the noise added to the signals and to reduce the frequency of radiometric calibration.

The radiometric correction is effected by applying the radiometric correction model (cubic polynomial) developed above to the received earth scan values. The radiometric calibration and correction package has been developed at Lannion based on algorithms provided by NASA.

Geometrically corrected data

In the geometric-correction processing, variations in spacecraft attitude are compensated for. In general terms, the processing can be divided into three steps:

- definition of a relation between the raw data and the corrected image by identification of corresponding points (tie-points, landmarks)
- definition of a deformation model using the results of the previous step
- application of the deformation model to the raw data to obtain the corrected image (rectification).

In the case of the HCMM, the relation between the raw data and the corrected image is defined by means of a model that uses spacecraft attitude measurements only. This has the advantage that no ground-control points are used in the correction step; the disadvantage is that higher degree attitude variations are not compensated for.

The correspondance between raw and correct images can be established on the basis of a given cartographic projection, specified by NASA in the case of the

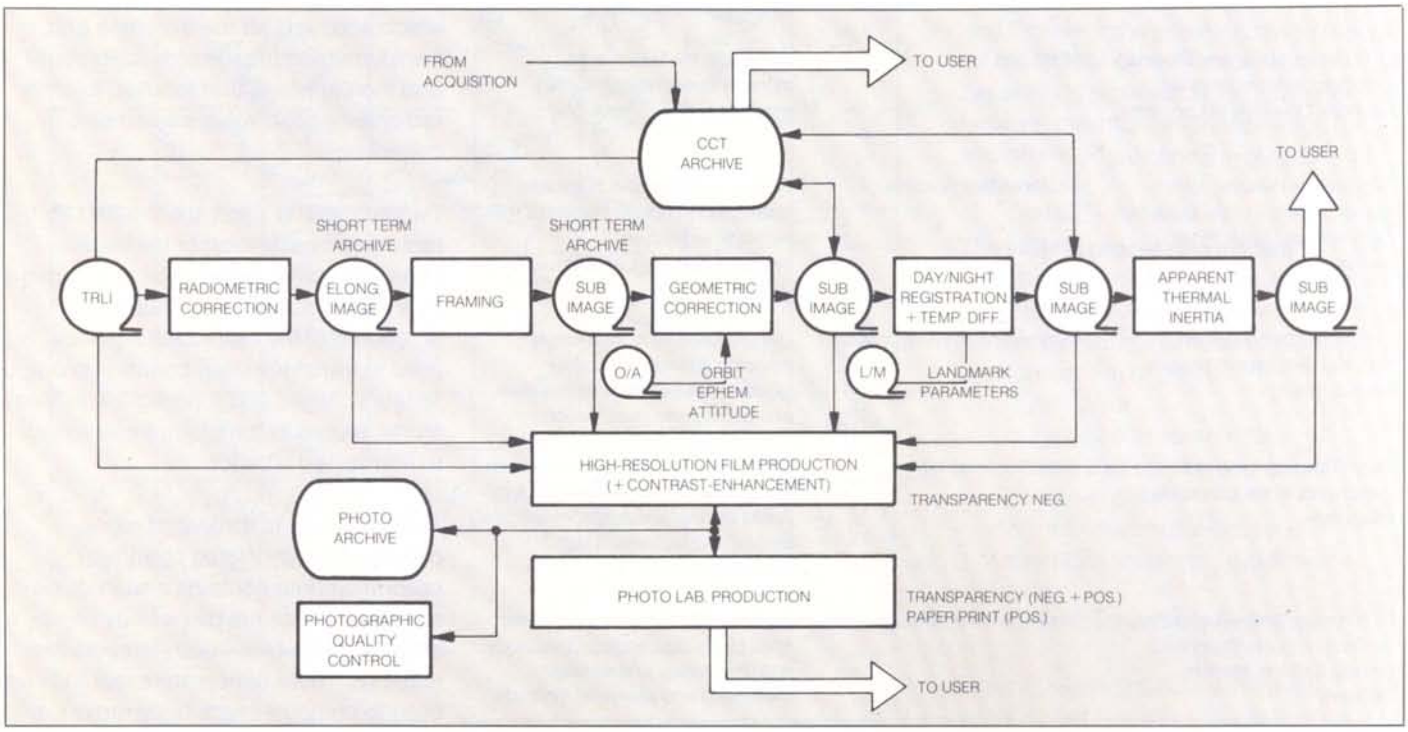


Figure 5 – HCMM night quick-look (IR)

Figure 6 – HCMM day quick-look (VIS)

Figure 7 – HCMM night infrared geometrically and radiometrically corrected image frame

Figure 8 – HCMM day infrared geometrically and radiometrically corrected image frame

Figure 9 – HCMM night infrared frame remapped on the corresponding day frame

Figure 10 – HCMM apparent-thermal-inertia frame

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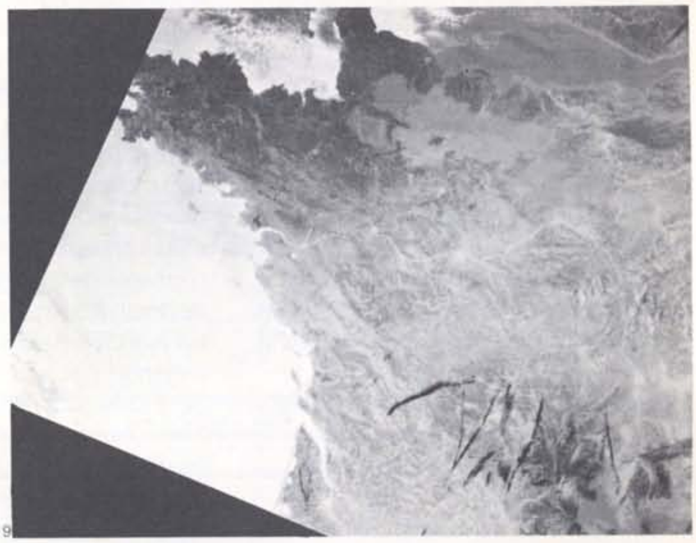

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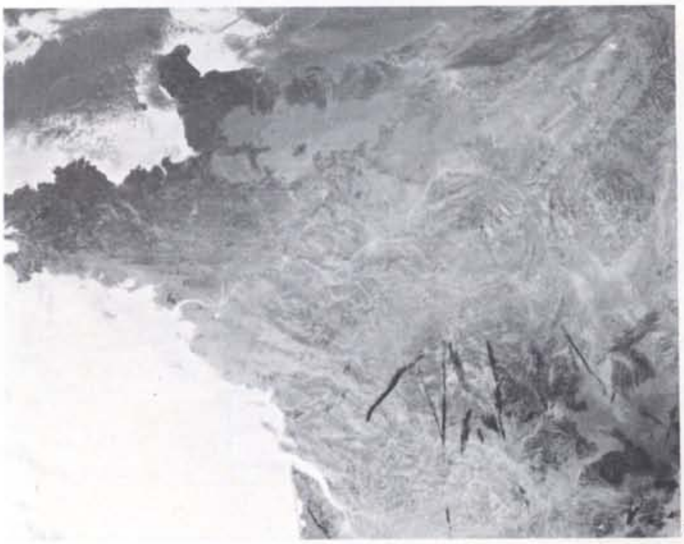

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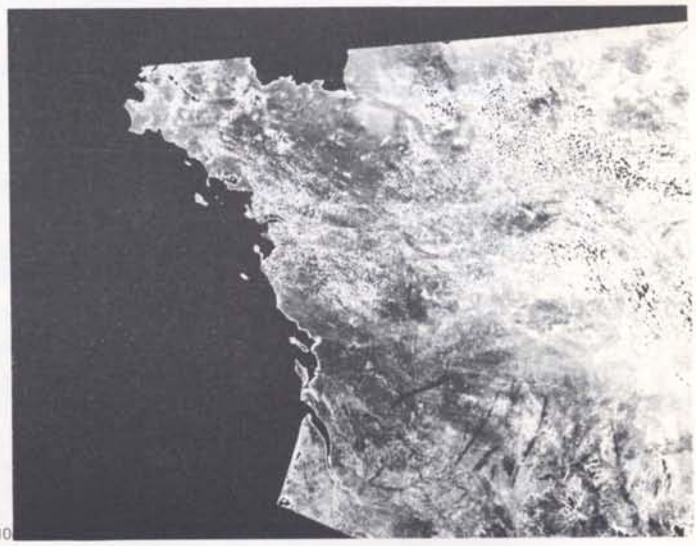

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HCMM to be a Hotine Oblique Mercator (HOM) projection.

The rectification process implies:
a) Choice of an appropriate processing strategy, depending on the type of distortion. In the case of HCMM and the HOM projection, where the distortion (mainly rotation) of the image is not very great ($<5°$), the chosen strategy does not segment the raw image, which gives a saving in I/O operations. This strategy consists of computing the maximum width of vertical image strips into which the raw image may be cut, given the memory buffer size and the distortion parameters. During processing the raw image is read as many times as the number of strips and only one strip is processed with each reading. In practice, the whole processing can be accomplished in one or two passes, with a considerable saving in computer resources.

b) Computation of the inverse deformation model. The computed direct deformation model shows the distortion (displacement) of a grid of 25×25 points in the raw image. What is needed during the correction processing are the deformations (displacements) of a grid of points in the corrected image. This process is known as inversion of the deformation model. The solution implemented for the HCMM uses a local iterative approach for the deformation inversion. The error introduced is of the order of 0.5 pixels compared with the more sophisticated method of polynomial inversion.

c) Interpolation to compute the radiance of each pixel in the corrected image. Of the various interpolation schemes available (next neighbour, bilinear, biquadratic, bicubic, sin x/x), the linear and the quadratic schemes have been found to be the most interesting from a cost/performance ratio viewpoint.

To give an idea of the time scale of the geometric correction process, for 2 min of HCMM image data, correction takes about 25 min of computer (CPU) time using bilinear interpolation on an IRIS-80 machine. Examples of radiometrically and geometrically corrected images are shown in Figures 7 and 8.

Night and day registered data
Remapping of night images onto day images is used to evaluate the properties of a given soil as a function of the temperature change over a 12 h period. To produce these remapped images it is necessary to:

a) Extract tie-points in the two images with the best possible accuracy. This process is performed in three steps. In the first the operator inspects enlarged day and night IR images and compares them with atlas maps on a scale of about 1:2 000 000. Experience has shown that the best landmarks are located at land/water separations. In the second step the images are displayed on the CIT-Alcatel Image Display system available at CMS Lannion, and the precise correspondence between day and night landmarks is established with the help of the available hardware facilities (contrast-enhancement and cursor). Up to 32 landmarks may be defined for a given 2 min scene. In the third step a landmark quality control check is performed via a correlation algorithm and evaluation of a sample of output parameters (separation of correlation peaks, quality of correlation). The landmark-extraction procedure has been designed and developed at CMS Lannion.

b) Compute the remapping parameters of the defined remapping model and perform the transformation. The system used was initially developed by NASA and has been installed subsequently at CMS Lannion. The image to be remapped is subdivided automatically into triangular regions (defined by the tie-points and by some automatically extracted boundary points). The image data to be processed is divided into small rectangular blocks, which are written on a random-access file. These blocks are recalled to main memory only as needed. Bilinear interpolation is used to resample the image. Figure 9 is an example of a remapped night image.

Day/night temperature difference and apparent thermal inertia
A temperature difference is computed by taking the difference of the observed HCMR day and night radiometric temperatures. No correction for atmospheric effects is applied and the resulting difference is therefore not the same as the surface-temperature difference, since the night and day atmospheric corrections do not cancel out.

The 'apparent thermal inertia' is a satellite-derived product which has many of the attributes of true thermal-inertia measurements. Both temperature-difference and apparent-thermal-inertia products are computed using the overlaid data set from the HCMM spacecraft's day and night passes. The software package for both products was developed at NASA.

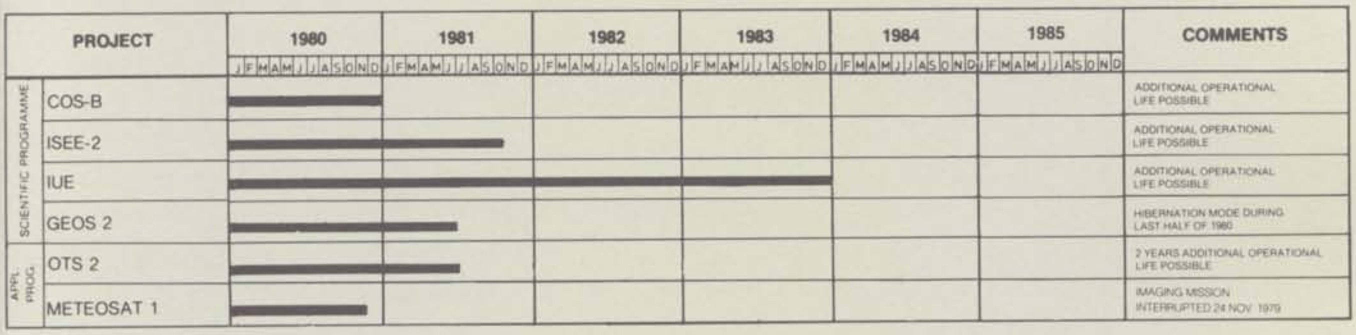
Figure 10 is an apparent-thermal-inertia frame produced at CMS Lannion.

Acknowledgement
The products produced at Lannion are the result of a keen collaborative effort by all parties directly involved in the project. Special thanks are due to Dr John Price (HCMM Project Scientist/NASA Goddard Space Flight Center) for his always helpful suggestions and support.

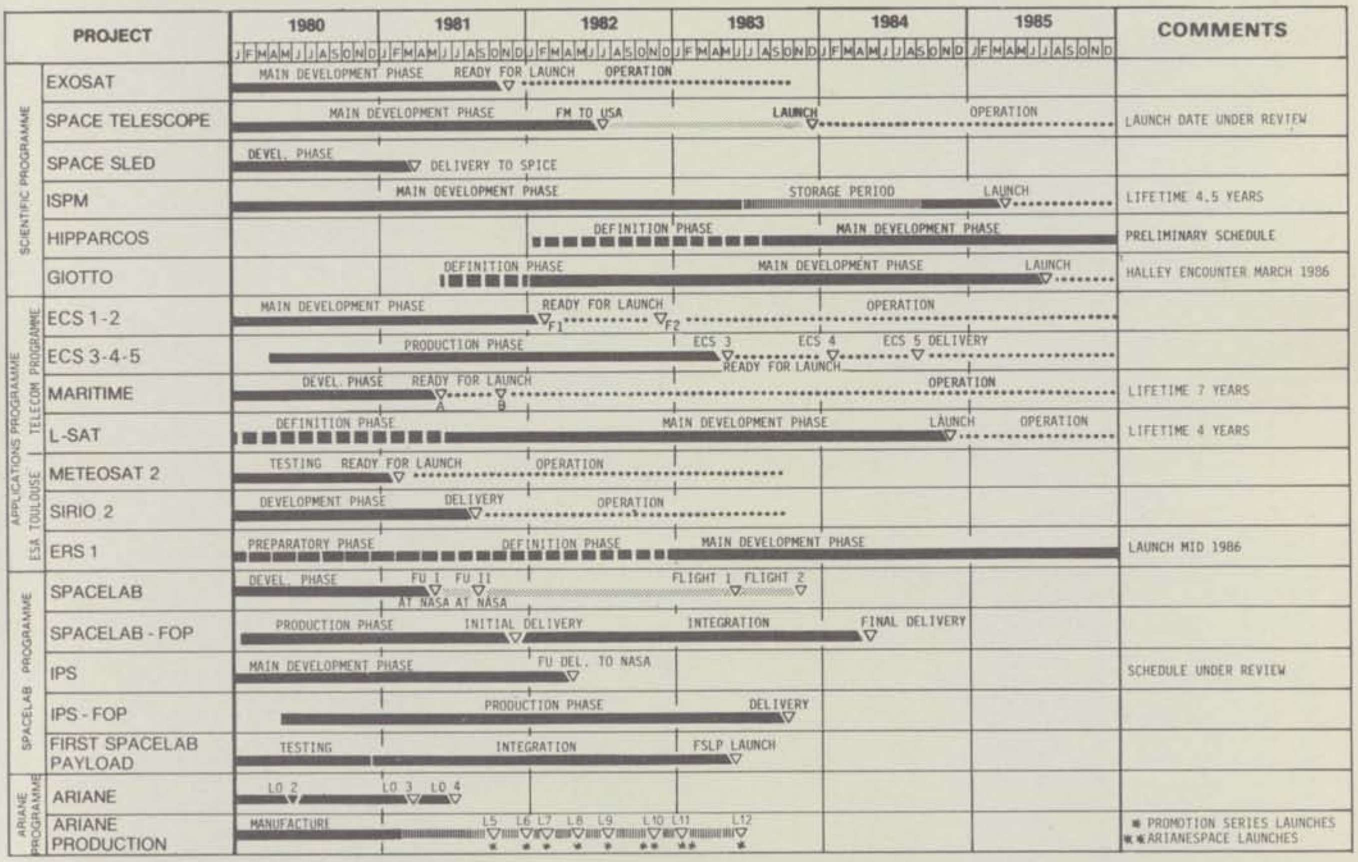
Programmes under Development and Operations*

Programmes en cours de réalisation et d'exploitation

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



* Reporting status as per end August 1980/Bar valid per end September 1980. *Planning fin septembre 1980 — Situation des projets décrits: fin août 1980.*

OTS

Les résultats des mesures semestrielles effectuées en mai sur OTS dans le cadre du système d'intéressement ont été analysés et montrent que les performances du satellite continuent de dépasser le niveau spécifié en ce qui concerne la puissance radioélectrique rayonnée sur chaque canal.

OTS est utilisé de façon intensive pour des essais et expériences diverses; le niveau moyen d'utilisation a atteint en juillet environ 90% du temps.

Les premières expériences de vidéoconférence au moyen de petites stations terriennes ont été exécutées avec succès entre les administrations des postes allemande et britannique. Dans le domaine de la réception directe de la télévision, plusieurs démonstrations ont eu lieu, notamment au salon aéronautique de Farnborough et au FIRATO d'Amsterdam où les programmes de télévision de France, du Royaume-Uni, d'Italie et des Pays-Bas retransmis par OTS ont été reçus sur de petits terminaux adaptés à la réception collective. L'excellente qualité de la réception a suscité un intérêt considérable chez les sociétés de distribution par câble.

Météosat

Secteur spatial

En raison d'une panne survenue à bord, Météosat-1 continue à n'assurer qu'une seule mission, la collecte des données. La cause du problème a été identifiée et des modifications ont été apportées au second modèle de vol qui doit être lancé lors du troisième tir de développement d'Ariane (L03).

Des manoeuvres d'inclinaison de l'axe de rotation ont été effectuées sur Météosat-1 pour éviter le réchauffement des canalisations d'hydrazine gelées qui alimentent les propulseurs axiaux. Aucune fuite d'hydrazine n'a été détectée.

Météosat-2 est pratiquement prêt pour le lancement, mais celui-ci a de nouveau été reporté du 7 novembre 1980 à mars 1981 en raison de l'échec d'Ariane L02. Le programme de qualification du moteur d'apogée MAGE-1 s'est terminé avec succès en juillet par deux tirs statiques réussis pour MAGE-1 et un pour MAGE-1S.

Exploitation

La seule mission qui puisse être exploitée à l'heure actuelle est la mission de collecte des données, qui dessert 19 plates-formes. L'expérience effectuée avec des plates-formes ASDAR embarquées sur Boeing-747 a donné des résultats extrêmement satisfaisants, si bien qu'on étudie maintenant la création d'un service opérationnel ASDAR utilisant les satellites de Météosat, GOES, GMS et GOMS qui couvrirait le monde entier et commencerait à fonctionner en 1985.

D'anciennes bandes de données sont utilisées pour améliorer le logiciel et, par conséquent, les produits qui deviendront disponibles après le lancement de Météosat-2.

Programme opérationnel

La proposition de l'Agence relative à un programme Météosat opérationnel a été adressée aux services météorologiques au mois d'août. Le programme de base fera appel à 5 satellites assurant un service opérationnel pendant 10 ans à partir de 1985.

Exosat

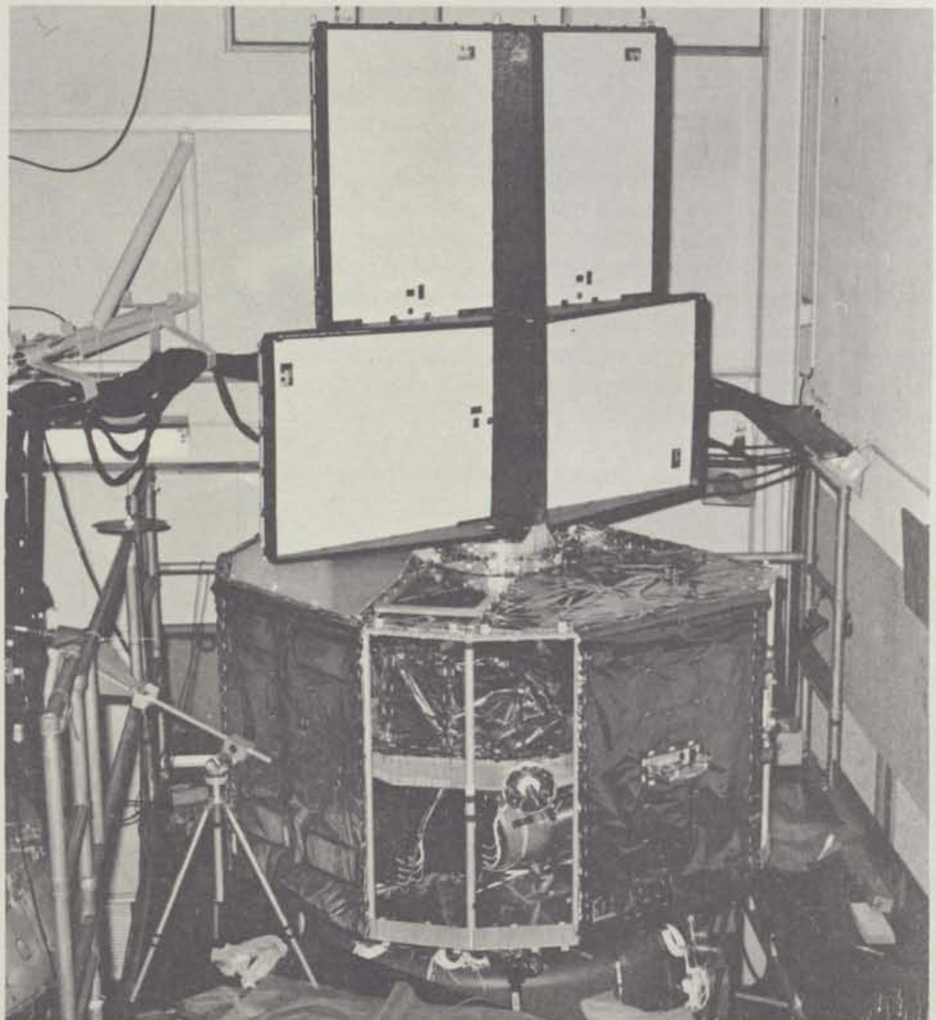
Satellite

Après le succès de l'intégration des organes du sous-système de commande d'orientation et de correction d'orbite dans le modèle d'identification (EM), on a redoublé d'effort pour achever les essais obligatoires au niveau système (essais de système intégré, compatibilité électromagnétique etc.) avant l'expédition au CNES, Toulouse, pour les mesures du bilan thermique.

Le fait que l'on ait rencontré des difficultés dans la mise en oeuvre des séquences d'essai automatique et que le programme des essais ait souffert d'interruptions fréquentes causées par des problèmes techniques, souligne l'ampleur de l'effort accompli pour

Installation of thermal blankets on the Exosat engineering model

Installation des couvertures thermiques sur le modèle d'identification d'Exosat



OTS

The results of the six-monthly incentive measurements made last May on OTS have been analysed and show that the performance of the satellite continues to exceed the level specified for the radiated RF power in each channel.

The utilisation of OTS for tests and experiments is very intensive and reached a daily average of about 90% in time during July.

First experiments with videoconferencing between the German Bundespost and the British Post Office using small earth stations have been successfully completed. In the field of direct TV reception, several demonstrations have taken place, in particular at the Farnborough Air Show and at the FIRATO fair in Amsterdam when TV programmes from France, UK, Italy and the Netherlands were transmitted by OTS and received by small terminals suitable for community reception. The excellent quality of the reception has raised a considerable amount of interest on the part of cable distribution companies.

Meteosat

Space segment

Meteosat-1 is still only supporting the data-collection mission because of the on-board malfunction. The cause of the problem has been identified and modifications have been incorporated in the second flight model, due to be launched on the third Ariane development flight (L03).

Spin-axis tilting manoeuvres have been performed to avoid heating of the frozen hydrazine pipes supplying the spacecraft's axial thrusters. No hydrazine leaks have been detected.

Meteosat-2 is virtually ready for launch, but the failure of Ariane L02 has delayed the launch date still further, from 7 November 1980 until March 1981. The MAGE-1 apogee motor successfully completed its qualification programme in July, with two successful MAGE-1 firings and one successful MAGE-1S firing.

Exploitation

Only the data-collection mission, which is servicing 19 platforms, can be exploited at the moment. The experiment with ASDAR platforms on Boeing-747 aircraft was highly successful, with the result that plans are under way to establish a world-wide operational ASDAR service using Meteosat, Goes, GMS and GOMS, starting in 1985.

Operational programme

The Agency's proposal for an operational Meteosat programme was forwarded to the meteorological services in August. The baseline programme would employ five satellites to provide an operational service for ten years, starting in 1985.

Exosat

Satellite

Following successful integration of the attitude and orbit control subsystem (AOCS) units into the engineering-model satellite, extra efforts were made to complete the mandatory system-level tests (integrated system tests, EMC, etc.) prior to the model's shipment to CNES, Toulouse, for thermal-balance tests. The fact that difficulties were experienced in commissioning automatic test sequences and the frequent interruptions to the test programme caused by technical problems have meant that a considerable effort was needed to achieve the requisite standards necessary to start thermal-balance testing on schedule.

During the test programme at Toulouse, the engineering-model satellite was subjected to hard-vacuum conditions for two weeks, the first for thermal-balance testing to qualify the thermal control subsystems. This objective was achieved, temperatures being somewhat higher than predicted but still within the design limits. The second week of vacuum testing was devoted to functional testing of the satellite, and a number of malfunctions in both the payload and satellite subsystems are now the subject of further investigation.

A Development Results Review (DRR) was held during the last week in June to review the status of the engineering-model programme. This review (Part A) specifically excluded AOCS performance because of the delays in delivery and integration of that subsystem into the satellite. Part B of the review will be held on completion of the engineering-model programme in December.

Tests on the mechanical model have been hampered by a failure in the vibrator system. The effects of the shock load absorbed by the satellite are still under investigation, but the LEIT mirror assembly, regarded as the satellite's most sensitive unit, appears unaffected. Tests will be resumed with a low-level resonance search to check for any as yet unseen damage.

Payload

Payload engineering models have undergone thermal-balance and thermal vacuum testing at satellite level during August at CNES, Toulouse. The gas-scintillation proportional counter experiment was damaged when a high-tension command was inadvertently transmitted while the chamber pressure was still within the corona region. The position-sensitive gas-proportional counter within the Low Energy Experiment could not be operated due to a leak in its thin (1 μm) plastic window, which could have been damaged during spacecraft transport.

The test results will be reviewed by the end of September, at which time retesting in thermal vacuum may be considered necessary.

Manufacture and unit testing of flight models is proceeding within tight schedule constraints, the medium-energy detectors being the most critical items.

Launcher

The Ariane fourth-stage active nutation damper validation tests which are examining potential fuel-sloshing problems associated with Exosat's propellants have been completed and the preliminary results are satisfactory.

Assessment of the data available from the early seconds of the L02 flight have led to the conclusion that the acoustic blanket is as effective as predicted.

ESOC activities

Preliminary steps have been taken to obtain NASA TTC support during Exosat's early orbit phase and for back-up purposes during the remainder of the mission.

The procurement schedule for the new 15 m antenna for the Agency's Villafranca (Spain) ground station continues to be critical.

In general, the development of the

atteindre les normes requises, dans les délais impartis par le calendrier, avant de faire démarrer les mesures de bilan thermique.

Le programme d'essais appliqué à Toulouse s'est traduit par le maintien du modèle EM sous vide poussé pendant deux semaines. La première semaine a été consacrée au 'bilan thermique', l'objectif étant de qualifier les sous-systèmes de régulation thermique. Cet objectif a été atteint. On a obtenu des températures quelque peu supérieures aux valeurs prévues, mais dans les limites nominales de la conception. La deuxième semaine a été entièrement consacrée à l'essai de fonctionnement du satellite et, bien que celui-ci ait été exécuté avec succès, on a relevé un certain nombre de défauts de fonctionnement tant dans les sous-systèmes de la charge utile que dans ceux du satellite; ces défauts vont être l'objet d'investigations poussées.

Un examen des résultats de la réalisation a eu lieu la dernière semaine de juin afin de revoir la situation du programme EM. Cet examen, appelé partie A, a exclu spécifiquement les performances du système de commande d'orientation et de correction d'orbite en raison des retards intervenus dans le fourniture et l'intégration de ce sous-système dans le satellite. La partie B aura lieu à l'achèvement du programme EM en décembre prochain.

Les essais effectués sur le modèle mécanique ont été brutalement interrompus par une panne du vibrateur. On étudie actuellement les contraintes de choc subies par le satellite. Il semble toutefois que la partie la plus sensible, le miroir LEIT, n'ait pas souffert. Les essais seront repris en effectuant des recherches de résonance à faible niveau pour vérifier l'existence possible de dommages cachés.

Charge utile
Au cours du mois d'août, les modèles d'identification ont été soumis aux essais thermiques sous vide et aux essais de bilan thermique au niveau satellite, au CNES à Toulouse.

Le compteur proportionnel à scintillateur gazeux a été endommagé par l'application inadvertante d'une tension élevée alors que la pression dans la chambre se situait encore dans la région de l'effet corona.

Le compteur proportionnel à gaz, pour la détection de position, qui fait partie de l'expérience 'basse énergie', n'a pu fonctionner par suite d'une fuite très importante de la fenêtre mince (1 μm) en plastique, probablement détruite au cours du transport du satellite.

Les résultats des essais doivent être examinés vers la fin de septembre. On envisage de refaire le cas échéant des essais thermiques sous vide.

La fabrication et l'essai à l'échelon unité des modèles de vol progressent dans les limites étroites du calendrier; les détecteurs d'énergie moyenne en sont les éléments les plus critiques.

Lanceur
Les essais de validation de l'amortisseur actif de nutation du quatrième étage, portant sur les problèmes potentiels de ballottement des ergols d'Exosat, se sont achevés et les conclusions préliminaires sont satisfaisantes.

L'évaluation des résultats disponibles sur le vol de courte durée L02 ont permis de conclure que l'efficacité du revêtement acoustique est conforme aux prévisions.

Activités ESOC
Des mesures préliminaires ont été prises en ce qui concerne l'obtention du soutien de la NASA en matière de poursuite, télécommande et télémesure au cours du début de la phase orbitale et à titre de recoupement pendant la durée de la mission.

Le calendrier d'approvisionnement pour la nouvelle antenne de 15 m destinée à la station au sol de Villafranca continue d'être critique.

D'une manière générale, les travaux sur l'élaboration de la conception du logiciel opérationnel au sol progressent conformément au calendrier.

Télescope spatial

Réseau solaire
Les essais de bilan thermique d'un panneau solaire ont été exécutés avec succès, les essais d'endurance d'unités critiques ont démarré et l'assemblage du modèle de développement du mécanisme de déploiement secondaire est en cours. Des vols de ballon ont été exécutés pour étalonner les photopiles à haute altitude.

Plusieurs essais d'unités de développement ont été menés à bien, mais on a enregistré deux défaillances. A chaud, le fonctionnement sous vide du mécanisme d'actionnement Bi-stem n'a pas répondu aux prévisions, et la stabilité du déploiement primaire paraît insuffisante. Ces deux défaillances sont à l'étude et pourraient conduire à modifier l'équipement ou le mode de fonctionnement du réseau solaire. L'examen préliminaire de la conception de l'électronique d'entraînement du réseau solaire a été mené à bonne fin et une maquette du réseau solaire complet destinée à la formation du personnel a été livrée à la NASA dans les délais convenus.

Chambre pour objets de faible luminosité (FOC)
La période écoulée a été marquée par les essais du modèle structure/thermique de la FOC complète. Les résultats préliminaires des essais acoustiques et de vibration permettent d'escompter que la qualification de la structure a été obtenue. Les essais thermiques sous vide et les essais de bilan thermique ont montré l'excellent fonctionnement du système de régulation thermique active, grâce auquel la stabilité de l'image au niveau de la chambre proprement dite se situe largement dans les limites spécifiées. Les essais des unités électroniques ont également démarré. Pour différentes raisons, les prévisions de masse actuelles donnent pour la FOC un excédent de poids, qui est en cours d'évaluation. Un autre problème concerne la qualité des supports mémoire C/MOS de 4 K utilisés pour le stockage des données scientifiques, qui entraîne également certaines difficultés pour le calendrier. Le document de contrôle des interfaces avec le système de télécommande et de gestion des données des instruments scientifiques a été signé. L'examen critique de la conception de la partie chambre de la FOC est prévu pour début novembre.

Détecteur de photons (PDA)
Une nouvelle résistance de 500 mégohms à couche épaisse a été mise au point pour résoudre les problèmes d'effet corona au niveau de l'intensificateur. Les décharges qui se sont produites dans les câbles à haute tension ont amené à mettre en place un nouveau câble. Pour dissocier les travaux relatifs à l'intensificateur du problème de la résistance, on a décidé de monter la chaîne diviseur dans une unité séparée. Des difficultés ont été rencontrées lors des

ground-based operational software is progressing according to schedule.

Space Telescope

Solar array

The thermal-balance tests on a solar panel have been successfully completed, life tests on critical units have started, and assembly of the development model of the secondary deployment mechanism is in progress. Balloon flights have been carried out to calibrate the solar cells at high altitude.

Several successful development-unit tests have been completed and only two problems have been recorded: the bi-stem deployment actuator failed to operate under hot conditions in vacuum as anticipated, and stability during primary deployment appears insufficient. Both problems are under investigation.

The Preliminary Design Review of the solar-array drive electronics has been satisfactorily completed and a crew mock-up of the complete solar array has been delivered to NASA on schedule.

Faint object camera

The period has been dominated by the testing of the structural thermal model of the complete FOC. The preliminary results of the acoustic and vibration tests promise satisfactory qualification of the structure. The thermal-vacuum and thermal-balance tests have shown excellent performance of the active thermal control system, giving the camera module an image stability performance well within specification. Testing of the electronic units has also started.

For several reasons, present mass projections for the FOC show an overrun and this is being evaluated. A problem with the quality of 4 K CMOS memory devices used in the scientific data store is also giving some schedule difficulties.

The Interface Control Document for the ST scientific instrument command and data-handling system has been signed off. The FOC Camera-Module Critical Design Review is scheduled to take place in early November.

Photon detector assembly

A new thick-film 500 M Ω resistor has been developed to overcome coronal problems in the intensifier section. Discharges in high-voltage cables have led to the use of an alternative cable. To decouple the intensifier work from the resistor problem, it was decided to install the divider chain in a separate unit. Some difficulties have been encountered in testing camera-tube assemblies for the qualification model and it might be necessary to replace the camera tube. System testing of the camera section of the engineering model has started. The various problems that have occurred with coronal discharges have led to a delay in the delivery of PDA units, a delay that it will be difficult to recover completely.

NASA activities

A new Project Manager, Mr. G. Burdett, has been nominated for Goddard Space Flight Center's ST tasks (scientific instruments and operations). There are signs that it may be difficult, in the light of the Shuttle and fiscal-year funding problems, for NASA to maintain the ST's presently planned launch date.

Sled

The second model of the Sled mechanical subsystem, the flight model, was delivered to ESTEC at the end of June. Both the training and flight models have been fitted with their electrical harnesses and preparations for the coming system assembly, integration and test phase at ESTEC are almost complete.

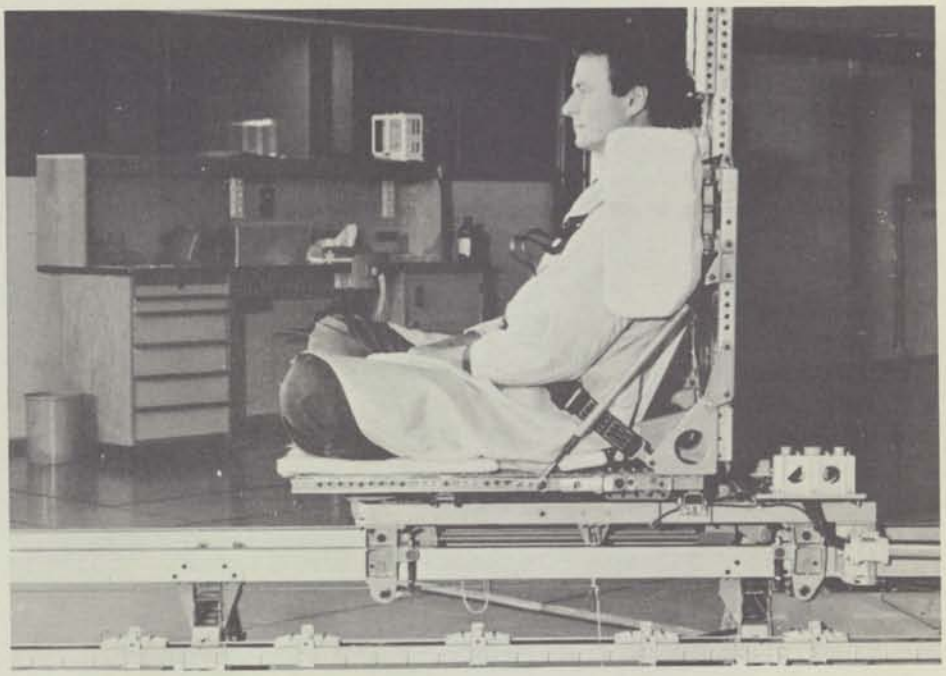
All electronic components for the electrical subsystem have been delivered, so that final assembly and testing of this subsystem can now proceed. The work is proceeding with considerably increased manpower in an effort to maintain the programme schedule. The January 1981 delivery date to SPICE indicated in the schedule in the last Bulletin was critically dependent upon electrical subsystem deliveries to ESTEC of the end of September for the trainer and the end of October for the flight model.

The two possible flight opportunities for Sled (Spacelab D-1 or SL-4 missions) were discussed by the Spacelab Programme Board in June. This Board is expected to make the choice at its next meeting, in September.

ECS

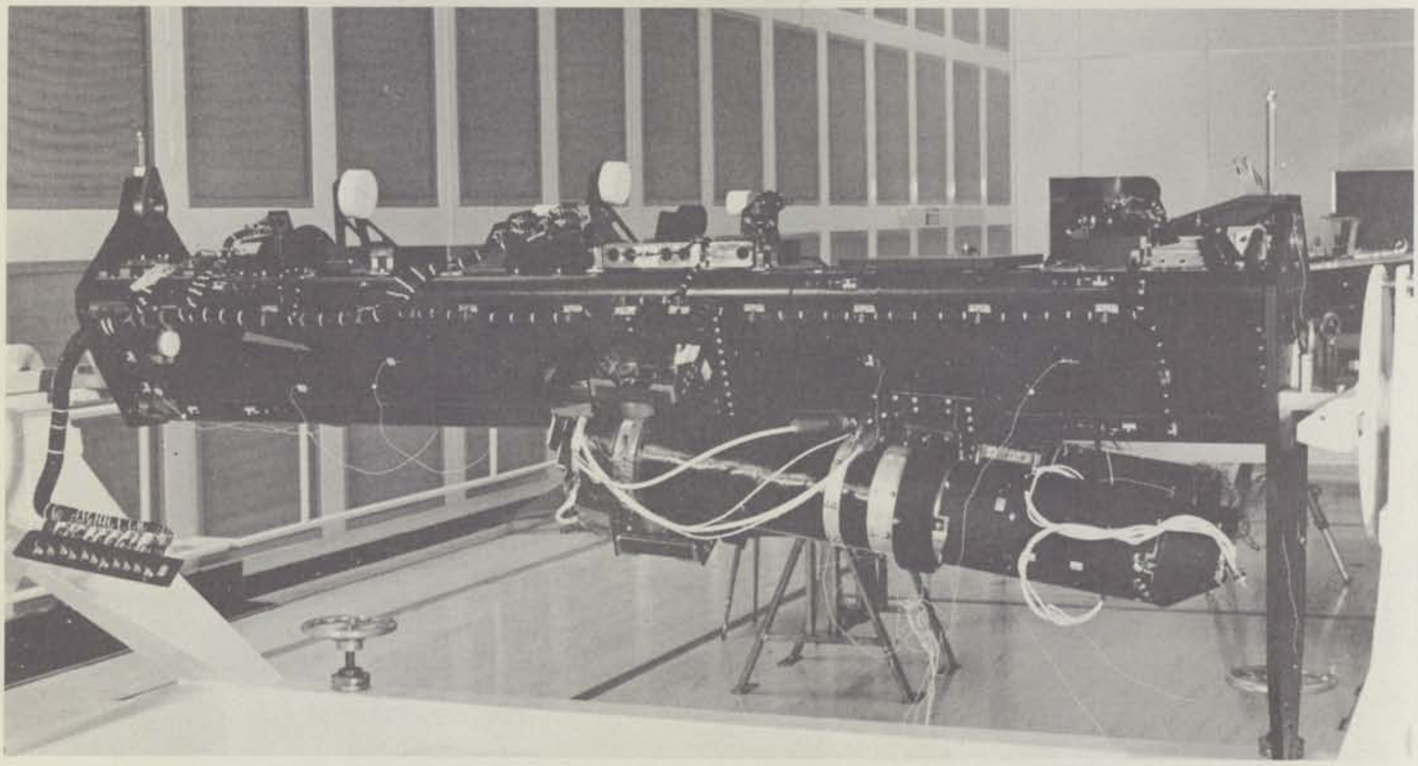
The contractual arrangement with industry for the whole of the ECS series was finalised during July by signature of the contract amendment for ordering satellites 3, 4 and 5.

Simultaneously, and continuing throughout the summer, negotiations were being pursued both with industry and the ECS user organisation EUTELSAT, to define the various technical aspects of providing full (nine channels)



Sled protoflight model on the test floor at ESTEC

Modèle prototype du Traîneau au cours des essais à l'ESTEC



Structural thermal model of Space Telescope's Faint Object Camera (FOC) being prepared for test at ESTEC

Modèle de structure/thermique de la Chambre pour objets de faible luminosité en cours d'essai à l'ESTEC

essais des organes du tube analyseur destiné au modèle de qualification. Le remplacement du tube analyseur paraît nécessaire. Les essais au niveau système de la partie chambre du modèle d'identification ont commencé. Les différents problèmes apparus dans la zone des décharges corona ont entraîné dans la livraison des unités du détecteur de photons un retard qui semble difficile à rattrapper complètement.

Activités NASA

Un nouveau Chef de projet, M.G. Burdett, a été désigné pour les activités du Goddard Space Flight Center (Instruments scientifiques et Opérations) relatives au projet Télescope spatial. D'après certaines indications, la date actuellement prévue pour le lancement du Télescope sera peut-être difficile à maintenir, du fait de problèmes propres à la Navette ainsi que pour des raisons budgétaires.

Traîneau spatial

Le second modèle du sous-système mécanique, ou modèle de vol, a été livré à l'ESTEC fin juin. Le modèle destiné à l'entraînement de l'équipage et le modèle de vol ont été équipés de câblages électriques et les préparatifs de la phase d'assemblage, d'intégration et d'essai au niveau système, qui doit se dérouler prochainement à l'ESTEC, sont presque terminés.

Tous les composants électroniques du sous-système électrique ont été livrés de sorte que l'assemblage et les essais de ce sous-système peuvent maintenant reprendre. Les effectifs ont été considérablement renforcés pour ces travaux afin de respecter le calendrier du programme. Selon le calendrier publié dans le dernier Bulletin, la date de livraison au SPICE – fixée en janvier 1981 – s'est fondée sur les dates de livraison prévues pour les sous-systèmes électriques à l'ESTEC: fin septembre pour le modèle destiné à l'entraînement de l'équipage et fin octobre pour le modèle de vol.

Le Conseil directeur du programme Spacelab a consacré en juin un premier examen aux deux possibilités de vol qui s'offrent pour le Traîneau spatial (missions Spacelab D-1 ou SL-4). On pense qu'il se prononcera sur ce point à sa prochaine réunion en septembre.

ECS

Les arrangements contractuels avec l'industrie ont été définitivement arrêtés en juillet pour l'ensemble de la série ECS, avec la signature de l'amendement concernant la commande des satellites no. 3, 4 et 5.

Dans le même temps, les négociations se sont poursuivies tout au long de l'été, avec l'industrie et avec l'organisme utilisateur d'ECS, EUTELSAT, pour d'une part, préciser la définition des différents aspects techniques de la fourniture d'une pleine capacité de fonctionnement en éclipse de neuf canaux en fin de vie et, d'autre part, inclure deux canaux spécialisés pour les transmissions de données à grande vitesse entre petits terminaux terriens. Ces modifications seraient apportées à partir d'ECS-2, qui doit être lancé vers la fin de 1982, et sur les satellites suivants.

La date du lancement d'ECS-1 a été reportée de novembre 1981 à février 1982, en accord avec le calendrier Ariane actuel.

Des mesures sont prises pour l'introduction d'une antenne Eurobeam de conception améliorée, destinée à assurer des performances de transmission conformes aux spécifications.

end-of-life, eclipse capability and to include two dedicated channels for high speed data transmission between small earth terminals. These changes would be introduced on ECS-2, due to be launched towards end of 1982, and on subsequent spacecraft.

The launch date of ECS-1 has been changed from November 1981 to February 1982, in line with the current Ariane schedule.

Steps are being taken to introduce an improved version of the Eurobeam antenna to secure communications performance that complies with specifications.

Development of one main payload, test and monitoring station (TMS-1), is proceeding, and procurement activity has commenced for the acquisition of a number of smaller, mobile test facilities, known as TMS-3s.

Marecs

The structural model underwent development tests in June and July and will enter the qualification phase in October.

Integration of the first flight model is practically completed and performance tests at system level will begin once the last items of equipment have been received. The test programme is now planned with a view to a launch in June 1981 (on L04).

ESA's offer to Inmarsat for the leasing of the communications capability available on board the Marecs satellite has been favourably received. The Inmarsat Council is expected to take a contract decision in November.

L-Sat

Phase B1 of the project definition was concluded at the end of June with the completion of the major system and subsystem trade-off studies and the establishment of a satellite configuration. Agreement to start Phase B2 with a subphase denoted 'Preliminary Phase B2' was given after a detailed appraisal of the Phase B1 results had been made and a shortlist established of design areas requiring further analysis and eventual improvement.

One of the principal objectives of the Preliminary Phase B2, which started in early July with a planned duration of four months, is to choose the responsible contractors for certain platform subsystems on a competitive basis. Invitations to tender (ITT) were prepared by British Aerospace, approved by the Agency and issued at the beginning of August with responses expected in early September.

Work has continued in parallel on the payload definition, system and AIT aspects and on subsystems not subject to the competitive activity. Various design problems identified during the review of Phase B results are the subject of ongoing analysis by the industrial team.

The main part of the Phase B2 is planned to follow on after the Preliminary Phase B2. A request for quotation (RFQ) has been issued by the Agency and a proposal taking into account the results of the competitive activity is expected at the end of September. The main Phase B2 of the project definition will be in two parts, the first part ending with the issue of the industrial Phase C/D proposal early next year. The Phase C/D RFQ will be formally issued at the end of October. The second part of Phase B2 is now scheduled to finish in May/June 1981 at which point Phase C/D is scheduled to go ahead.

The definition of the four missions for the first flight model of L-Sat is now substantially complete and the composite satellite performance specification is being prepared by the Agency. During July/August there has been extensive discussion of the mission definition for the specialised services payload to attempt to simultaneously satisfy a series of objectives. Work has continued and certain applications have been the subject of detailed study and presentation to the user organisations.

Sirio-2

To adapt Sirio-2 development-programme planning to the current Ariane launch schedule, the prime contractor has been asked to re-arrange satellite assembly, integration and test activities. He has also been requested to undertake a number of additional tasks aimed at optimising the scope of certain tests and the mission analysis. In the meantime, qualification-level testing of electronic satellite units and subsystems is proceeding satisfactorily.

Preparations for the Sirio-2 exploitation phase are in progress, with detailed definition studies of ground-segment hardware and software. Procurement of long-lead items has been initiated for the S-band station at Fucino which will

Demonstration of direct reception via OTS of a Dutch TV programme on the ESA stand at 'Farnborough International 80'

Démonstration de transmission directe d'un programme de télévision néerlandais via OTS au stand ESA au Salon international de Farnborough 1980

La réalisation d'une station d'essai et de surveillance pour la charge utile principale (TMS-1) se poursuit et la procédure d'approvisionnement a commencé pour l'acquisition d'un certain nombre d'installations d'essai mobiles plus petites dites TMS-3.

Marecs

Le modèle de structure a subi des essais de développement en juin et juillet et entrera en phase de qualification en octobre.

L'intégration du premier modèle de vol est pratiquement achevée et les essais de performance au niveau système commenceront dès réception des derniers équipements manquants. Le programme d'essais est maintenant planifié pour un lancement en juin 1981 (sur Ariane L04).

L'offre soumise par L'ESA à INMARSAT pour le 'leasing' de la capacité de communication des satellites Marecs a reçu un accueil très favorable. Une décision contractuelle est attendue du Conseil d'INMARSAT en novembre prochain.

L-Sat

La phase B1 de définition du projet s'est terminée fin juin avec l'achèvement des principales études de compromis au niveau système et sous-système et l'établissement d'une configuration de satellite. Après l'évaluation détaillée des résultats de la phase B1 et l'établissement d'une liste de points de conception nécessitant un complément d'analyse et une amélioration éventuelle, le feu vert a été donné pour le démarrage de la phase B2 sous une forme préliminaire.

L'un des principaux objectifs de la phase B2 préliminaire, mise en route début juillet pour une durée prévue de quatre mois, est de sélectionner sur une base concurrentielle les contractants qui seront responsables de certains sous-systèmes de la plate-forme. Les invitations à soumissionner ont été préparées par British Aerospace, approuvées par l'Agence et lancées début août, avec appel des offres pour début septembre.

Les travaux se sont poursuivis en parallèle dans les domaines définition de la charge utile, système et assemblage, intégration et essais, ainsi que pour les sous-systèmes ne faisant pas l'objet de l'appel à la concurrence. L'équipe industrielle procède actuellement à l'analyse de differents problèmes de conception relevés lors de l'examen des résultats de la phase B.

Après la phase B2 préliminaire doit se dérouler la phase B2 proprement dite. L'Agence a lancé une demande de prix et attend pour fin septembre une proposition prenant en compte les résultats de l'appel d'offres. La phase B2 principale de définition du projet comprendra deux parties, dont la première prendra fin avec la proposition industrielle de phase C/D au début de l'an prochain. La demande de prix de phase C/D sera officiellement lancée fin octobre pour faciliter l'exécution de ce calendrier. L'achèvement de la seconde partie de la phase B2 est désormais prévue pour mai/juin 1982, date à laquelle la phase C/D devrait alors démarrer.

La définition des quatre missions du premier modèle de vol de L-Sat est pour l'essentiel terminée et l'Agence élabore la spécification des performances du satellite composite. En juillet et en août ont eu lieu de nombreux échanges de vues sur la definition de la mission pour la charge utile consacrée aux services spécialisés, pour essayer de répondre simultanément à une série d'objectifs. Les travaux se sont poursuivis et certaines applications ont fait l'objet d'une étude détaillée avec présentation aux organismes utilisateurs intéressées.

Sirio-2

Afin d'adapter le planning du programme de développement de Sirio-2 au calendrier actuel des lancements d'Ariane, il a été demandé au maître d'oeuvre de réorganiser les activités concernant l'assemblage, l'intégration et les essais du satellite, ainsi que d'effectuer un certain nombre de tâches supplémentaires ayant pour but d'affiner certains essais et l'analyse de la mission. En attendant, les essais des équipements et sous-systèmes électroniques du satellite au niveau de la qualification se poursuivent de façon satisfaisante.

Les préparatifs de la phase d'exploitation de Sirio-2 se poursuivent par des études de définition détaillées des matériels et logiciels du secteur sol. Des commandes d'articles à long délai de livraison ont été passées pour la station de réception en bande S de Fucino qui assurera le soutien du satellite pendant les campagnes de démonstration de LASSO et de MDD. Le scénario de ces campagnes est actuellement élaboré en étroite coopération avec les utilisateurs potentiels dans le monde entier.

Télédétection

Dans le cadre du programme préparatoire de télédétection, 38 activités (sur environ 50) ont été mises en route.

La préparation de la campagne SAR-580 se poursuit: 57 propositions d'expériences, toutes de bonne qualité, ont été reçues et sont en cours d'évaluation.

La premiere réunion de travail consacrée à la définition préliminaire du plan de vol a eu lieu en août.

En ce qui concerne les études de système et de charge utile, l'étude de définition de l'instrument de prise d'images optiques du LASS (Land Application Satellite System), effectuée par Matra, a été terminée en juin. L'élément critique, sur le plan du développement, devrait être le détecteur de l'infrarouge proche dont le prédéveloppement par l'industrie européenne résulte d'une initiative prise par l'Agence en 1979 dans le cadre du programme préparatoire de télédétection.

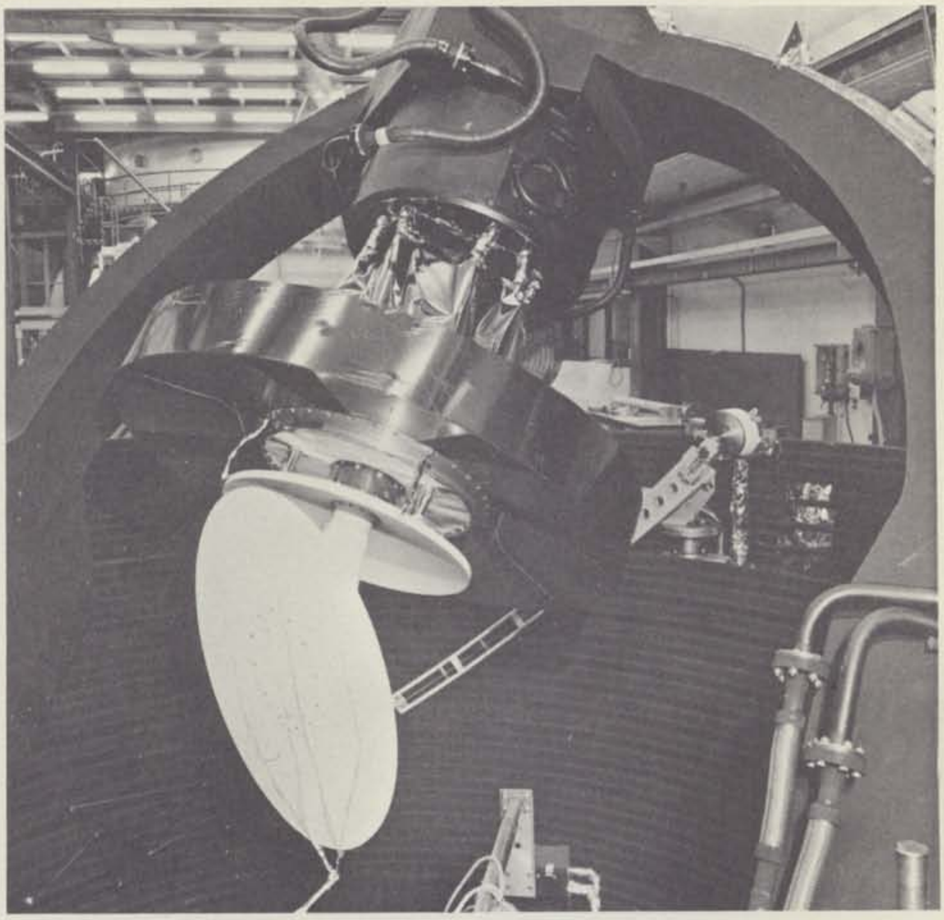
L'étude du diffusiomètre a été entreprise en juin 1980 par Dornier System qui étudie deux options: un diffusiomètre 'vecteur vent' (type Seasat et un diffusiomètre 'vagues' (type MRSE, 2 fréquences).

A titre d'extension de la phase A du programme COMMS, la firme BADG intègre les résultats des différentes études d'instruments dans une étude de configuration afin d'en évaluer la faisabilité.

Les commentaires formulés par différentes délégations lors de la réunion du Conseil directeur du programme de télédétection du 22 juillet sont pris en compte pour la rédaction d'une proposition permettant de poursuivre les travaux préparatoires concernant la

Sirio-2 spacecraft antenna under test in the HBF-3 chamber at ESTEC

Essai d'antenne du véhicule spatial Sirio-2 dans la Chambre HBF-3 de l'ESTEC



support the satellite during the LASSO and MDD demonstration campaigns. The campaign scenario is being worked out in close collaboration with potential users around the world.

Remote sensing

Thirty-eight of the fifty or so activities foreseen as part of the Remote Sensing Preparatory Programme (RSPP) have now been initiated.

The SAR-580 campaign preparation is continuing. Fifty-seven proposals for experiments, all of good quality, have been received and are presently being evaluated.

The first working session for the preliminary definition of the flight plan took place in August.

As far as system and payload studies are concerned, the definition study of the Optical Imaging Instrument (OII) of the LASS (Land Application Satellite System) was completed by Matra in June. The critical element in the development programme could be the near-infrared detector, pre-development of which by European industry was initiated by ESA in 1979 in the framework of the RSPP.

The scatterometer study was initiated in June 1980, with Dornier System GmbH studying two options called 'wind scatterometer' (Seasat type) and 'wave scatterometer' (2 FS, MRSE type).

As an extension of the COMSS Phase-A study, British Aerospace is integrating the results of the different instrument studies into a configuration study, in order to assess feasibility.

Comments by the Delegations at the Remote-Sensing Programme Board meeting on 22 July are now being taken into account in drawing up a proposal permitting preparatory work to continue on the configuration to be selected, before starting a detailed definition phase (B1) in 1981.

Spacelab

Europeans join NASA's Mission Specialist training course

Two European candidates have entered the NASA Mission Specialist training programme at the Johnson Space Center (JSC), Houston, Texas.

NASA has agreed to train the European candidates nominated by ESA in recognition of the substantial contribution ESA is making to the Space Transportation System (STS) by funding development of Spacelab. ESA will reimburse NASA for the costs of training the two European candidates.

The two European candidates have undergone a screening and selection process similar to that of US candidates and they enter the Mission Specialist training programme with the same commitment as the other candidates selected by NASA, that is, to undergo the full training in preparation for possible duty as Mission Specialists utilising the Space Transportation System.

The two European candidates selected for training are Dr. Claude Nicollier (Swiss) and Dr. Wubbo Ockels (Dutch).

The opportunity for Mission Specialist training arose when additional time became available for preparing for the Spacelab-1 mission currently scheduled for launch in May 1983.

Spacelab Follow-On Development study programme

The study programme consists of a detailed definition, preliminary design and cost analysis of improved Spacelab subsystems in particular in terms of extended mission duration and increased electrical power availability. Another study will concentrate on the application potential of Spacelab and Spacelab elements for the evolving Space Transportation System.

The study programme will be carried out in 1980/1981 by the European industrial companies involved in Spacelab's development. The funding amounts to approximately 1.3 MAU.


nasa

Europe's Spacelab payload specialists Claude Nicollier and Wubbo Ockels (kneeling, first and second from left, resp.), in the company of 16 US astronaut candidates, at Johnson Space Center (JSC)

Les spécialistes 'mission' européens du Spacelab Claude Nicollier et Wubbo Ockels (au premier rang, de gauche à droite), en compagnie de 16 candidats astronautes américains au Johnson Space Center (JSC)

configuration à choisir avant d'entreprendre en 1981 une phase de définition détaillée (phase B1).

Spacelab

Des Européens participent aux cours de formation de spécialistes 'mission' de la NASA

Deux candidats européens ont commencé à suivre le programme de formation des spécialistes 'mission' de la NASA, au Johnson Space Center (JSC) à Houston (Texas).

La NASA a accepté d'assurer la formation des candidats européens désignés par l'ESA pour marquer l'importance de la contribution que l'Agence apporte au système de transport spatial (STS) en finançant le développement du Spacelab. L'ESA remboursera la NASA des frais de formation des deux candidats européens.

Les deux candidats européens ont suivi une procédure d'examen et de sélection analogue à celle qui est imposée aux candidats américains. Ils participent au programme de formation des spécialistes 'mission' dans les mêmes conditions que les autres candidats sélectionnés par la NASA, c'est-à-dire qu'ils passeront par tous les stades de la formation qui les préparera à une éventuelle affectation comme spécialistes d'une mission utilisant le système de transport spatial.

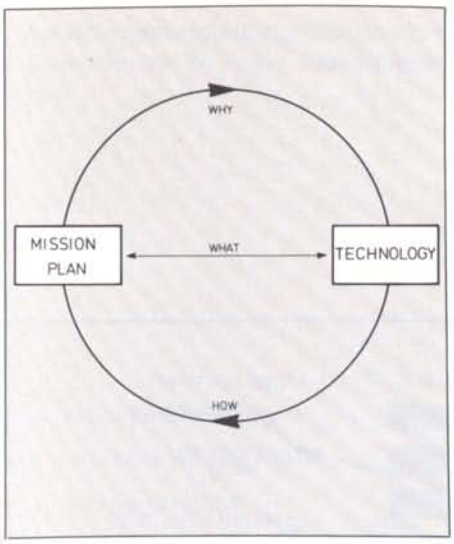
Les deux candidats européens retenus pour ce cours de formation sont le Dr Claude Nicollier (de nationalité suisse) et le Dr Wubbo Ockels (de nationalité néerlandaise).

S'ils peuvent participer à ce cours de formation de spécialistes 'mission' c'est que l'on a constaté qu'il restait du temps pour préparer la première mission du Spacelab dont le lancement est actuellement fixé à mai 1983.

Développement ultérieur du Spacelab – Programme d'étude

Ce programme d'étude porte sur la définition détaillée, la conception préliminaire et l'analyse du coût de sous-systèmes Spacelab améliorés, en ce qui concerne notamment la durée de mission et la puissance électrique disponible. Une autre étude sera consacrée aux possibilités d'utilisation du Spacelab et de ses éléments pour le système de transport spatial en cours d'élaboration.

Le programme d'étude sera exécuté en 1980-1981 par les industries européennes ayant participé au développement du Spacelab. Le montant de son financement est d'environ 1,3 MUC.



The New Approach to the Definition of the ESA Technological Research Programme

H. Stoewer, J.J. Capart, G. Mica & G. Whitcomb,
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After a thorough review in 1979, the approach for updating of the Agency's Technological Research Programme has been reoriented. The need for this re-orientation stemmed from the increasing technological complexities of the spacecraft that will be developed in Europe in the 1980s and 1990s and the consequent difficulty in selecting research items to be funded from a limited budget. To assist the choice, a detailed analysis has been made of trends in each of the technical disciplines required for the Agency's spacecraft and six major 'technological themes', subdivided into thirteen 'projects', have been derived. These are intended to serve as a focus for the most important technological research undertakings for the coming decade.

The technology/future missions relationship
The planning and content of ESA's Technological Research Programme must be compatible with the Agency's future space-mission planning. There is an equally strong reciprocal dependency of the mission planning on the technological research capability in that the technological state of the art governs to a large extent the nature of the missions that Europe can contemplate. The birth of new technologies can thus facilitate missions that were hitherto unthinkable. In view of these relationships, it follows that the direction and content of the technology programme should stem not only from anticipated future missions, but there must also be latitude to explore new technological avenues. The approach adopted meets the requirements by analysis of the future mission requirements, identification of technological trends, and the selection of themes and projects that act as focuses for technological developments.

Future-mission requirements/trends
The agency's analysis of future-mission opportunities in the various scientific and applications disciplines for the 1980s and 1990s has shown generally:

- increasing user interest in the deployment of larger payloads and hence in the use of large platforms
- an increasing need for sophisticated data collecting, processing, and distribution technologies
- increasing emphasis on the development of advanced instrumentation
- a need for space rendezvous and docking technologies
- a need for propulsion systems to augment the use of Ariane for nongeostationary missions;
- an emphasis on precision pointing and high stability,

and specifically:

- in space science, the need for the enhancement of the European deep-space capability as a result of the trend towards non-earth-orbit missions
- in communications, the need for large-scale systems to serve the various classes of user
- in earth sciences, new operating technologies will be needed for the eventual use of multiple spacecraft.

Trends in technological sectors
To identify the technological trends, the following questions have been raised:

- What will constitute the next two or three generations of space technology?
- What is likely to be the state of the art of European technology in the late 1980s and early 1990s?
- How do these compare with anticipated technological developments in the USA?

In seeking answers to these, in the light of past technological achievements, the current European state of the art, and a critical analysis of future requirements, it is clear that an important evolution is taking place in space technology. The need for increased performance is evident in several areas, particularly antennas for communications and microwave instrumentation, optical instruments, power systems and, obviously, the supporting platforms. More complex structures and more complex deployment and orienting mechanisms are also implied.

Figures 1 and 2 show the trends identified for two of the thirteen disciplines that have been analysed. In summary, it is concluded that relative increases in priority can be justified in a number of areas, such as:

- mechanisms, to account for more complex and 'flexible' new spacecraft with a multitude of deployable appendages (antennas, booms, solar arrays, etc.)
- software, to prepare for the increased complexity and cost of software in future systems
- earth-observation techniques (technologies still in their infancy)
- energy storage, to cope with strongly increasing demands
- heat collection and rejection technologies, to cope with qualitative increases in demand

and relative decreases in priority in such areas as:

- solar generators
- attitude-control actuation
- power conditioning
- conventional optical sensors

which, technologically speaking, are already comparatively mature and therefore do not require an increase of effort in the foreseeable future (Fig. 3).

Generally speaking, the payload-supporting 'advanced' technologies have been given a boost, while the funding of the more 'classical' technologies has been held in check compared with earlier plans.

Figure 1 – Trends in the development of satellite communications payloads

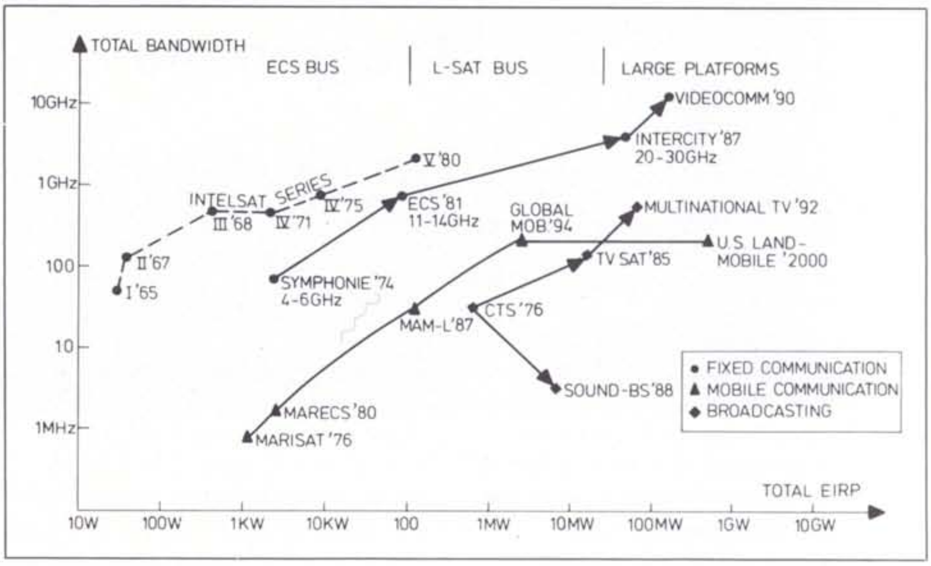
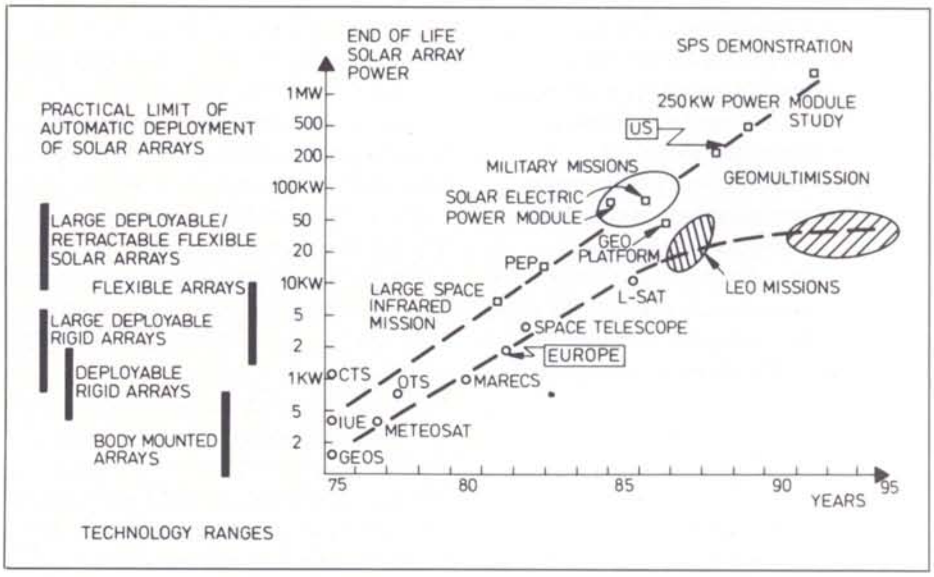


Figure 2 – Evolution of spacecraft power requirements

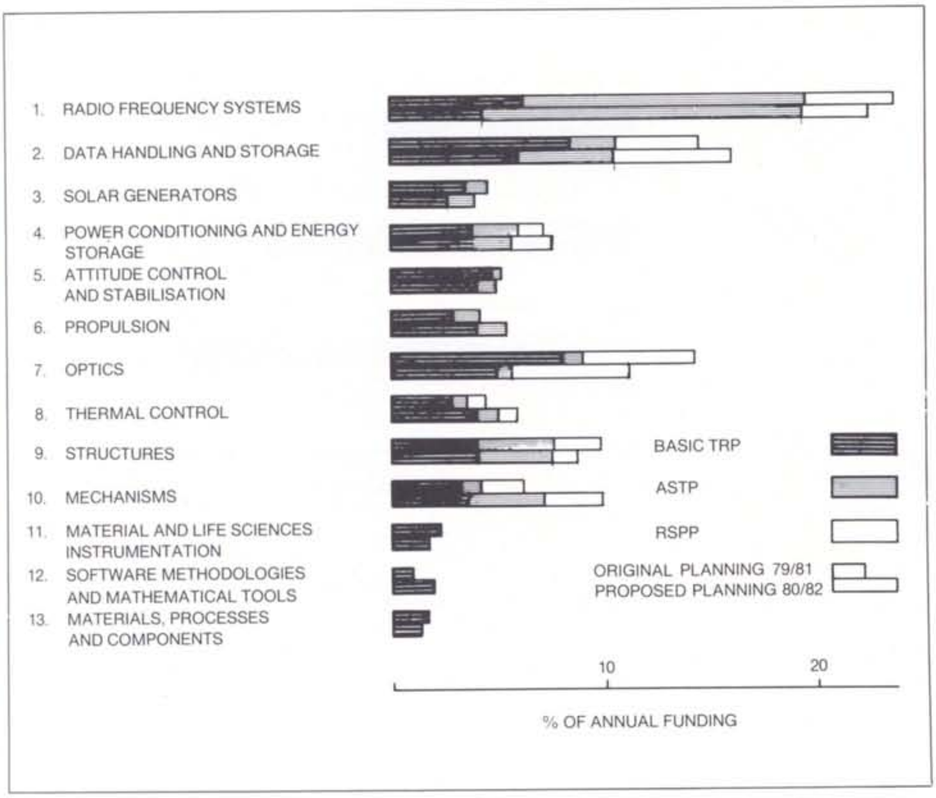


Technology themes and projects

In redirecting the Technological Research Programme, special emphasis has been placed on streamlining the multitude of individual technological activities around a few major long-term technology themes and projects, with a view to conserving ESA resources and making it feasible to employ prime contractors for major technology efforts. The themes so far identified (Fig. 4) are:

- optimisation of the earth/space telematic network (data-management infrastructure) for the 1990s
- major technology infrastructure for space communications in the 1990s
- global weather/climate/environment monitoring system (early 1990s)
- maximised use of Ariane for earth-orbit and deep-space missions (mid-1980s to mid-1990s)
- maximised use of Spacelab in the US Space Transportation System (STS) missions (mid-1980s to mid-1990s)
- maintenance of Europe's competitiveness in selected areas.

Figure 3 — Approximate distribution of annual research funding by technological sector



They respond to foreseen needs highlighted by the analysis of future missions and technological trends and the additional needs to:

- exploit to the maximum extent the major ESA (transportation) systems, Ariane and Spacelab
- develop an effective technology infrastructure for the 1980s and early 1990s, and
- streamline in the most effective way and in a multidisciplinary manner the future technological developments.

The 'translation' from themes to projects has been prompted by the wish to identify technology drivers for particular critical development efforts. The emphasis is on grouping related technological activities into multidisciplinary projects or 'mini-projects' to ensure coherent progress in all the elements of relevance to, for example, a new deployable mesh antenna (i.e. its mechanisms, structure, thermal coatings, feeds and electronics).

Figure 4 — Technology themes and projects identified so far and their interrelationships

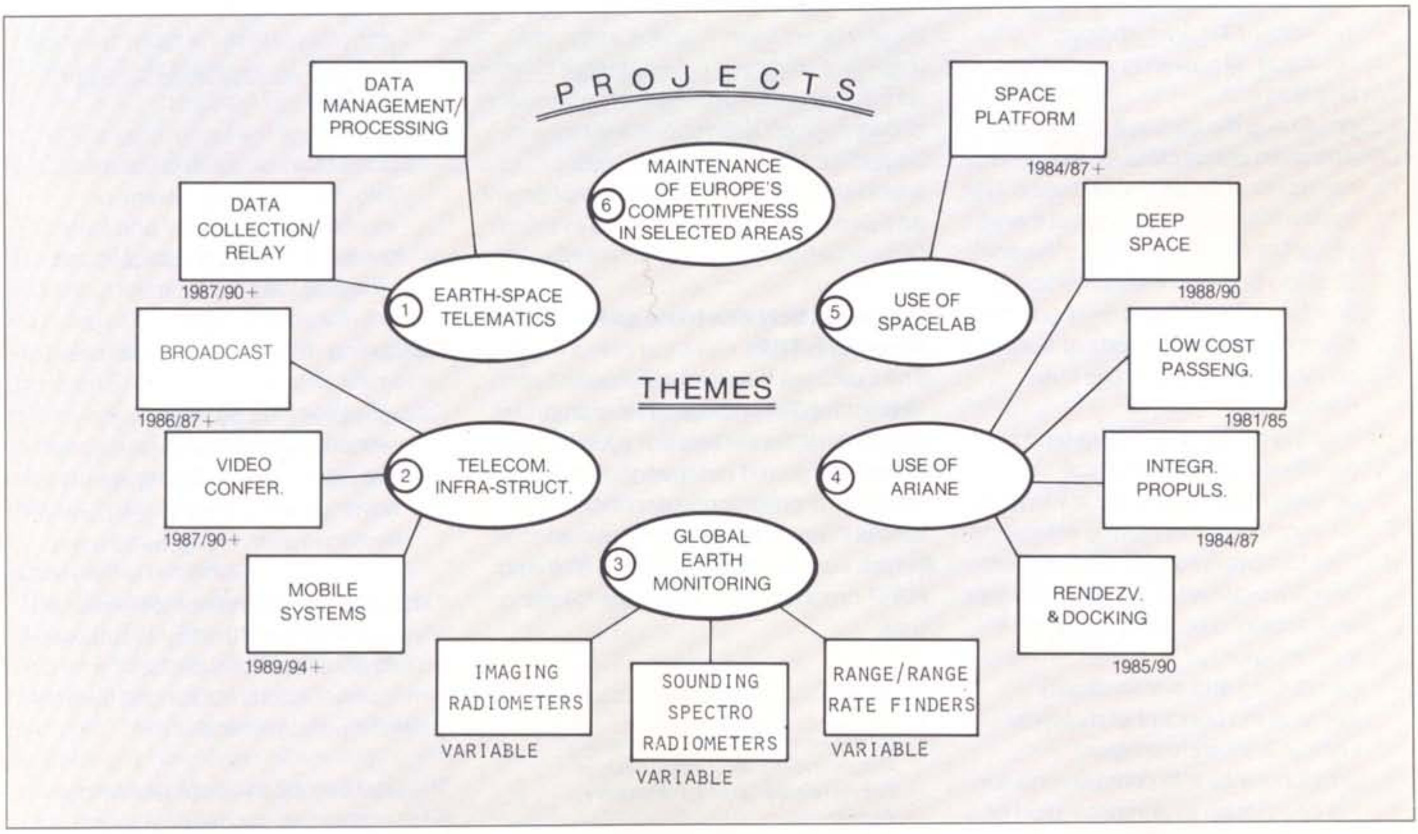
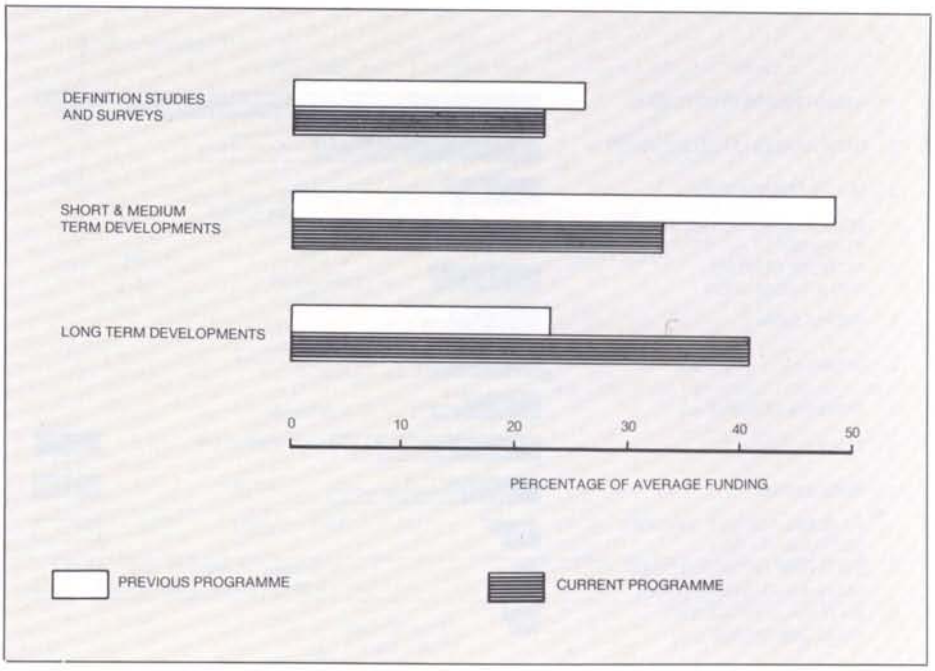


Figure 5 — Impact of the changed objectives on the Basic Technology Research Programme



The changed emphasis due to the new approach

Figure 5 shows a breakdown of the current plan for the basic Technological Research Programme (TRP) into definition studies and surveys, and short-, medium- and long-term developments.

Comparison with the previous programme shows a change in emphasis towards long-term development work and a corresponding reduction in the Programme's short and medium-term goals. This reflects a certain shift from near-term and concurrent 'project-support-type' activities more towards preparation for meeting the medium- and long-term technological infrastructure requirements associated with the increasing complexity of future missions.

The Programme's implementation

To make the Agency's technological contracts more effective, the Executive intends to streamline its management of the technological effort by:

- significantly reducing the number of individual TRP development contracts by grouping related activities
- employing the concept of principal and main contractors for the execution of larger, more diverse TRP activities at the technological theme, project or mini-project level, thereby allowing both more effective use to be made of ESA manpower and the possibility of making tests at a more advanced technical stage than hitherto
- defining medium and long-term milestones for technological developments, to provide a yardstick for accomplishments, and estimating cost-to-completion for development-oriented activities to facilitate analysis and decisions on competing technologies
- introducing and systematically applying the concept of multiyear contracts for technological developments, with commitments for the completion to demonstration or flight-qualification of a working system.

By way of example, Figure 6 traces the individual steps in a representative technological development programme. It shows a rough definition of the tasks to be performed and the milestones associated with the study predevelopment and development phases, up to eventual flight qualification.

Distinction between basic and supporting TRPs

The Executive intends to gradually redirect the Technological Research Programme on the basis of specific objectives divided between the basic technology programme and the supporting technology programme (which currently consist of the ASTP and RSPP programmes)* along the following lines.

Basic technology programme:

- to support the generation of technologies for the more common domains as applicable to medium and far-term missions
- to advance the technology to the point of demonstrated feasibility through a working system, i.e. establish the feasibility and identify the remaining technical cost and schedule risks.

Supporting technology programmes:

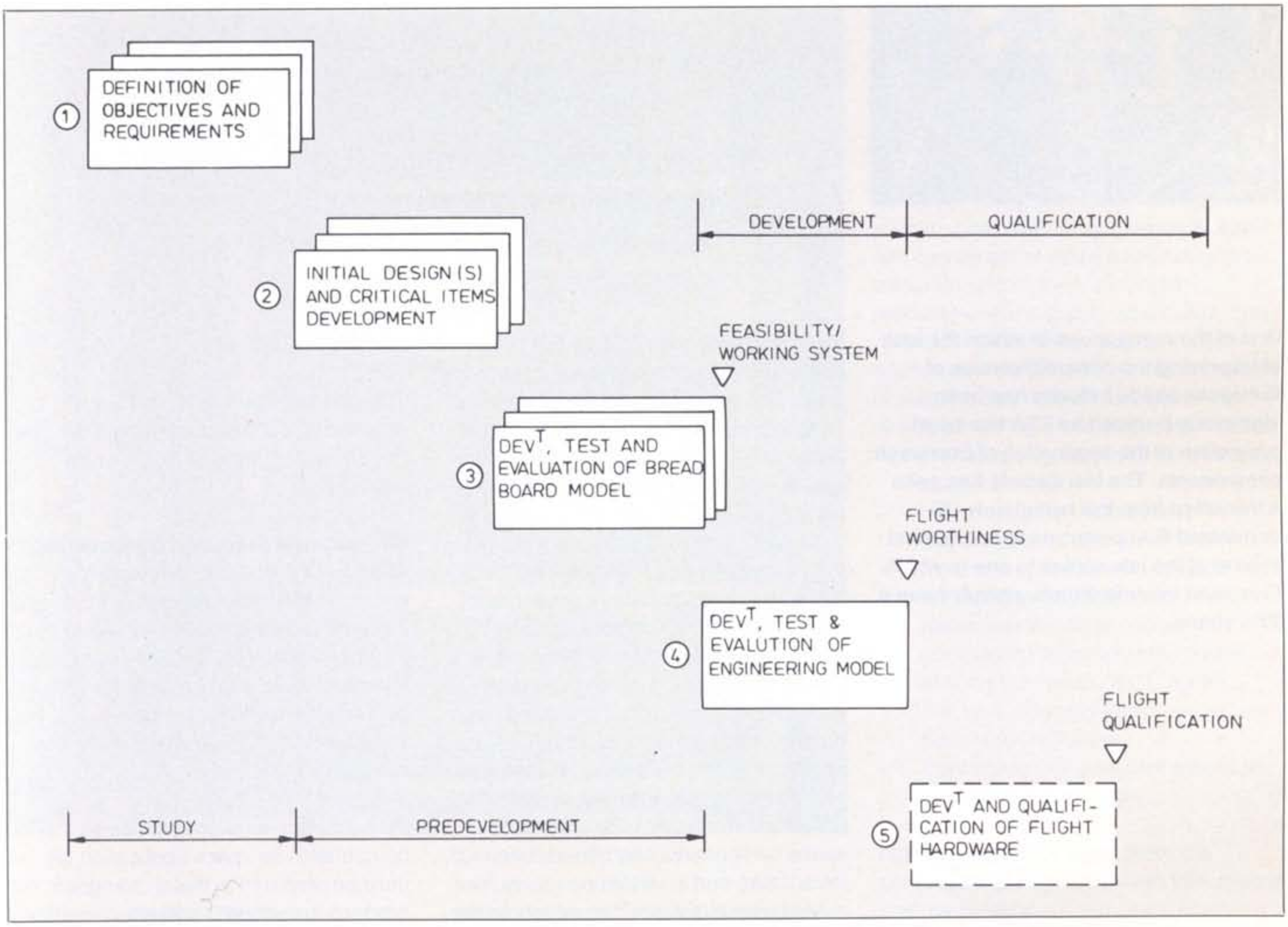
- to support the generation of technologies needed primarily for near and medium-term missions to advance technology to the point of demonstration of flightworthiness.

It should be noted that the development and qualification of the flight hardware is performed as part of a project development and is not funded from the technology programme.

The total European space technology effort consists of the developments

* ASTP - Advanced Systems Technology Programme (for telecommunications)
RSPP - Remote-Sensing Preparatory Programme.

Figure 6 – Steps in a typical space technology development programme

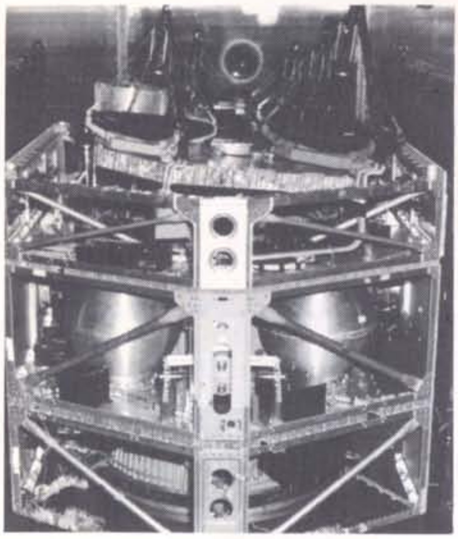


funded by ESA and those undertaken by individual Member States through nationally sponsored activities. In this respect, the harmonisation policy agreed between ESA with certain of its Member States will assist in the achievement of a coherent and more effective space-technology programme for Europe as a whole.

Concluding remarks

The 1980 programme content of the Agency's TRP is currently being implemented through a multitude of industrial contracts and in-house activities. The programme and its new orientations have been extensively discussed with Member States and industry, with a very encouraging response from both.

The new programme orientations are already being gradually applied and consolidated. The 'autumn up-date' of the Technological Research Programme will serve to verify the shifts in emphasis, especially in the light of the updated medium-term mission plans of the Agency, and to define the specific actions to be undertaken in 1981.



Promotion of European Components for ESA Projects

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One of the many areas in which the task of improving the competitiveness of European space industry has been vigorously pursued by ESA has been promotion of the application of European components. The last decade has seen a transition from the completely US-dominated European space-component market of the late sixties to one in which European manufacturers already have a 50% share.

From the days when Europe first embarked on space activities until the late sixties, the electronic components for its various projects were purchased almost exclusively from the United States. There was practically no other option because the vast majority of European component manufacturers lacked specific knowhow in this new field and there were no adequate reliability data or appropriate procurement specifications available. In the United States, on the other hand, a military specification system had been established and was in widespread use; a data-exchange system had been implemented for the collection, evaluation and distribution of test reports; various procurement specification systems for space components had already been fully introduced; and an enormous consumer market, with NASA and the military as the main customers, had already come into being. Without adequate support, European manufacturers stood little chance of acquiring a foothold in this market, let alone of becoming serious competitors.

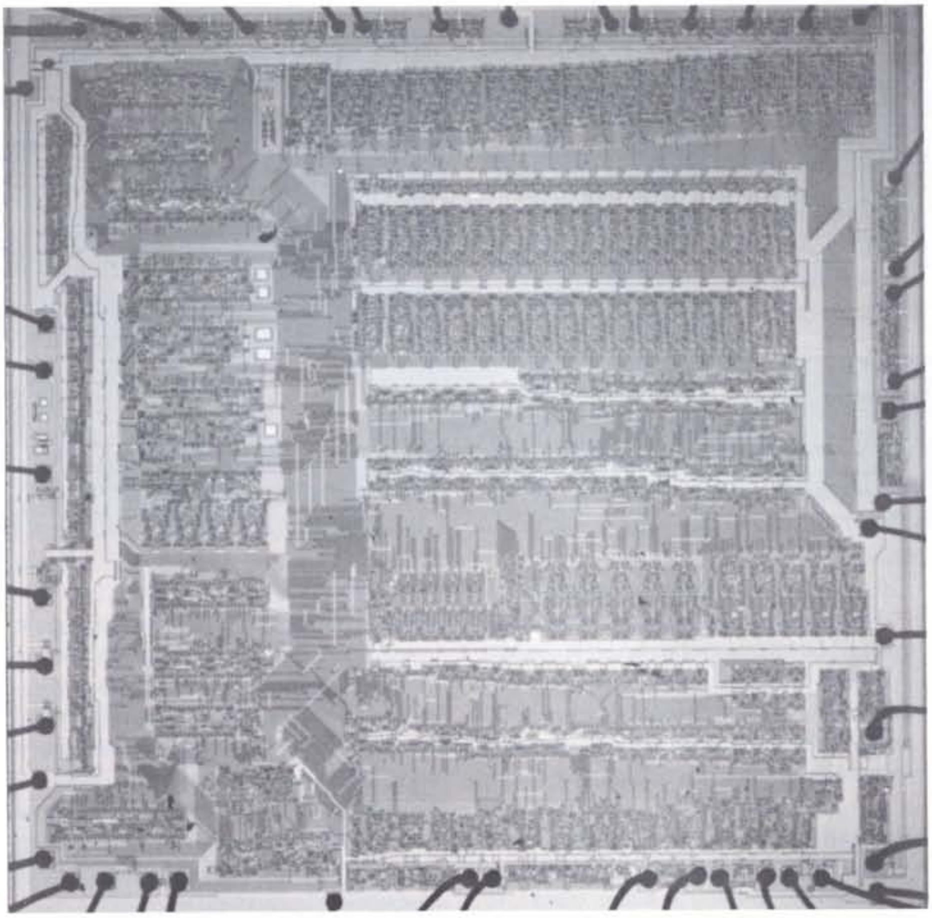
Since then, however, the situation has changed considerably. Roughly 50% of all electronic components used in ESA projects are of European origin; a comprehensive system of procurement specifications is available and is being implemented; adequate data packages are being established, evaluated and approved; and the number of European manufacturers with official qualification status is steadily increasing. This progress is largely a result of continuous efforts by ESA and its Member States, and the cooperation of both the manufacturers and the user industry.

The question one might now ask is: should ESA continue to promote the use of European components for space application?

Why promote European components?
Although it is one of ESA's tasks to improve the competitiveness of European industry, this objective in itself would not justify promotion of European component sources if there were no other benefits to be gained in terms of technological improvement, improved availability and competitive cost.

If a manufacturer wishes to supply components for space application, he must be prepared to make changes in his production methods, to invest in new test equipment, and to carry out new and stringent test sequences. However, it is precisely these demands that will increase his knowledge of the susceptibility of his product to severe environmental conditions and its degradation behaviour, failure modes, wear-out phenomena and, in principle, technological limits – in short, the type of knowledge he would not normally gain from routine development and verification test programmes. Knowing a product's technological limits already provides a basis for further improvement and this, in turn, should lead to a better yield and increased competitiveness. At the same time, the manufacturer will be able to control his production processes better, allowing him to manufacture more complex devices with more sophisticated performances.

Figure 1 – European 16-bit microprocessor chip using bipolar technology. Maximal clock frequency 13 MHz, typical power dissipation 425 mW



A further reason why ESA should continue to promote products from European sources is the need for Europe to be as independent of other markets as possible. The availability of components from these other markets and, in particular, of key complex-technology components essential in the realisation of a project has often been ruled in the past by factors outside our influence. For example, high-reliability components are often subject to the priorities that a government assigns in its national programmes and are therefore not generally available. At times when there is a large demand from the home market for key components, supplies to European customers can dry up altogether or there may be delivery times of up to 100 weeks. Under such conditions short-term projects can never be realised and the only alternative is to find a European supplier.

Last, but certainly not least, one has to consider the economic aspect. Set against the total industrial cost of a space segment, the total sum involved in the procurement of components for a space project varies from 5 to 12%, i.e. approximately the cost of a major subsystem. The total value of contracts placed annually for ESA projects alone is of the order of 8 MAU (1 AU= ± 1.2 US $), of which roughly 50% goes to European manufacturers. When compared to US expenditure in this field, this figure may not sound very high, but to European component manufacturers it represents interesting business.

How does ESA promote European components?

As can be inferred from the above, the promotion of European components for ESA projects is more than desirable. Any promotion of a product is usually linked with either direct or indirect financial support. The concept for which the Agency has settled in this respect is based on a policy of indirect financial support with world-wide competitiveness of European component suppliers as the ultimate goal. ESA firmly believes that this aim can be achieved by implementing a complete system for component procurement and quality assurance. This system, once widely understood and accepted, should operate with a minimum of support. Steps taken by ESA with a view to achieving these objectives include:

- the standardisation of procurement specifications;
- the qualification of standard components;
- the introduction of an approach for nonstandard components;
- the incorporation of space-component requirements into the existing European CECC (CENEL Electronic Components Committee) Specification System;
- the inclusion of adequate provisions in ESA Calls for Tender.

Apart from these actions, there is a continuous dialogue between ESA experts and the component manufacturing/user industry aimed at better understanding and resolution of each other's problems, each party being well aware that only a joint effort will lead to success.

Procurement specifications

A procurement specification, when attached to a purchase order, is a contractual document binding both the orderer and the manufacturer. It specifies the technical, quality-assurance and documentation requirements pertinent to the product to be delivered. Because of the legal and financial aspects involved, the negotiation of procurement specifications is a costly and time-consuming activity, requiring a great deal of expertise on both sides. Bearing in mind that about 250 to 300 individual procurement specifications are required per project, there is clearly an advantage in selecting only those suppliers and specifications on which agreement has already been reached. The key to Europeanisation of component usage is therefore the availability of a set of fully integrated procurement specifications.

To establish and implement such a system, ESA has set up the Space Component Coordination Group (SCCG), which advises the Agency's Director General on space-component matters and has a consultancy function in the establishment of a specification system.

The ESA/SCC Specification System is the most advanced and complete system currently available for space components. It is largely thanks to the ready cooperation of the experts in its Member States that ESA has been able to implement this system, which presently comprises more than 500 documents, covering approximately 400 individual components and component types. Although not all of these detailed specifications are yet fully integrated with European component manufacturers, the system can be said to be generally operational and is being continuously expanded and improved.

This set of specifications, which is used almost exclusively by projects such as Spacelab and Ariane, makes it possible to implement a uniform European quality standard and to rationalise the logistics associated with high-reliability-component procurement.

Qualification of space components
When a component has successfully withstood the qualification tests specified in the ESA/SCC System, it is acceptable for all projects and given official qualification status.

Evidently, there is no point in promoting European components if insufficient qualified products are available. Over the last decade, ESA and the national space agencies of its Member States have made great strides in the qualification of European components, but unfortunately it was not until 1977, when the SCCG requirements were available, that the standards to be applied were commonly agreed. A Qualification Board was formed which reviews not only the results of the more recent qualifications performed according to the ESA/SCC System, but also those of qualifications performed previously according to different systems. It also evaluates the degree to which the latter results meet the ESA/SCC requirements. Based on the recommendations of the Board, ESA has so far granted full-qualification status to 84 component types/families and these have been incorporated in the ESA Qualified Parts List. Thirty further component types are currently under review. In parallel with these qualification activities by ESA and the national space agencies, the SCCG has drawn up a Medium-Term Qualification Programme (MTQP) for the qualification of additional standard components. As provided for by this programme, 24 component types/families are currently being evaluated and/or qualified.

At the present time, there are sufficient space-qualified European components available to satisfy 60–70% of a project's needs for standard devices. Once all the envisaged actions have been completed, it will be possible to satisfy 80–90% of a project's component demands from European sources.

Nonstandard components
Components whose technology is still subject to evolution or which have little or no previous history of high-reliability application are defined as 'nonstandard components'. They are mainly advanced-technology devices for which the normal qualification concepts have been found to be impracticable. To make it possible for projects to apply advanced technologies, ESA has issued a comprehensive guideline document containing a logical sequence of procedures for establishing adequate confidence in this type of component. The advantage of this programme is that it is tailored to the actual product, concentrates on the technological aspects, and strikes a balance between schedule, cost and degree of confidence.

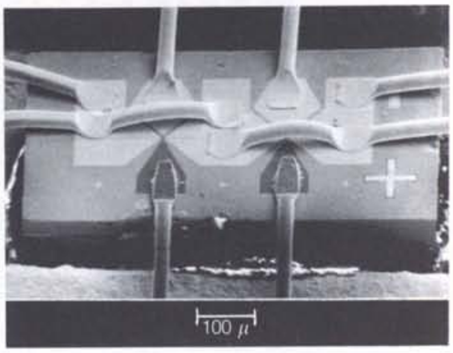


Figure 2 – Internal view of a European gallium-arsenide field effect transistor, suited for low-noise application with an operating frequency up to 18 GHz

These modified requirements have been favourably received by the user industry because they make it possible to provide for the use of advanced-technology components of European origin, even in fields that have so far been exclusively the domain of non-European suppliers, such as microwave transistors and diodes, opto-electronic devices; in addition a programme for a 16-bit microprocessor has been started quite recently.

CECC system of specifications
The CECC (CENEL Electronic Components Committee) is in the process of establishing a system of specifications in Europe for assessing the quality of electronic components. From a test and inspection viewpoint, this system can be compared with the normal US MIL system.

Following detailed discussions between CECC and ESA's SCCG, it has been decided to incorporate an additional level of requirements in the CECC system, called 'enhanced assessment of quality', to which ESA/SCC space requirements can be added without difficulty. With the implementation of this system, we can expect a further improvement in quality standardisation and European competitiveness. Although cooperation between the CECC and SCCG is still in its early stages, within three to four years the

Figure 3 – Scanning electron microscope set-up at ESTEC with secondary ion mass-spectrometer and X-ray analysis facilities, used for qualitative and quantitative analysis of materials and surfaces

two specification systems should be fully merged and implemented to the benefit of the whole space industry.

ESA tender requirements

The benefits expected from the standard ESA/SCC Specification System can be realised only if it is universally applied in all projects. Although small deviations from the system for a particular project may appear to offer certain advantages, it should be borne in mind that they can have severe financial consequences for ESA as a whole. The same applies when non-European components are procured when qualified equivalent products are available from European sources. To protect ESA interests, a set of well-defined requirements has been incorporated into the key Agency documents issued with the Calls for Tender to the space industry [PSS-54 (QRC-01)]. Although these requirements spell out that the contractor shall be fully responsible for the selection of both components and suppliers, they also state that the contractor shall use European sources and that, if he wishes to deviate from these demands, he must obtain ESA approval in each case. Similarly strict conditions are included for the preferred application of the ESA/SCC Specification System. These requirements could not be introduced until quite recently because the prerequisite for an operational system had to be met first.

The industrial viewpoint

All the steps taken by ESA/SCC towards standardisation of procurement requirements and the Europeanisation of component usage were discussed in great detail with the user industry, and its willingness to cooperate has already been demonstrated. The European manufacturing industry is also reported to be highly appreciative of the new system and there is little doubt that the benefits to be gained from the ESA standardisation programme are widely recognised.

Nevertheless, some criticism of the measures taken has also been expressed; one often heard remark is that progress in standardisation and the issue of procurement specifications is too slow. It has also been said that a more effective system for the feedback of information is desirable and that ESA should play a greater role in this respect.

Present situation

As mentioned earlier, European components are now satisfying about 50% of the total demand. If all available European sources were to be used, including those recently qualified, a 15 – 20% increase in this share could be achieved. A realistic aim for the near future is therefore an 80% share, based on the assumption that the CECC System for Enhanced Assessment of Quality is implemented and that additional effort is provided for the assessment of nonstandard components.

The obstacle to increased usage most frequently mentioned by users is component price. An ESA study of this aspect has, however, revealed that in the selection of procurement sources more weight is attached to quality and delivery time than to the component price and that when the same quality standard is applied to non-European devices, there is little difference in cost when taking into account extra charges and the higher costs of procurement control when using non-European suppliers. On the contrary, quite a number of parts can be procured more advantageously from European suppliers. Delivery times – a criterion mentioned by users as being decisive – are shorter in most cases in Europe and this helps indirectly to increase European component sales.

Outlook

Notwithstanding the remarkable progress already made, there is still a need for ESA and its Member States to continue their efforts in the European component field. The fruitful dialogue between ESA and the user/manufacturer industry also must be kept going. The incorporation of space requirements into the CECC System of Enhanced Assessment of Quality is expected to considerably improve the Europeanisation of component usage and to increase still further the competitiveness of European sources. Every effort is therefore being made to complete the integration of the two specification systems as quickly as possible.

ESA, realising the need for and the benefits to be gained from its policy on the promotion of European components, plans to continue its work along the lines set out in this article, fully supporting all activities aimed at increasing the European suppliers' share of the space component market.

European Industrial Consortia for Space Projects – Their Origins, Development and Possible Evolution

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European space industry has responded successfully to the challenge of a varied and growing space programme through the international grouping of firms, or 'consortia', capable of supplying complete spacecraft, systems or services. Despite the positive contribution that the 'consortia system' has made to the development of space activities in Europe, the consortia's role is now undergoing a critical reappraisal. An attempt is made here to provide both an historical perspective to the problem and some views on the possible evolution of the current industrial structures of European space industry.

History of consortia formation for European space projects

The need to have structured groups capable of assuming full responsibility for the major ESRO projects emerged in the first years of the life of the Organisation (1964–1966) and was mainly produced by two facts:

- the need to ensure a balanced geographical distribution of contracts between the Member States of the Organisation; consortia were found to represent a useful way of discharging this problem to industry, which was usually able to cope with the problem flexibly and efficiently,
- the need to utilise rare competences in a new field on a European scale, avoiding the costly creation of these competences in several countries.

It was really in 1966, when the TD satellite programme started, that the European space industry, guided informally by ESRO, began first to group itself into the loose industrial structures that were later to become more formal industrial associations with permanent management structures and well-defined procedures for the distribution of tasks between the consortium members.

Originally, two groups were formed:

MESH, comprising:

Matra	F
ERNO	D
Saab	S
HSD	UK

EST, comprising:

Elliot	UK
Thomson	F
CGE-FIAR	I
Fokker	NL
ASEA	S

The second of these groups, partly as a result of the awarding of the TD project to MESH, had a somewhat unstable development. Some further firms joined and another group was eventually formed, grouping the remaining aerospace firms which were not yet part of a structure.

When the Cos-B programme started in 1970, three groups had come into being:

MESH, comprising:

Matra	F
ERNO	D
Saab	S
HSD	UK
FIAT	I

EST, comprising:

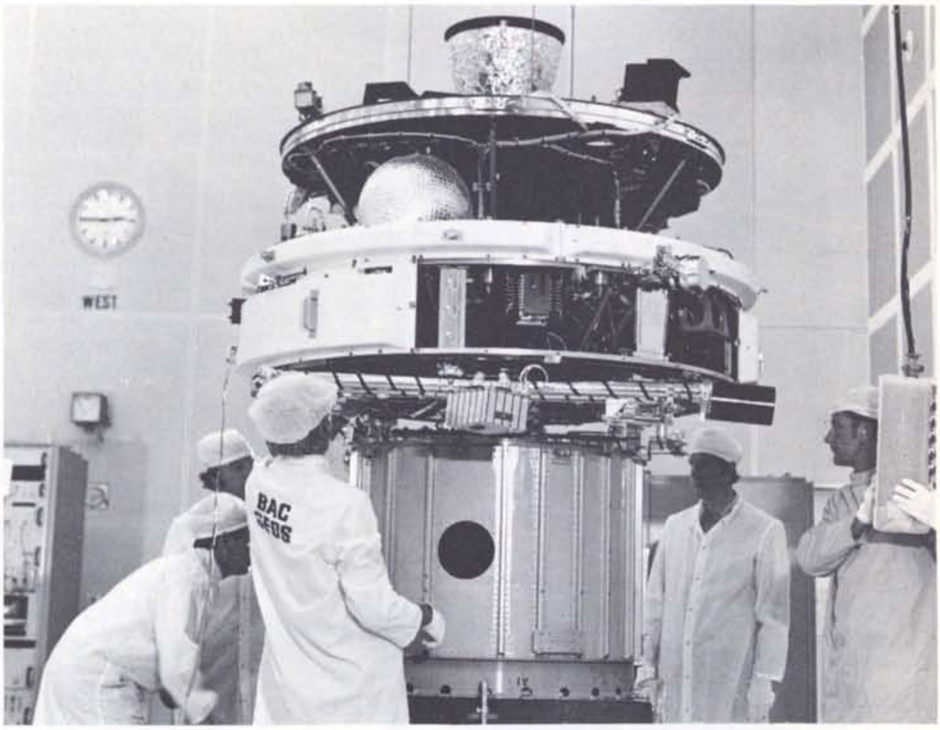
Elliot (Marconi)	UK
Thomson	F
Dornier	D
CGE-FIAR	I
Fokker	NL
Contraves	CH
SABCA	B

CESAR, comprising:

BAC	UK
SNIAS	F
MBB	D
Selenia	I
ETCA	B

EST and CESAR were not well balanced initially in terms of technical specialisations, EST having too many

Figure 1 — Geos launch-adaptor fit check at ESTEC by staff of BAC, the prime contractor



electronics firms (Marconi, Thomson, CGE-FIAR) and CESAR too many aerospace firms (BAC, MBB, SNIAS).

The groups themselves solved the problem by organising an exchange, with Marconi and BAC switching consortia. This structure was accompanied by a change of consortia names and since 1971 the composition of these three consortia MESH, STAR and COSMOS has remained more or less the same. Their compositions and main achievements are summarised in Table 1.

As a result of the role that the consortia have played in the implementation of ESRO/ESA projects, a clear trend can be found in the chronological succession of ESRO/ESA projects (Table 2). Until 1966, contracts for major projects were awarded to individual firms leading industrial groups not yet formalised into

Table 1 — The European space consortia: constitution, composition and main achievements

Denomination	MESH: Matra, Erno, Saab, Hawker Siddeley	STAR: satellites for telecommunications, applications and research	COSMOS: consortium for study and manufacture of satellites
Constitution	October 1966: four-firm consortium December 1969: joining of FIAT	1969: creation of EST September 1970: evolution to STAR	1969 creation of 'BAC' consortium 1970: creation of CESAR November 1970: evolution to COSMOS
Represented countries	Matra (F) ERNO (D) HSD (now BADG Stevenage) (UK) FIAT (now Aeritalia) (I) Fokker (NL) INTA (E) Saab-Scania (S)	Thomson-CSF and SEP (F) Dornier (D) BAC (now BADG Bristol) (UK) FIAR and Laben (I) Sener (E) L M Ericsson (S) Contraves (CH)	SNIAS and SAT (F) MBB and Siemens* (D) MSDS (UK) Selenia (I) ETCA (B) Casa (E)
Tech. ass./special commercial relations	TRW Systems (USA)	Hughes Space and Comm. (USA)	Aeronautic Ford (USA)
Main achievements	TD-1A Spacelab (enlarged consortium) OTS, Marots/Marecs, ECS Telecom 1 (French programme) L-Sat (BADG Stevenage + ad-hoc consortium)	Geos 1 and 2 ISEE-B Space Telescope (BADG Bristol) ISPM	Meteosat 1 and 2; preparation of operational Meteosat Intelsat V (with Ford) Exosat (H-Sat) – TV-Sat/TDF (Franco-German programme)

* Siemens withdrew from space activities in 1979 except for ground stations

Table 2 — Role of the consortia in ESRO/ESA projects

Period	Project	Main contractor	Consortium	Notes
1964–1968	ESRO II	HSD	(MESH)	Consortia not yet formed
	ESRO I	LCT	–	
	ESRO IV	HSD	(MESH)	
	HEOS A1	Junkers	(COSMOS)	
	HEOS A2	Junkers	(COSMOS)	
1966–1974	TD	Matra	MESH	Contracts with a prime contractor representing a consortium
	OTS	HSD	MESH	
	Marots platform	HSD	MESH	
	Geos	BAC	STAR	
	ISEE	Dornier	STAR	
	Cos-B	MBB	CESAR/COSMOS	
	Meteosat	SNIAS	COSMOS	
	Marots payload	MSDS	COSMOS	
After 1974	Spacelab	ERNO	–	Contracts with a prime contractor not representing (or only partially representing) a consortium
	S/L IPS	Dornier	–	
	Ariane	SNIAS	–	
	Exosat	MBB	(COSMOS)	
	Space Telescope	Lockheed + Perkin Elmer (US)	Solar array: BADG; PDA: Dornier; Camera mod.: BADG	
	ISPM	Dornier	(STAR)	
	ECS	BADG Stevenage	MESH	
	Marecs	BADG Stevenage + MSDS	(MESH)	
	Sirio 2	CNA	–	
	L-Sat	BADG Stevenage	–	

'consortia'. It is nevertheless clear that some of these groups were 'de facto' evolving towards future consortia. From 1966 to 1974, contracts for major projects were awarded to prime contractors representing well-defined (even if still evolving) consortia structures. Since 1974, however, the trend has been towards a slow disintegration of these structures. Spacelab and Ariane, in view of their importance and of the financial contribution arrangements, were awarded to ad hoc industrial structures, only loosely related to the MESH and COSMOS consortia. Exosat represents the first attempt at a new procurement procedure, whereby a prime contractor is selected by ESA, and subcontractors are then competitively selected by the prime in cooperation with ESA. This new procedure has been used again recently for procurement of the ISPM satellite.

The advantages and limitations of consortia

Positive aspects

The positive aspects of the structuring of the European space industry in consortia may be summarised as:

(a) improvement of the geographical distribution of contracts between ESRO/ESA Member States

(b) improvement of international cooperation (in particular European cooperation) in an advanced technological field, ensuring:
- the participation of smaller countries in activities in which their industry could otherwise hardly afford to engage in view of the limited market
- the implementation of complex projects, allowing learning of how to participate in 'joint-ventures'
- industrial 'spin-off' to other aerospace fields as a consequence of the commercial relations developed in space projects
- enhancement of market exploration/exploitation possibilities, which are especially important for small firms and small countries

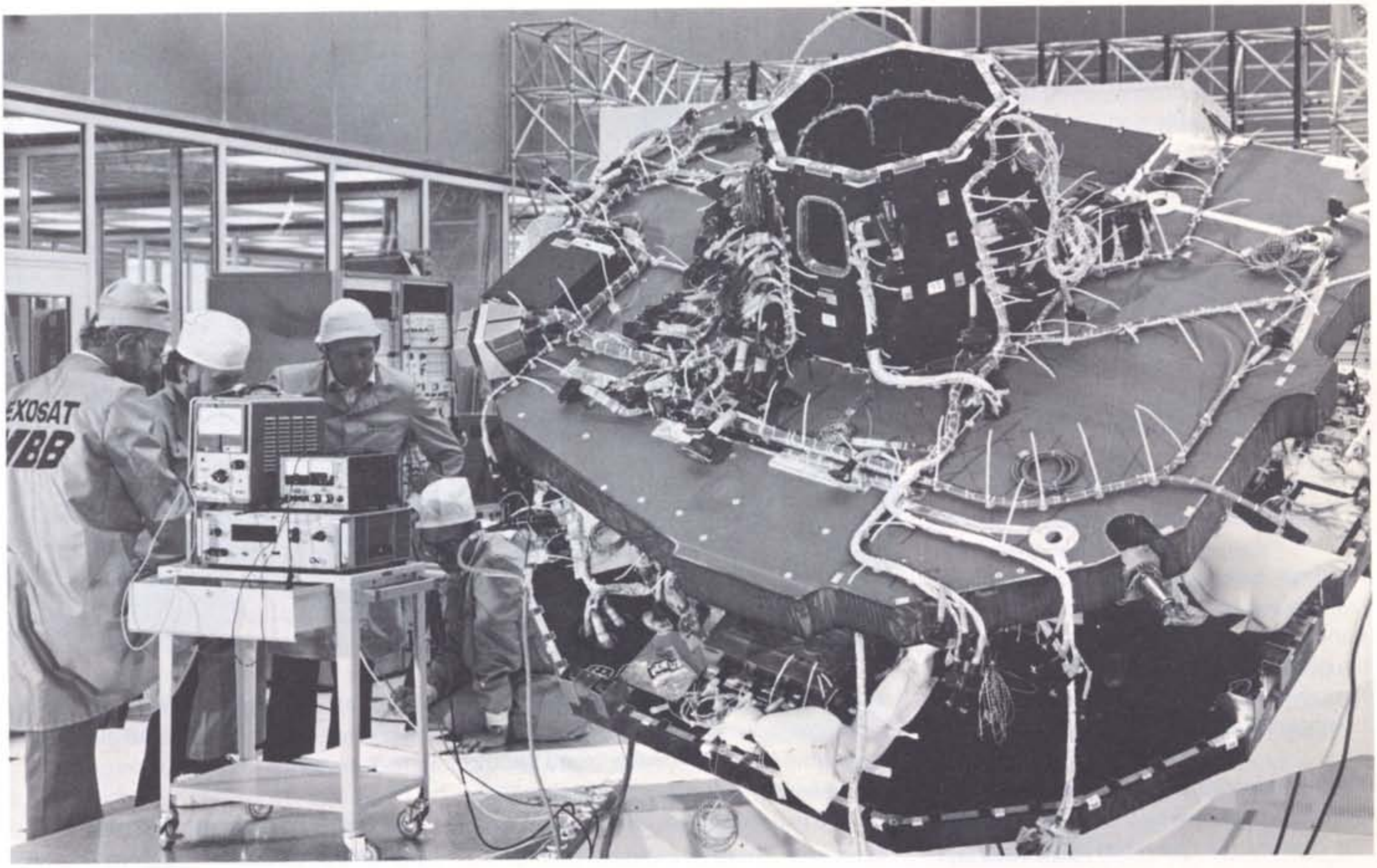
(c) short reaction times in the setting up of or redirection of Agency programmes. This factor is particularly important in view of the diverse nature of the Agency's projects and the need for a flexible industrial structure capable of responding to such inputs.

(d) indirect support to space activities from a structured and efficient industry vis-à-vis the political decision makers.

Negative aspects

Three main criticisms have been levelled at the consortia concept.

Figure 2 — Integration of the Exosat engineering model at MBB, the prime contractor



(a) Insufficient industrial specialisation
It is a recognised fact that, in relation to the potential market for satellites, there are too many prime contractors in Europe; and a similar overcapacity is also apparent at subsystem level (structural and thermal subsystems, telecommunications transponders, etc.). This overcapacity is at least partially due to the fact that, within each consortium, several members have expressed the desire to have prime contractor responsibility, leading to the principle of 'prime contractorship by rotation'; and also to the fact that in order to make a consortium as independent as possible, new capacities have sometimes been created in fields where sufficient capacity was already available.

(b) Too wide a dispersion of work
This is in a way the ransom to be paid for a more balanced geographical distribution of contracts; it is nevertheless a source of management complication and, in the final analysis, extra cost.

(c) Insufficient industrial competition at certain levels
It is a fact that some consortia members have sometimes been protected from external competition by the solidarity of the consortium structure. This is especially true at equipment level, where interchangeability of contractors is, in principle, more easily arranged than at subsystem level.

Current industrial structure situation for European space projects
The present status of co-operation among the major industrial space contractors in Europe is as follows. There is:

- an industrial group centred around the association SNIAS-MBB, and specialised in heavy telecommunications satellites of the Ariane class (TV Sat/TDF), earth-observation satellites (Meteosat programme), and the Ariane launcher;
- an industrial group centred around MESH, and specialised in telecommunications satellites of the Delta class (OTS, ECS, Marecs), earth-observation missions (Meteosat radiometer, Spot), manned spaceflight (Spacelab);
- an industrial group, less tightly associated than the other two (but continuing the STAR association), specialised in scientific satellites and, in particular, cooperative ventures with US partners;
- several national groups covering ground stations for telecommunication systems; for example France, Telspace; Germany,

AEG, Siemens; Italy, STS; Belgium, BTM; Netherlands, Philips; United Kingdom, Marconi Communication Systems, Cable and Wireless.

This broad picture has been simplified by necessity and does not take into account discrepancies with two main causes:

- due to mergers in the aerospace field, firms belonging to different, competing groups have become part of the same firm, creating instances of commercial loyalty by one group to two competing consortia
- as already mentioned, 'international' consortia are now undertaking 'national' programmes.

A certain evolution has already taken place in the consortia concept; the consortium, originally a rather rigid structure has already become a more flexible organisation, accepting competition at equipment level.

The need for flexibility has been impressed not only by the development of the Agency's programmes but also by recent decisions on a number of national projects, where technical decisions have also necessitated distribution of work between international partners, albeit on a different basis than for ESA projects.

For the future, it would seem desirable from an efficiency point of view that consortia progress towards a reduced number of partners responsible for the system/management/integration aspects of a project, thereby leaving a wider field open to competition. In other words, even if the role of the co-contractors (responsible for a complete subsystem) is recognised, the number of co-contractors in a consortium should preferably be reduced and the role of the prime contractors correspondingly increased.

Future evolution of industrial structures

Any evolution of the current European industrial structures for space activities has to be viewed against the background of foreseeable trends in future space activities that hold potential for commercial exploitation. It seems reasonable to assume three broad trends in the development of commercial space activities in Europe:

- in the short term such activities seem likely to be concentrated mainly in the telecommunications and direct-television fields (space segment and earth stations)
- in the medium term earth-observation missions both for civil and military purposes will probably become interesting commercially, with a market for the ground segment developing before the market for the space segment
- finally, in the long term, missions linked to the industrialisation of space itself will become of interest: development of large multipurpose platforms, development of space stations, development of elements for solar power stations, etc. with implications for space transportation systems, manned spaceflight, and new space technologies adapted to in-orbit working.

Against this background of possible fields of interest, which kind of development will the present industrial structure of European space industry undergo?

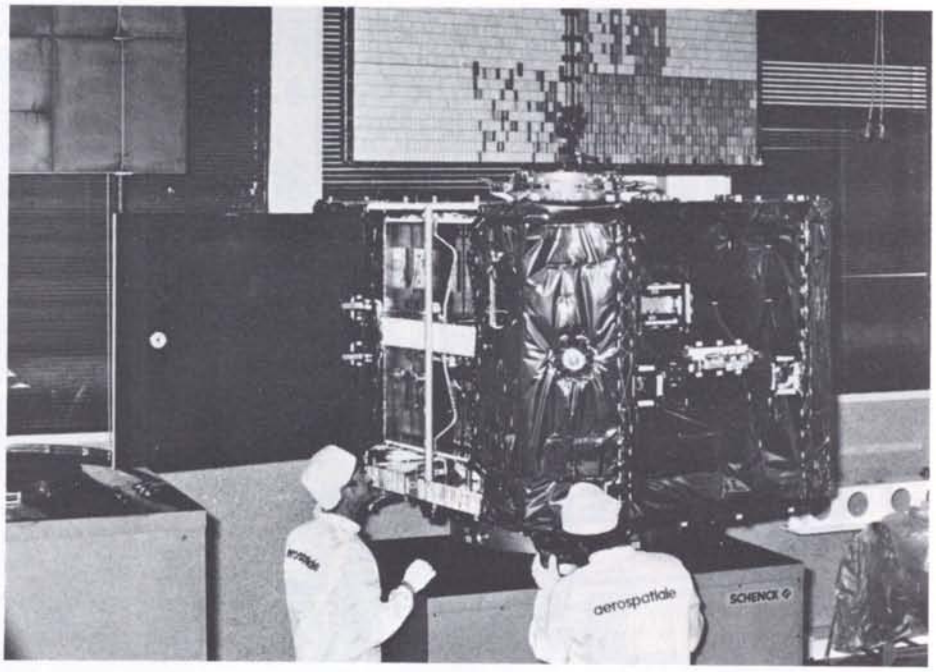


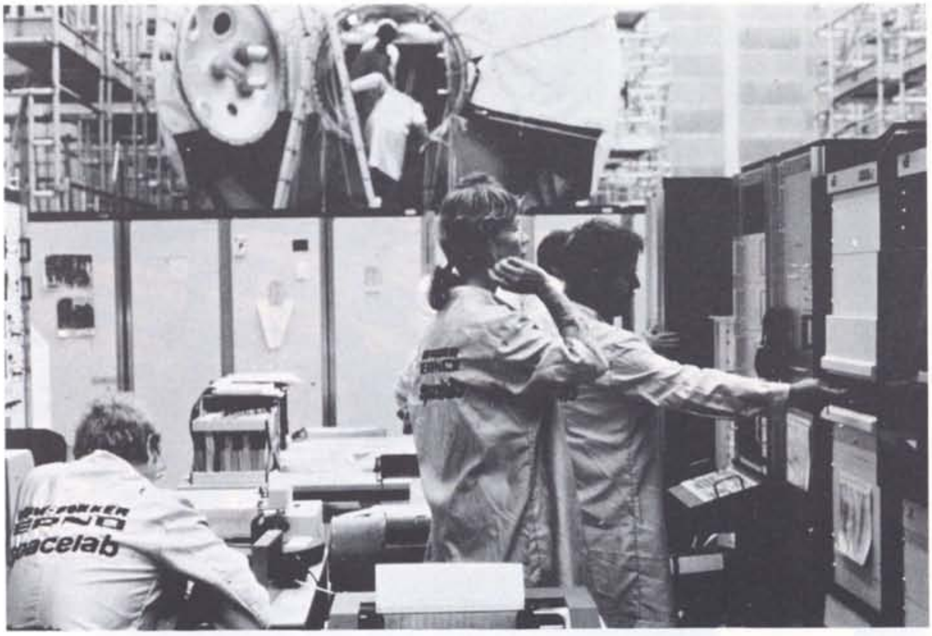
Figure 3 — Aerospatiale engineers at work on the Exosat engineering model

To predict what will eventually happen calls for a good deal of imaginative power, because one must foresee the effects of the mergers between major aerospace firms that have already taken place (BAC and HSD incorporated into BADG) or are on the verge of occurring (VFW and MBB), on the current international groups participating in space activities. One must also take into account the effects of national programmes, with their tendency to maintain implementation at national level, on industrial structures created expressly to cater for international projects.

Forgetting individual firms for the moment and focusing our attention on the space systems needed in the next decade, one could envisage European space industry evolving towards a structure with:

1. One industrial group capable of supplying and developing space-transportation systems and supporting manned space missions (Ariane/Spacelab technology

Figure 4 — Spacelab in the process of integration at ERNO, the prime contractor



development culminating in a European Shuttle-like capability).

2. Three industrial groups for spacecraft projects, two of them being specialised in satellite telecommunications systems and able to cover:

- other applications missions (earth observation, etc.)
- a wide spectrum of spacecraft (ranging from small to medium-sized satellites optimised for Delta/Shuttle launch to heavy satellites optimised for Ariane flights).

Both groups would probably be open to cooperative industrial ventures with non-European space industry whenever commercial considerations dictate.

The third group might well be specialised in scientific satellites or payloads, while also being capable of supporting observation missions.

3. Several suppliers of ground stations, their number growing in parallel with the opening up of new markets for small ground stations for telecommunications and for earth-observation data reception.

Apart from the question of the number of industrial groups that will be actively pursuing space activities in future years, there is also the question of whether they will be 'extrapolations' of the current consortia or different industrial structures altogether.

On several occasions mention has been made of the desirability of an evolution of the consortium grouping towards a more closely integrated form of association, namely a GIE (Groupement d'Intérêt Economique, i.e. a management company in which partners are more directly 'responsibilised' vis-à-vis the risks to be incurred). An obvious example of this type of international association is Airbus Industrie, where firms of different countries are jointly charged with the management and risk of the complex project that culminates in the production and sale of the Airbus family of aircraft.

European space activities could certainly benefit from an evolution of this kind in which the common undertakings so necessary to the development of space activities in Europe would clearly be put on a more solid footing and given a longer-term perspective.

The recent enlargement of the Eurosatellite Group is, perhaps, a good example of this kind of evolution.

The picture presented above is an extrapolation of current trends, but unforeseeable developments are not uncommon in civilian space projects, due to such factors as government support to space projects (subject to the priorities and timing imposed by national considerations), fashion (often dependent on political events, such as elections), commercial interests and corporate links (usually dictated by nonspace activities), national interests sometimes strongly oriented by military requirements, etc. It therefore represents one possible scenario among many. Nevertheless it would seem safe to assume that the industrial grouping projected above is close to the limits of what Europe will be able to support, taking into account the space market that can reasonably be considered accessible to European space industry over the next ten years.

The ESA view

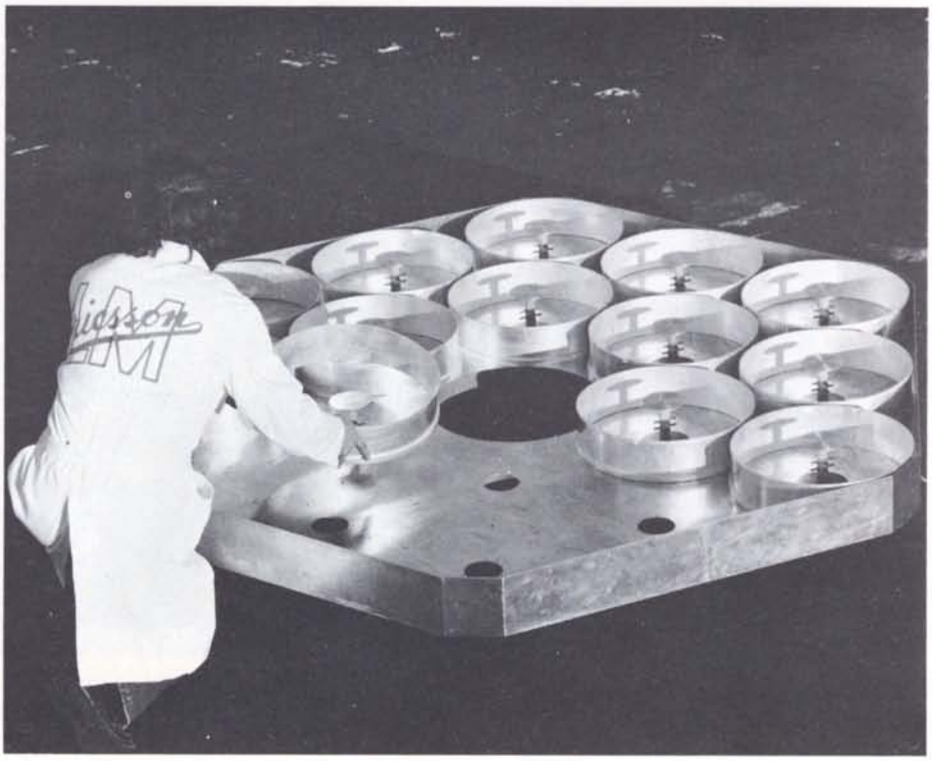
Three questions immediately spring to mind when the problem of industrial structures is analysed from an ESA point of view:

- In the hypothesis put forward in the last section, will there be enough work for all European space firms over an extended period?
- Which industrial structures would suit ESA best?
- What industrial policy should ESA pursue in order to make them a reality?

The workload question

According to current projections and estimates, the future market for space systems looks rather promising. Nevertheless, the fact that a market exists does not necessarily mean that the European industry can automatically count on it as its own. Few countries can hope to support their home industry by satisfying only their national needs. The fact that the market for space systems is

Figure 5 — Breadboard model used to demonstrate the multibeam-array antenna principle for communications satellites, being worked on at L.M. Ericsson



an international one means that the competitiveness aspect is bound to be particularly important. Last but not least, governmental support, which has so far been the backbone of the European space activities, will not necessarily be as expansive as it has been in the past.

The most suitable industrial structures
The industrial structures most suited for the implementation of ESA programmes will always be dictated by a compromise ensuring a bridging of the gap between:

- on the one hand, efficient utilisation of ESA money through: industrial groups made up of a few firms, with a concentration of tasks at prime-contractor level; avoidance of excessive 'work dispersion'; strict enforcement of competitivity criteria at all levels, etc.
- on the other hand, effective utilisation of European industrial capabilities, through: industrial groups representing all Member States; protection of the capabilities of the countries less advanced in space technologies; careful adaptation of industrial capacity to the potential market by discouraging 'wasteful' competition, etc.

As already mentioned, the creation of an industrial structure based on the GIE principle could represent a first attempt at overcoming this dilemma.

The industrial-policy question
Clearly industrial structuring is just one facet of the Agency's approach and policy vis-à-vis the European space industry. Any industrial policy is obviously very dependent on the Agency's objectives and future programmes. Taking two extreme examples, different industrial policies will certainly result if priority is given to the development of a space-transportation system oriented towards manned flights or to scientific missions. Similarly, a different type of industrial support will be called for if priority were given to the preparation of future missions (technological research effort) or to the support of current projects.

Conclusions
In the last decade, European space industry has made visible strides forward and has gained deserved recognition, thanks mainly to the consortia concept. The time has now come for an evolution in this concept and ESA faces the double challenge of defining a set of programme priorities, and within these priorities, of selecting the actions most suited to ensuring fruitful and harmonious relations with European industry. The apparent irreversible trend towards the internationalisation of space efforts and the well-proven flexibility of the European space industry serve as reasonable guarantees that the challenges that the Agency is now facing will be met successfully.

UNISPACE 82

J. Arets, Chef du Service des Affaires internationales, ESA, Paris

Une première Conférence des Nations Unies sur l'exploration et les utilisations pacifiques de l'espace extra-atmosphérique avait eu lieu en 1968 à Vienne. Peu avant le débarquement de l'homme sur la lune, la conquête de l'espace était l'apanage des superpuissances qui voyaient dans cette activité un moyen d'affirmer leur supériorité. A cette époque, l'exploration de l'espace était, pour beaucoup, plus importante que l'utilisation de l'espace pour satisfaire des besoins terrestres.

Les perspectives des activités spatiales ont bien changé en une décennie. Après l'enthousiasme pour l'exploit spatial, l'opinion publique a été blasée puis désabusée. Il a fallu les résultats très spectaculaires de l'activité scientifique dans l'exploration de notre système solaire pour éveiller de temps à autre l'attention du public. Les applications spatiales sont, aujourd'hui, présentes dans la vie de tous les jours: télécommunications intercontinentales grâce à Intelsat, prévisions météorologiques, etc., mais elles ne représentent qu'une technique qui a perdu beaucoup de son prestige et qui s'apprécie en termes de rentabilité économique. Seuls les échecs spatiaux suscitent encore quelques réactions de l'opinion publique de nos pays développés.

Pendant cette période, également, l'établissement de relations plus équilibrées entre les pays développés et ceux qui le sont moins a été reconnu comme un problème essentiel pour l'avenir de l'humanité. A la compétition Est-Ouest, s'est ajouté le dialogue Nord-Sud.

L'espace: nouveau facteur de développement

C'est dans ce contexte que l'Assemblée générale des Nations Unies a pris la décision d'organiser une deuxième Conférence sur l'espace – appelée UNISPACE 82 – qui se réunira très probablement à Vienne en août 1982 pour une période de 15 jours. Tous les Etats membres des Nations Unies sont invités à y participer.

L'ordre du jour adopté par cette Conférence reflète bien l'évolution de la perception que les Etats se font de l'activité dans l'espace. Il ne s'agira pas d'admirer les exploits de quelques superpuissances, ni les efforts de quelques pays ou groupes de pays qui se sont engagés dans des programmes spatiaux plus ou moins ambitieux.

Le but clairement annoncé est d'étudier comment les pays qui n'ont pas les moyens d'entreprendre des programmes spatiaux peuvent bénéficier de ceux qui sont réalisés par les pays développés afin que l'exploration et l'utilisation de l'espace extra-atmosphérique se fassent pour le bien et dans l'intérêt de tous les pays quelque soit le stade de leur développement économique ou scientifique, conformément aux dispositions du traité sur les principes régissant les activités des Etats en matière d'exploration et d'utilisation de l'espace extra-atmosphérique, y compris la lune et les autres corps célestes.

Les difficultés spécifiques

La préparation d'une telle conférence, qui réunira des représentants de 150 Etats et de nombreuses organisations internationales, nécessite un effort considérable, tant de la part du Secrétariat des Nations Unies, qui en assure l'organisation, que des participants qui souhaitent aboutir à des résultats tangibles.

Indépendamment de la complexité inhérente à ce genre de conférence internationale, on mentionnera quelques difficultés spécifiques à la coopération

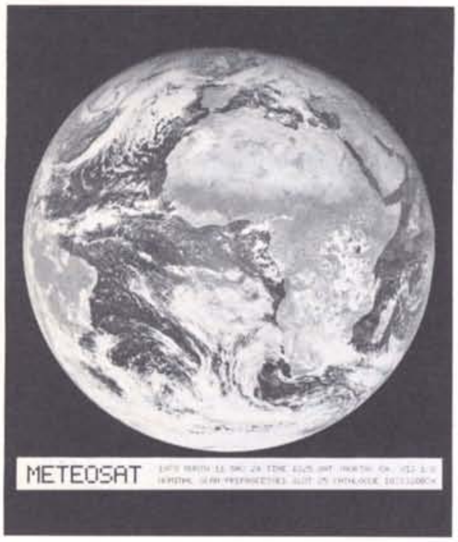


Figure 1 — Une des dernières images de la terre transmise par Météosat, un satellite européen pour l'Afrique

internationale dans le domaine spatial.

La première provient de la *diversité des objectifs* que la technique spatiale permet d'atteindre. Une conférence sur l'espace est nécessairement une conférence sur les télécommunications, sur la télédétection des ressources terrestres, sur la météorologie, etc. Il existe donc un risque considérable de dispersion dès le moment où les participants s'efforceront de sortir des idées générales et de traiter des problèmes concrets.

Une deuxième difficulté résulte de *l'attitude* parfois ambiguë *des Etats en voie de développement* qui, tout en appréciant parfaitement les potentialités que les techniques spatiales offrent pour leur développement, craignent que cette technologie appliquée à leur pays ne soit surtout profitable à ceux qui la détiennent et ont les moyens d'en exploiter toutes les ressources.

On mentionnera, en outre, que les *techniques spatiales sont encore jeunes* et que toutes leurs potentialités sont loin d'être connues. Si les télécommunications classiques par satellites sont déjà bien développées, les possibilités offertes par la télévision directe, par la télématique et les perspectives de liaison par satellites avec des mobiles n'en sont qu'au stade exploratoire.

Les satellites de télédétection Landsat ont apporté des informations très utiles dans les domaines agricoles, géologiques, cartographiques, etc. mais ils ont aussi permis de mieux comprendre la complexité de l'interprétation des données acquises. L'établissement d'un système opérationnel de satellites de télédétection fait l'objet de discussions qui sont loin d'être achevées aux Etats-Unis.

Dans ces conditions, il n'est pas facile de déterminer, avec précision, les bénéfices que les pays en voie de développement peuvent retirer des activités spatiales, ni d'organiser ces activités de manière efficace, tout en conciliant les exigences opérationnelles et celles qui sont de nature politique.

La voix de l'Europe
L'Exécutif de l'Agence spatiale européenne a proposé aux Etats membres que l'Europe prépare avec soin et dynamisme UNISPACE 82. Déjà, des points de contacts nationaux ont été désignés pour assurer le maximum de coordination dans les travaux préparatoires de l'Agence et de ses Etats membres. Il a été convenu qu'un document unique retraçant les activités de l'Agence serait présenté au nom des Etats membres de l'Agence et qu'un effort de concertation serait entrepris en vue d'harmoniser dans toute la mesure du possible les positions des Etats membres et de les présenter à la Conférence de manière commune.

En décidant de préparer ainsi cette Conférence, les Etats membres de l'Agence montrent leur souci d'apporter une contribution constructive au succès d'UNISPACE 82.

Il peut être utile de rappeler que les pays membres de l'Agence sont aussi ceux qui consacrent à l'aide au développement le pourcentage le plus élevé de leur produit national. Il serait donc normal qu'ils jouent un rôle important dans une conférence destinée à déterminer le rôle des activités spatiales dans le développement du tiers monde.

Dans le cadre de la Communauté économique européenne, nombre d'Etats membres de l'Agence se sont associés à 58 pays en voie de développement en signant la Convention CEE-ACP de Lomé*. Ils ont ainsi entrepris un effort unique de coopération multilatérale pour le développement, dont le caractère exemplaire est généralement reconnu. Les principes fondamentaux sur lesquels repose cette Convention pourraient, sans doute, inspirer les Etats européens dans les propositions qu'ils formuleront au cours de la Conférence.

Si celle-ci ouvre la perspective d'un dialogue Nord-Sud, dans le domaine de l'espace, l'Europe a toutes les raisons et tous les moyens d'y participer d'une manière constructive, originale et généreuse. Une des conditions de l'efficacité de sa participation sera, sans doute, sa capacité à parler d'une seule voix dans le concert universel.

C'est pour cette raison que, dans le cadre de l'IRAG, Groupe consultatif des Relations internationales, les Etats membres de l'Agence vont examiner ensemble, de manière approfondie, les différents points de l'ordre du jour de la Conférence et vont s'efforcer de définir en commun leurs positions et leurs propositions.

Les efforts que les Etats membres ont déjà consentis en créant l'Agence et en décidant de ses programmes devraient permettre l'élaboration d'une politique spatiale européenne vis-à-vis des pays en voie de développement, conformément aux termes de la Convention portant création de l'Agence et conformément aussi à l'intérêt général tant de l'Europe que des pays du tiers monde.

* ACP: Les Etats ACP sont les Etats d'Afrique, des Caraïbes et du Pacifique qui ont signé la Convention de Lomé.

In Brief

Farnborough International 80

Like all the major international exhibitions in which the European Space Agency participates, Farnborough (1–7 September) provided the Agency with the opportunity to present to the press and the public the full range of its scientific, technical, applications, manned-Spacelab and Ariane-launcher programmes. This year's stand covered 350 m² of the South Hall. A number of models were on display, including a Spacelab pallet element equipped with a payload mockup, and full-scale models of the ECS telecommunications satellite, the Meteosat weather satellite, and the thermal model of the Geos scientific satellite. The Spacelab pallet on show, identical to a flight unit, was a development model that has been used for qualification tests and more particularly for vibration and stress testing.

European television programmes were transmitted live via the OTS satellite to the ESA stand, where they were received by a ground station linked to a 3 m diameter antenna on the exhibition site.

Demonstrations of the Agency's Information Retrieval Service (IRS) were provided for visitors to the stand throughout the exhibition by IRS and TRC (Technology Reports Centre of the Department of Industry – representing IRS in the UK) engineers, with two terminals providing on-line access to all ESA's documentary data bases in Frascati, near Rome.

A multiple-projection audio-visual slide display was used to present a review of Europe's past and future space effort and programmes.

Mr. E. Quistgaard, ESA's Director General (right), in conversation with HRH Prince Michael of Kent, on the ESA stand


S 82
esa
esa
uropean
pace


spacelab pallet
spacelab


communications
direct via OTS
esa
communica
by satellite

Cause of the failure of the second Ariane launch (L02) found

The failure of the Ariane L02 launch on 23 May 1980 was due to combustion instability at high frequency (above 2000 Hz) in one of the four first-stage engines 5.75 s after ignition. This extremely violent phenomenon, lasting 0.3 s, abruptly altered the characteristics of the injector, degradation of which led to the destruction of the engine at H0+64 s. The fire that then broke out in the propulsion bay caused the vehicle to be destroyed 108 s after lift-off.

Much meticulous work was needed to narrow the range of hypotheses for the cause of the failure and finally to reproduce on the test-stand the behaviour of the faulty engine. This involved analysing the telemetry recordings from the launch, inspecting the damaged hardware recovered from the sea, static firings of engines (37 between July and mid-October 1980), acoustic simulation and an investigation of manufacturing and inspection processes.

In particular, it has been proved that the cause of the engine failure could not have been external to the engine itself, and the hypothesis of the presence at ignition of a foreign body (e.g. an identification tag or filings) has been eliminated. Furthermore the interaction of acoustic effects between the ground and the vehicle during lift-off was slight, being comparable to that observed during the ground qualification tests.

Work by specialists at SEP, ONERA, SNIAS and CNES has led to the conclusion that the high-frequency combustion instability of engine 'D' was caused by dispersion in the characteristics of the system for injecting fuel into the combustion chamber. This dispersion probably resulted from slight variations in the manufacture of successive units with respect to certain geometrical characteristics of the injector, the sensitivity of which did not come to light in the numerous engine development tests (nearly 200). In the light of the results attained, it had not been considered necessary to impose stricter manufacturing tolerances. It took a prolonged research effort on some 30 groups of parameters for each injector and correlation with the development tests to reveal the variations in question.

(The injector is extremely complex with nearly 1000 injection orifices delivering almost 250 kg of fuel and oxidant per second).

The first and totally successful L01 launch on 24 December 1979

In consequence, ESA and CNES have jointly decided to adjust the manufacturing tolerances for the injectors and to select the latter on the basis of static firings on the engine test-stand.

Provided that the tests scheduled from now until the end of the year are satisfactory, this programme should allow the Ariane L03 vehicle to be equipped with test-selected injectors for a launch under good technical conditions in the second half of March 1981. The fourth and last test flight would then be scheduled for June 1981, leading to a first operational launch in October, and the subsequent operational programme schedule should be unaffected.

Five-year anniversary for Cos-B

On 9 August Cos-B completed five years of successful operation. Designed for a minimum operational lifetime of one year, with on-board consumables provisioned for two years, this space-based 'gamma-ray telescope' has carried out the first complete detailed survey of the Milky Way in high-energy gamma rays, providing new insight into the structure of our Galaxy and the mechanisms of cosmic gamma-ray production. Among the many new gamma-ray sources that have been discovered with Cos-B is the quasar 3C273, the most distant source of gamma radiation found so far. The brightest 'gamma-ray star', the Vela pulsar, and the Crab pulsar have also been investigated in great detail by Cos-B, providing major contributions to the study of this important class of object.

The Cos-B payload was designed and supplied by a collaboration of research groups from Centre d'Etudes Nucléaires de Saclay (France), Max Planck Institut für Extraterrestrische Physik (Germany), the Universities of Leiden, Milan and Palermo, and ESA's Space Science Department. The spacecraft was developed by the CESAR consortium, led by Messerschmitt-Bölkow-Blohm (Germany) and involving industrial firms in seven of ESA's eleven Member States.

The fact that the spacecraft and the experiment have exceeded their design lifetime by a factor of five is due not only to the high quality of the satellite and its subsystems, but also to the excellent performance of the experiment. Cos-B's five years of data have given Europe a leading role in gamma-ray astronomy in the world's scientific community, no mean feat for a satellite carrying a single 120 kg experiment based on a novel spark chamber design with which there was no prior space experience at the time of its construction.

Principal components of Cos-B's central detector package ready for integration. From front to back: anticoincidence dome, energy calorimeter, triggering telescope and associated electronic units

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 88 and using the Order Form on page 89

ESA Journal

The following papers were published in ESA Journal Vol 4 No 3:

AURORAL PARTICLE ACCELERATION – AN EXAMPLE OF A UNIVERSAL PLASMA PROCESS
HAERENDEL G

AN INTRODUCTION TO THE METEOSAT IMAGE PREPROCESSING AND IMAGE NAVIGATION SYSTEM – PART 1
JONES M, HAMMER R O & LAUQUE J-P

COMMUNICATIONS MISSION AND SYSTEM ASPECTS OF THE EUROPEAN REGIONAL SATELLITE SYSTEM
HOWELL T F

THE SPACE INFORMATICS NETWORK EXPERIMENT (SPINE)
LOUET J & GARRIDO C

THE ESA SATELLITE-CHECKOUT INFRASTRUCTURE
ROWLES J B & HOWIESON J S P

THE PROBABILITY OF COLLISIONS ON THE GEOSTATIONARY RING
HECHLER M & HA J C VAN DER

SPACECRAFT ATTITUDE MEASUREMENT USING THE ESA STARMAPPER
WOERKOM P TH L M VAN & SONNENSCHEIN F J

Special Publications

ESA SP-147 PHOTOVOLTAIC GENERATORS IN SPACE – PROC OF SECOND EUROPEAN SYMPOSIUM, CO-SPONSORED BY ESA AND DEUTSCHE GESELLSCHAFT FUR LUFT- UND RAUMFAHRT E.V. HELD AT HEIDELBERG, GERMANY, 15–17 APRIL 1980 (JUNE 1980)
BURKE W R (ED)
PRICE CODE: C2

ESA SP-152 FIFTH ESA SYMPOSIUM ON EUROPEAN ROCKET AND BALLOON PROGRAMMES AND RELATED RESEARCH (JUNE 1980)
GUYENNE T D & LEVY G (EDS)
PRICE CODE: C4

ESA SP-1028 THE FAINT OBJECT CAMERA FOR THE SPACE TELESCOPE (OCT 1980)
MACCHETTO F ET AL
PRICE CODE:E1

Technical Translations

TT-525 CALCULATIONS OF FREE TURBULENT SHEAR FLOW WITH A THREE EQUATION TURBULENCE MODEL
ROTTA J C, DFVLR, GERMANY

TT-606 THEORY AND NUMERICAL METHODS OF RESOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS
LAVAL P, ONERA, FRANCE

TT-607 DIGITAL COMPENSATORS FOR SAMPLED SYSTEMS AND MINIMUM TIME CONTROL
BERNARD A, ONERA, FRANCE

TT-608 COHERENT ANTI-STOKES RAMAN SCATTERING AT ELECTRONIC RESONANCE: APPLICATION TO IODINE
ATTAL B, ONERA, FRANCE

TT-611 MECHANICAL MODELLING OF MICROSTRUCTURAL INSTABILITIES IN CYCLIC VISCOPLASTICITY AT VARIABLE TEMPERATURE
CAILLETAUD G, ONERA, FRANCE

TT-613 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1979–5
ONERA, FRANCE

TT-632 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN 1979–6
ONERA, FRANCE

Brochure

ESA BR-04 TELEMATICS AND SATELLITES – PART 1: INFORMATION SYSTEMS. (JUNE 1980)
HANELL S. PRICE CODE E1

Scientific and Technical Report

ESA STR-205 CONTRIBUTION A L'ETUDE DE LA MECANIQUE INTERNE D'UN GENERATEUR PHOTOVOLTAIQUE SPATIAL (JUL 1980)
RICHARD D C
PRICE CODE: C1

Contractor Reports

ESA CR(P)-1302 DEVELOPPEMENT D'UNE BIBLIOTHEQUE DE MODELES THERMIQUES: APPLICATION A LA SIMULATION DYNAMIQUE DU CONTROLE THERMIQUE DES BOUCLES DE FLUIDES DE SPACELAB – RAPPORT FINAL. (OCT 1979)
UNIV. DE POITIERS, FRANCE

ESA CR(P)-1303 STUDY AND DEVELOPMENT OF PRINTED CIRCUIT ELEMENTS FOR SAR ARRAY ANTENNAS – FINAL REPORT. (OCT 1979)
IEC, SPAIN

ESA CR(P)-1313 RAPPORT FINAL SUR UN COMPLEMENT D'ETUDE CONCERNANT LA FAISABILITE D'UN SYSTEME DE RADIODIFFUSION SONORE A MODULATION DE FREQUENCE PAR SATELLITE. (DEC 1979)
THOMSON-CSF, FRANCE

ESA CR(P)-1316 COMET HALLEY PROBE STUDY – ON USE OF ISEE-B PLATFORM AS PROBE FOR ESA/NASA COMETARY MISSION – FINAL REPORT (OCT 1979)
DORNIER SYSTEM, GERMANY

ESA CR(P)-1317 EVALUATION OF RADIATION EFFECTS IN THE MA328 CCD IMAGE SENSOR – FINAL REPORT (JAN 1980)
SIRA INSTITUTE, UK

ESA CR(P)-1318 HIPPARCOS PAYLOAD STUDY – FINAL REPORT (JAN 1980)
MATRA, FRANCE

ESA CR(P)-1325 STUDY CONCERNING THE ROLE OF CDMS IN A FUTURE PAYLOAD OPERATIONS SCENARIO – FINAL REPORT (FEB 1980)
DORNIER SYSTEM, GERMANY

ESA CR(P)-1327 STUDY AND EVALUATION OF MODULAR PACKAGING TECHNIQUES FOR ON-BOARD DATA HANDLING – TECHNOLOGY A – FINAL REPORT (NOV 1979)
BRITISH AEROSPACE, UK

ESA CR(P)-1328 STUDY OF OTS-2 IN-FLIGHT BEHAVIOUR – NUTATION INTERACTION WITH MOMENTUM WHEEL (DEC 1979)
MATRA, FRANCE

ESA CR(P)-1329 RANDOM ACCESS MEMORY – FINAL REPORT (AUG 1979)
BRITISH AEROSPACE, UK

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