esa bulletin

number 38

xx years of european cooperation in space
european space agency
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may 1984

european space agency

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(b) by elaborating and implementing activities and programmes in the space field;

(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;

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agence spatiale européenne

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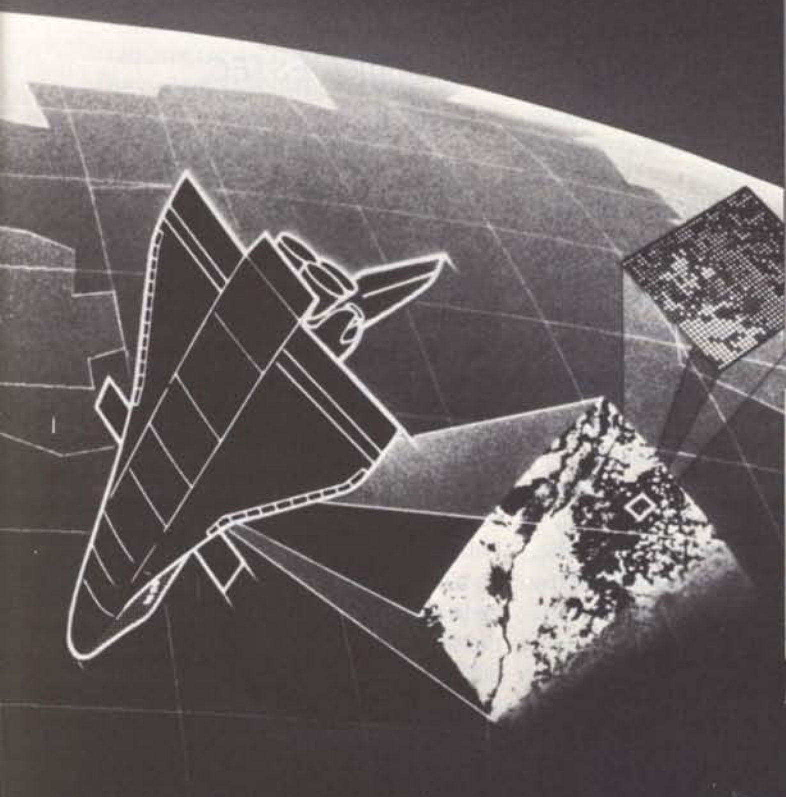

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Satellite Broadcasting in Europe

P. Bartholomé, Communications Systems Division, ESA Directorate of Application Programmes, ESTEC, Noordwijk, The Netherlands

Are the new techniques of distribution by cable, by communication satellite or direct broadcasting satellite vying with one another for pride of place, seeking to conquer the same market? Or are they complementary, together holding out the prospect of providing the European public with a variety of new services? This article sets out to show that the latter is certainly true.

Introduction

For about two years Europe has been the scene of intense activity as regards television, satellites and cable networks. Five Direct Broadcasting Satellite (DBS) projects are under way and these should result in experimental services being introduced from 1986. On the other hand, several governments have decided to make a firm commitment to programmes for the development of cable-distribution networks with the ultimate, albeit distant, object of giving every home in their respective countries the option of plugging into the cable network. Furthermore, the EUTELSAT organisation has decided to hire out the entire capacity of its first communication satellite ECS-F1, all transponders of which have already been reserved by organisations wanting to use them to distribute television programmes.

Legal aspects of satellite utilisation

The Radio Regulations established by the International Telecommunications Union (ITU), an umbrella organisation for public telecommunications administrations throughout the world, distinguishes between three main communications services: the Fixed Service, the Mobile Service and the Broadcasting Service.

The Fixed Service concerns telecommunications between fixed stations whose characteristics and geographical positions are clearly identified and registered with the ITU. In the Mobile Service one of the end stations providing the service is mobile; its characteristics are known, but not its position. Finally, in the Broadcasting Service transmissions are intended for reception by the general public; only the characteristics and position of the transmitting station are identified, whereas reception of the signals is completely unrestricted, at least according to the letter of the Radio Regulations.

As a result of the fundamental differences between the three Services, each has to be allocated different frequency bands so as to avoid mutual interference. In practice, this is proving more and more difficult because of ever-increasing telecommunications requirements.

So far satellites have been used for the Broadcasting Service only on an experimental basis in North America, India and Japan. In contrast, their use in the Fixed and Mobile Services has been commonplace for many years (INTELSAT, INMARSAT), and in Europe EUTELSAT has recently started exploiting the first ECS satellite, built and launched by ESA.

With regard to the use of satellites to transmit television programmes, the four applications described below may be mentioned:

(a) broadcasting proper, which means that the satellite transmits signals that are sufficiently powerful to be received by anybody in possession of some simple and inexpensive equipment. This service must be provided within the frequency bands allocated to satellite broadcasting;

(b) transmission via satellite of signals intended for retransmission to the public via terrestrial transmitters or for distribution via cable networks. Such transmission can be done at relatively low power and therefore requires more complicated reception equipment, in particular an antenna dish several metres in diameter. In principle, this 'distribution' service, often wrongly called 'indirect broadcasting', comes under the Fixed Service because the satellite link is made between fixed points, all of which are clearly identified. The service is in fact provided by satellites operating in the Fixed Service and within the appropriate frequency bands;

(c) an exchange of TV programmes between broadcasting organisations, as happens in Europe between the European Broadcasting Union (EBU) member organisations as part of the Eurovision activities. This comes under the Fixed Service, for which low-power satellites and fairly big stations are used;

(d) the relaying of signals televised from the spot where events are taking place to the studio for retransmission to the public. This also comes under the Fixed Service.

Under the terms of the Radio Regulations, there is an important distinction to be drawn from the legal viewpoint between the Broadcasting Service, and the Fixed and Mobile Services. Whereas in the case of the former, reception of the signals is, by definition, unrestricted, this does not apply to the two other services in which only duly recognised stations are authorised to receive the signals. In the cases of (b), (c) and (d) above, and particularly in the case of satellite distribution, it is therefore in principle just as illegal for an individual to receive a satellite signal as it is to plug into a telephone cable or intercept signals transmitted over a radio link. The responsible authorities are obliged to take appropriate measures to prevent and stop illegal reception. However, in practice this can prove very difficult and even impossible. In North America the illegal reception of TV programmes distributed by US domestic satellites has reached such a scale that the authorities have decided not to try to prevent it any longer. Hence those producing the transmissions have themselves to resort to signal-scrambling techniques if they want to restrict distribution to a particular group. As this is not always the case – in fact it is often the opposite – the distinction between broadcasting and distribution tends to become blurred, and one may assume that this tendency is bound to increase as time goes on, under the pressure of market forces and technological development.

Distribution by satellite in Europe

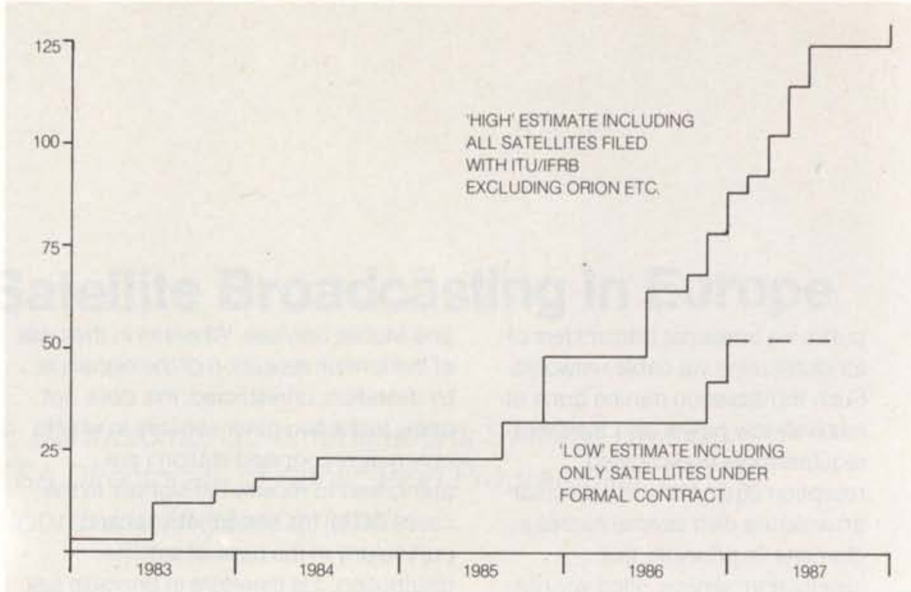
The ECS satellites, the first of which has recently been delivered to EUTELSAT by ESA (see ESA Bulletin No. 36, pp. 12–20), were originally designed to ensure the provision of an international public telecommunications service in Europe and to enable the EBU to extend its Eurovision network with the aid of two satellite transponders. However, following the example set by the United States and Canada, Europe is getting ready to devote a large proportion of its satellite capacity to a completely different use. The first ECS satellite will be used almost exclusively to distribute TV programmes. The second, due to be launched in the spring of 1984, will be assigned as originally planned to telephony, Eurovision and the business services, but it will also have a transponder for distributing TV programmes. Just recently, EUTELSAT asked ESA to go ahead as quickly as possible with the launch of a third satellite to allow them to comply more satisfactorily with the requests from many organisations wanting to use satellite channels for distribution. To meet current demands, some thirty transponders would be required. On the first two ECS satellites, ten will be allocated for TV distribution, as indicated in Table 1.

Insufficient capacity on board EUTELSAT's satellites has led two countries, the United Kingdom and the Federal Republic of Germany, to approach INTELSAT as well, in order to rent seven and three transponders, respectively, on Intelsat-V satellites. From

Table 1 – Plan for using ECS transponders for the distribution of TV programmes

Country	Satellite used	Number of channels	Public service	Commercial programme with advertisements	Pay-TV	Transmission relays
Germany	F1	2	ZDF	?	–	To Berlin
Belgium	F1	1	–	–	ESSELTE	–
France	F1	1	TV5	–	–	–
Italy	F1	1	RAI	–	–	RAI
Norway	F2	1	?	?	?	–
Netherlands	F1	1	–	–	Euro-TV	–
United Kingdom	F1	2	–	Sky channel	Goldcrest? News?	–
Switzerland	F1	1	–	–	Paysat	–

Figure 1 — Evolution in capacity available for the distribution of TV programmes



1984, there will be a further increase in capacity with the appearance on the scene of two French satellites belonging to the Telecom-1 network, which will make five transponders available for television distribution. The lower section of the graph in Figure 1 ('low' estimate) shows the increase over the coming years in available capacity at frequencies of 14/12/11 GHz on all the satellites in the INTELSAT, EUTELSAT and Telecom-1 networks.

Two other systems are currently being defined:

(a) the United Kingdom's Unisat, whose two satellites will each carry two payloads, one with two or three high-power transponders at 18/12 GHz and the other with six low-power transponders at 14/12 GHz
(b) DFS/Copernicus in Germany, with two satellites each carrying ten low-power transponders at 14/12/11 GHz.

Two newcomers about which not much is known should also be mentioned:

(c) GDL in the Grand Duchy of Luxembourg, whose two satellites would each carry sixteen low-power transponders
(d) Videosat in France, with two satellites each carrying twelve low-power transponders.

On the optimistic assumption that all of these satellites will come to fruition, the total capacity available in Europe would increase from 1986, as indicated in the upper section of Figure 1 ('high' estimate), to reach some 136 transponders in 1988. Details on the capacities of all of the satellites referred to are given in Table 2.

Satellite broadcasting

There are currently five projects under way for broadcasting satellites in Europe. The two oldest are the twin TV-Sat and TDF-1 projects, run by Germany and France, and their first two experimental satellites will be launched in 1985. Neither country has yet taken a decision about the possible progression towards setting up an operational service to follow the experimental phase.

The third project involves ESA's L-Sat/Olympus, which should result in a 1987 launch of a demonstration satellite carrying four payloads, one of which will consist of two high-power transponders. One of these will be used by RAI for a pre-operational service in Italy, and the other by the EBU, and probably other organisations, for the setting up of an experimental pan-European television service.

In Sweden the Tele-X project, carried out in cooperation with Norway and Finland, aims at the launch, also in 1987, of an experimental satellite with two broadcasting transponders. Its beam will cover the whole of Scandinavia including Denmark.

In addition, other projects are under discussion in various countries and could come to fruition by the end of the decade. In the United Kingdom, Unisat will be equipped with at least two high-power

Table 2 — Evolution in available capacity

Launch year	Satellite	Number of available transponders: Minimum satellite	Minimum total	Maximum satellite	Maximum total
1982	Intelsat V-F4	3	3	3	3
1983	ECS-F1	9	12	9	12
	Intelsat V-F7	3	15	3	15
1984	Intelsat V-F8	3	18	3	18
	Telecom-1A + 1B	5	23	5	23
1985	ECS-F3	9	32	9	32
	GDL-F1	–	–	16	48
1986	GDL-F2	–	–	16	64
	Unisat-F1	–	–	4	68
	Intelsat VI-F1 + F2	10	42	10	78
1987	DFS-F1	–	–	10	88
	Unisat-F2	–	–	4	92
	Intelsat VI-F3 + F4	10	52	10	102
	Videosat F1	–	–	12	114
	DFS-F2	–	–	10	124
1988	Videosat F2	–	–	12	136

transponders to be used by the BBC and possibly other TV organisations. This project is still in the planning stage. Contrary to the previous four projects, Unisat aims to provide an operational service to the British Isles without any experimental or pre-operational phase. The United Kingdom is also the only country to carry on a public debate about the commercial difficulties of such a course. The initial scheme was for Unisat to carry two DBS channels for the BBC, but this now seems unlikely. Some independent broadcasters would also like to join and all possible participants are now debating ways and means. Three- and four-channel versions of Unisat have been suggested recently. It now looks certain that the original launch date of 1986 will slip by a year or two.

Luxembourg and Switzerland have had studies carried out on projects called Luxsat and Helvesat respectively, but it would appear that plans for them have not yet been finalised. It seems that, for the time being, Luxembourg is opting for use of one or two TDF-1 channels, whereas for the immediate future Switzerland would be content with one ECS channel for programme distribution.

Finally, Ireland and Spain are at present at the preliminary study phase. Ireland has in fact just invited proposals for the commercial exploitation of the five channels allotted to her by the World Administrative Radio Conference (WARC) Plan.

The situation described above is summed up in Table 3, which shows the possible development towards a situation in which there would be about twenty high-power broadcasting transponders in orbit by about 1990.

Regional and pan-European broadcasting

By the very nature of things, the radiation emitted by a broadcasting satellite and contained within a circular or elliptical beam will not stop at the frontiers of the country to which it is directed, but will extend well beyond them. Such spillovers will have the effect of considerably increasing the potential audience for the programmes transmitted.

This phenomenon was recognised by the participants in the 1977 Geneva WARC, who drew up the plan allotting frequencies and orbital positions to the various countries. However, it would appear that at that time the parties concerned did not envisage the scale of the spillovers that would occur in practice. Technological advances in two specific areas are responsible for this development.

In the first place, receiver sensitivity has improved considerably since 1977, and there is no doubt that the state of the art will continue to make progress. This will make it possible to get good reception farther and farther away from the beam centre. Figure 2 shows the extent of the zones in which individual or community reception will be possible for various national systems working in accordance with the guidelines laid down in the Geneva Plan.

Secondly, the gradual expansion of cable networks will increase still further the audience for the programmes, by making distribution possible in areas where individuals cannot receive the signals.

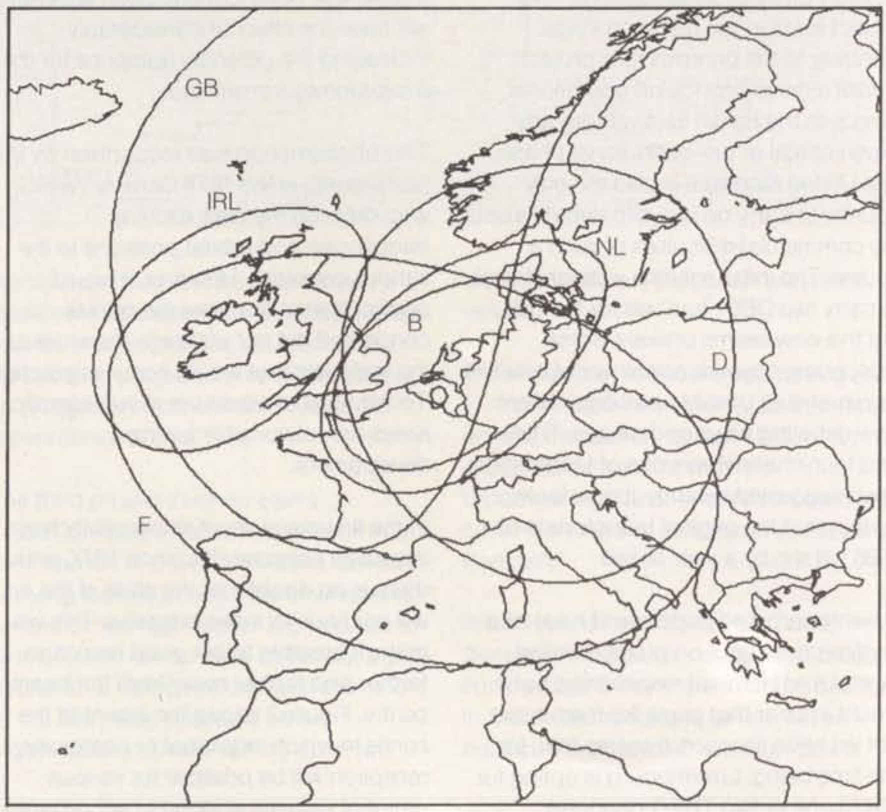
Furthermore, the EBU has recently adopted a new European standard, called C-MAC/Packet, for satellite broadcasting. If applied in all the European systems, as the EBU recommends, this standard will greatly simplify reception of programmes across the Continent, since it will eliminate at a stroke the conversion operations currently necessary to pass from one standard to another. It will also offer a significant technical advantage as regards reception quality, and this again will help increase the coverage of satellite transmissions at the fringes of the beam.

This situation has not escaped the attention of those with a professional interest in satellite broadcasting. The public broadcasting services, in the EBU, are working actively to set up a pan-European television service intended for an international audience. They are currently studying several formulas and

Table 3 — Deployment plan for the broadcasting satellites

Country/organisation	Number of channels	Launch year	Remarks
Germany	3	1985	Third channel: Multiple sound channels
France	3	1985	One or two channels for RTL?
ESA (Olympus)	2	1987	One channel for EBU One channel for RAI (Italy)
Sweden	2	1987	Experimental
United Kingdom	2 to 4	1987	BBC, IBA and others
Italy	2	1988	RAI
Ireland	5 ?	1988	Commercial
Switzerland	3 ?	1990	

Figure 2 – Coverage zones of the satellites of six European countries



envisage testing them on the general public with the aid of an ECS-F1 satellite channel and the cooperation of cable-network users. This experimental phase will be the follow-up to a series of closed-circuit experiments (Eurikon) carried out in 1982 with ESA's Orbital Test Satellite (OTS), the results of which were very encouraging. The EBU's work is supported by the European institutions such as the European Commission, the European Parliament and the Council of Europe, all of whom regard this project as a powerful means of promoting European unification.

Furthermore, many private firms working in the media and the audiovisual field are very keen to exploit the huge potential that satellites have for the broadcasting of television programmes with a commercial and international character.

In order to ensure coverage of a European region, embracing for example French- or German-speaking countries, or Scandinavia, it is perfectly logical and satisfactory to use a national satellite and exploit the inevitable spillover of its beam. The tendency towards regional television is already emerging in Scandinavia with the Tele-X project referred to earlier, and in the French-speaking countries with the TV5 project belonging to the Belgian, French and Swiss broadcasting organisations who exploit together a channel on the first ECS satellite.

However, in order to arrive at a truly European coverage, original solutions need to be found. The first will be offered by ESA's Olympus satellite which, by combining two steerable beams associated with two frequency channels, will be able to serve almost the whole Continent, as shown in Figure 3. This is the solution that the EBU will use to offer the general public the first DBS European television programmes from 1987.

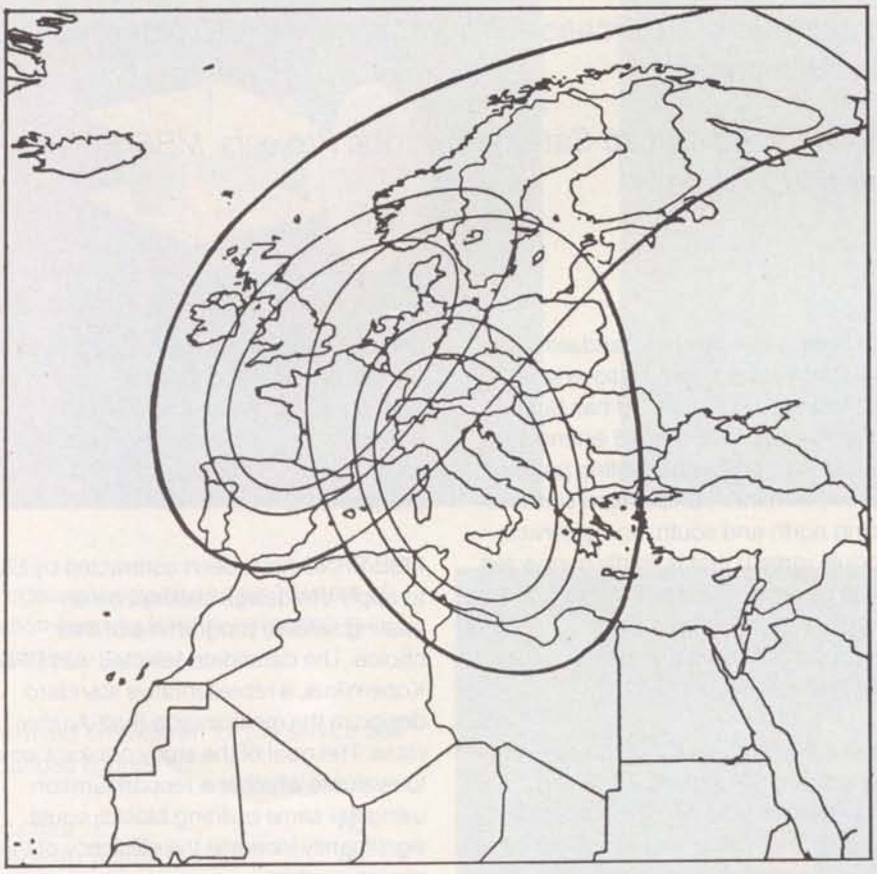
Being a satellite without an operational function, Olympus will not constitute a long-term solution, and it will be using frequency channels allocated to Italy and Austria in the Geneva Plan. ESA has undertaken the study of another solution which, in an operational European system, would consist of using frequency channels still available for certain orbital positions. The first results of this study seem to show that this would be perfectly feasible although it would place more severe requirements on satellite antennas.

Long-term prospects

The expansion of the cable networks in Europe is a phenomenon which, having been limited for a long time to a few small countries like Belgium, Switzerland and The Netherlands, now seems to have got off to a good start in several larger countries; particularly France, Germany and the United Kingdom. No-one doubts that this phenomenon will go hand in hand with an increase in the satellite capacity requirements for the distribution of TV programmes of all sorts, which will no doubt take on a more and more specialised character (finance, medicine, sports, hobbies, etc.).

While this process is certainly irreversible, it is nonetheless slow. According to the most optimistic forecasts, *the number of homes that will be plugged into a public cable network in ten years' time will not exceed 25 million, i.e. less than a quarter of all the homes in Western Europe.* To this number may be added about 25 to 30 million homes which will be connected to a community antenna large enough to receive signals from low-power satellites, provided that these signals are not deliberately scrambled on transmission. This means that the number of homes without a cable connection and with no hope of receiving television by cable in the foreseeable future is at least 60 million.

Figure 3 — Pan-European coverage zone of ESA's Olympus satellite



DBS therefore remains an attractive solution for those – public or private – bodies wishing to reach this large part of the general public. Though its initial cost will undoubtedly be high, DBS also has several indisputable advantages. Firstly, it can be set up in a country or region within the space of four or five years, and can cover the whole of the territory in which the service is to be provided. It is also compatible with the new C-MAC/Packet standard, which will immediately give a better quality picture and will lead to the introduction of a range of new services such as improved-definition television, multilingual dubbing and subtitling, and high-capacity videotex.

A pan-European system such as the one referred to above could take over from Olympus in about 1990. It may be estimated that the potential audience for programmes broadcast by such a system could take in several tens of millions of homes, because by that time half the 120 million European homes will still not have any access to a public cable network or to a community antenna.

As regards individual receivers, it is agreed that if mass-produced they should not cost any more than a present-day colour television set. Provided that the programmes on offer are original and innovative, it may reasonably be expected that this type of equipment will find a substantial market in Europe.

Conclusions

The expansion of cable networks and that of low-power distribution satellites are two mutually stimulative phenomena, and it may reasonably be expected that the promotion campaigns for cable television currently being conducted by governments in many European countries will lead to an increasing need for satellites able to distribute all types of programmes. It seems that the various satellite systems, present or future, will be able to meet this demand.

However promising the combination of cable networks and distribution satellites may appear, one cannot for all that expect, given the expense and scale of the cable-laying operations, that *it will ever interest more than a quarter of the 120 million or so European homes. High-power broadcasting satellites therefore have an important role to play because they can reach the rest of the total audience.* In addition, they are extremely flexible to use and can be set up within the space of a few years. Furthermore, these satellites too could benefit from the expansion of the cable networks, particularly during the initial period when there is no likelihood of there being a large number of individual and community receivers. Reciprocally, the broadcasting satellites will provide the cable networks with additional sources of programmes for distribution.

As in the field of public telecommunications, it is becoming more and more clear that, far from rivalling each other, satellites and conventional terrestrial networks do in fact have complementary functions.

The various national DBS projects have been based on the guidelines contained in the 1977 Geneva Plan, which was essentially founded on the principle of a purely domestic service. Over the years the picture has changed completely, and everyone now realises that satellites must play a supra-national role. Regional and pan-European television is now within sight, and the experimental projects have already reached an advanced stage.

A Sun-Pointing Communications Satellite

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Whereas the payload of a communications satellite is typically Earth-pointing, the satellite itself can be oriented in any direction. It can be shown that orientation towards the Sun is preferable, as the space environment is dominated by the Sun rather than the Earth. For a typical mission (DFS-Kopernikus), reconfiguration of the satellite for Sun-pointing can result in a significant reduction in complexity and an improvement in mass-carrying capability.

The basic elements of a standard three-axis-stabilised communications satellite are illustrated in Figure 1. It has Sun-pointing solar arrays (blue) extending north/south, an Earth-pointing payload (yellow) with thermal radiation surfaces facing north and south, and a service module (green) that is rigidly connected to the payload. The main element of the service module is a cylinder that contains the propellant tanks and provides the interface to the launcher.

Although it is obvious that the payload has to be Earth-pointing, there is no convincing reason why the satellite body has to be Earth-pointing as well, since the space environment is dominated by the Sun rather than the Earth. The Sun provides electrical power, thermal radiation, orbit perturbations and the only significant source of attitude disturbance. A satellite body that is Sun-oriented could cope much more easily with this prevailing environment.

As shown in Figure 2, the same building blocks can be rearranged if the service module is rigidly connected to the solar array rather than the payload, and the payload is decoupled from the service module by the same type of rotary joint (BAPTA*) used in the present configuration to decouple the solar arrays. The service module lies north/south, the solar arrays are deployed in the orbital plane, and the payload can still provide the necessary north-facing thermal radiation area.

This configuration is not new. It was patented by ESA five years ago and has been analysed by ESA and CNES in the context of advanced satellite configurations. What is new is the consideration of this configuration as a candidate for existing satellite programmes.

MBB/ERNO have been contracted by ESA to apply this design concept on an existing satellite programme of their choice. The candidate selected was DFS-Kopernikus, a representative standard design in the medium-size (half-Ariane) class. The goal of the study contract was to evaluate whether a reconfiguration, using the same building blocks, could significantly increase the efficiency of the service module.

DFS-Kopernikus

The core element of the DFS-Kopernikus satellite (Fig. 3) is a cylindrical structure with a diameter equal to the standard Delta/PAM-D II/Ariane launcher interface, i.e. 37 inches (93.7 cm). This cylinder contains two spherical tanks for the unified bi-propellant system.

The payload is spread over a north- and a south-pointing panel to facilitate maximum thermal radiation. The batteries are also located in this position for thermal reasons. The antennas are rigidly mounted on an Earth-pointing antenna platform.

The satellite's mass budget (rounded figures) is constituted as follows: 350 kg is needed for the service bus, 350 kg is available for the payload plus its associated power supply, and 700 kg is reserved for propellant, both for the

* BAPTA = Bearing and Power Transfer Assembly

Figure 1 – An Earth-pointing communications satellite (schematic)

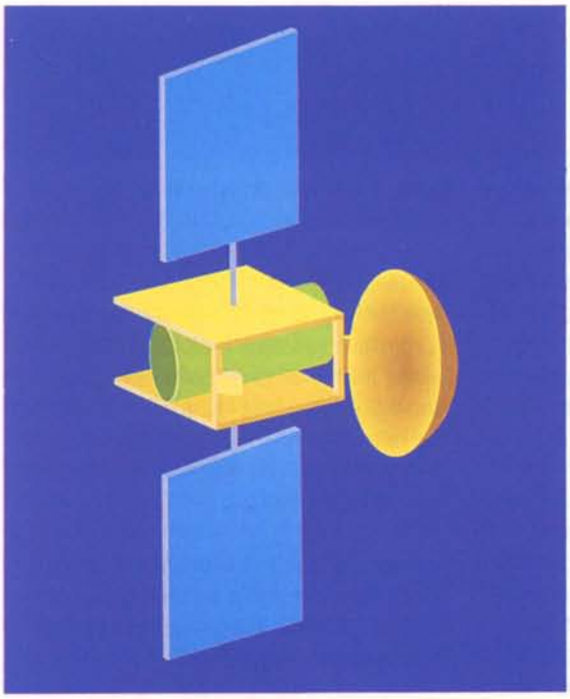


Figure 2 – A Sun-pointing communications satellite (schematic)

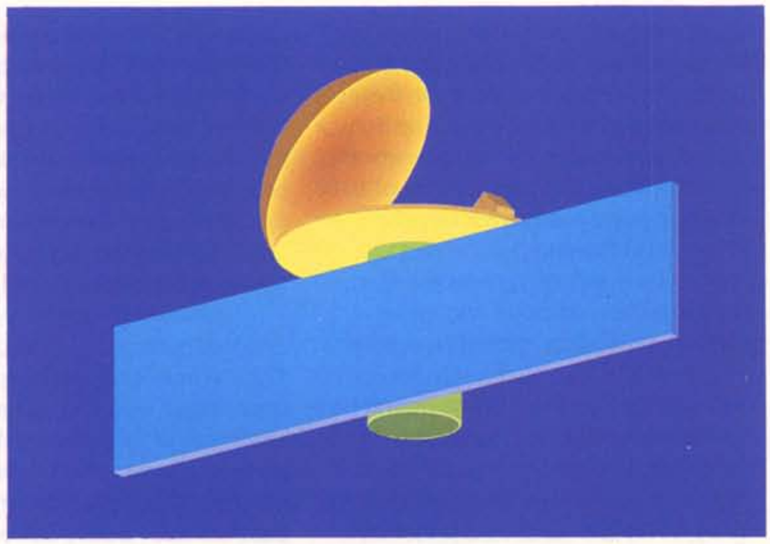
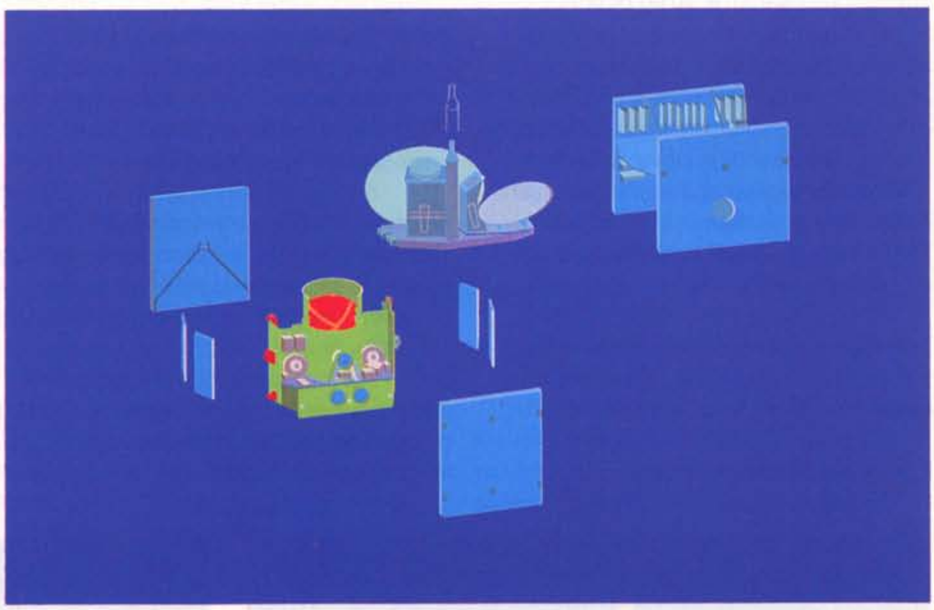


Figure 3 – Exploded view of the DFS-Kopernikus satellite



apogee manoeuvre and for 10 years of station-keeping (an Ariane launch is assumed).

The mass breakdown for the service bus (rounded figures) is:

Structure	80
Reaction control	80
Attitude control	45
Power control	40
Thermal control	40
Telemetry, tracking & command (TTC)	35
Harness	30
Dry service bus (excluding batteries and solar arrays)	350 kg

Three solar panels on each wing provide 1.5 kW of electrical power at the end of the 10 year nominal lifetime. Ni-Cd batteries provide full eclipse capability.

The satellite carries a payload mass of 175 kg. Eleven active repeater channels, each of 20 W RF, radiate 220 W of useful RF power and dissipate approximately twice as much through thermal radiation. Six spare channels are provided for redundancy.

Design changes

Figure 4 illustrates the transition from an Earth-pointing to a Sun-pointing service-module orientation. Step 1 is the transfer of the rotary joints (BAPTAs), resulting in the saving of one of them. Step 2 is the reconfiguration of, so far, three payload panels into a single flat disc, with an ample north-facing radiation surface.

These rather modest primary design changes lead to remarkable secondary design improvements in practically all subsystems:

Structure (green)

After the separation of the payload structure from the service module, all that remains is the unmodified central tube containing the tanks and the apogee motor. The remaining equipment of the service module can be mounted directly on the outer surface of the central tube. The elimination of a number of equipment platforms and brackets results in a mass saving of at least 10 kg.

Figure 4 — Sun-oriented configuration of DFS-B

Figure 5 — Reaction-control system of DFS-B

Reaction control (red)
The reaction-control system, as shown in Figure 5, remains unmodified with the following exceptions: (a) due to the Sun-oriented attitude-control concept, which will be discussed later, the number of 10 N thrusters carried can be reduced from 14 to 10, and (b) the length of the propellant lines can be significantly reduced. This results in a cost reduction and mass saving of a few kilogrammes.

A significant advantage for the operation of the satellite is the fact that plume impingement on the antenna reflectors and on the solar arrays can be completely avoided. This also leads to a propellant saving, of the order of 5 to 10% of the on-station propellant (i.e. 10 kg or so).

Power supply (blue)
The battery cells can remain unmodified or be exchanged for Ni-H_2 cells. They can be mounted directly on the central tube. This has the advantage that they remain continuously in shadow and they no longer occupy valuable payload mounting area.

The solar panels can also be re-used without modification. The yokes are no longer necessary and can be eliminated.

Power conditioning can now be performed before the power enters the BAPTA. In particular, the power to the service module can be branched off before it, so that only payload power has to cross the BAPTA. In total, the saving of one BAPTA, two solar-array yokes and significant improvements in the power control electronics, leads to a mass saving in the order of 20 kg.

Thermal control
The thermal-control concept remains unchanged. However, since the solar-array now protects the service module like an umbrella, temperature variations are reduced. The mass of the thermal blankets and heaters can easily be reduced by some 10 kg.

A side effect is a simplification of the thermal-vacuum test procedure, which benefits from the fact that the Sun will always be in the same direction with respect to the service module.

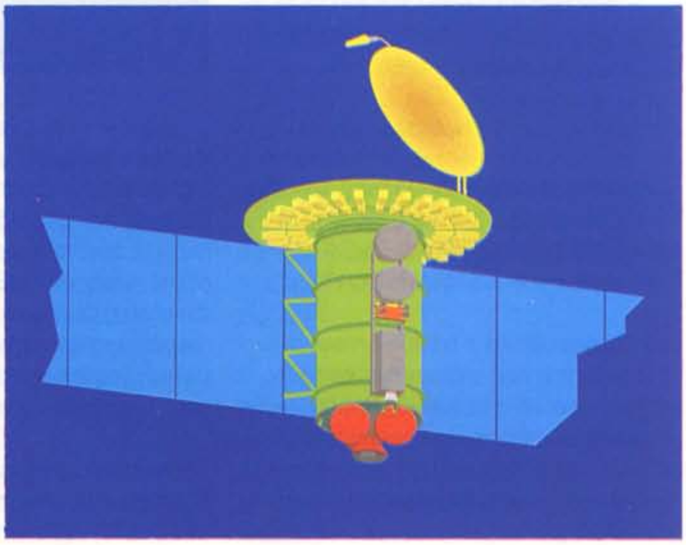
Telemetry, tracking and command (TTC)
This subsystem does not primarily depend on the recommended reconfiguration. However, it benefits from the secondary effect of a general reduction in complexity due to the elimination of some functions and equipment, and the simplification of others. The number of telemetry and telecommand channels can be reduced by 50% or more, leading to a mass saving of approximately 5 kg.

Harness
Due to the proposed introduction of a centralised avionics rack (grey box) rather than individual boxes, plus the general design simplification, the length of the harness and the number of connectors can be significantly reduced, i.e. by at least 10 kg.

In addition, due to the simpler routing of the power and signal busses, grounding is easier and the risk of electromagnetic interference is reduced.

Attitude and orbit control (AOCS) (grey)
The design modifications discussed so far were entirely eliminations of equipment and functions. The AOCS is the only subsystem on the service module that has to be redesigned due to the change in satellite orientation. For today's three-axis-stabilised satellites, two-axis attitude information is provided by an Earth sensor and the third axis is served, at least during station-keeping manoeuvres, by an inertial reference. A star reference in the north/south direction would be useful, but the field of view is currently blocked by the solar arrays.

The new Sun-pointing configuration



implies that the solar arrays extend in the orbital plane rather than north/south, so that the polaris star (or an equivalent target in the southern hemisphere) becomes available as a target for two-axis attitude control. The third axis will be served by a Sun sensor. A star sensor (at the bottom of the avionics rack) and a Sun sensor (grey square in Fig. 6) are therefore introduced as new equipment, whereas all Earth sensors and inertial reference systems can be discarded. The momentum wheels can be re-used without modification. The wheel axis will be oriented in the Sun direction or, more precisely, in the direction of the Sun's projection to the orbital plane.

These new targets for attitude control offer significant advantages:

(a) they are more precise than the Earth horizon
(b) they provide continuous three-axis information (with the exception of eclipse periods), and
(c) they are independent of the satellite orbit, i.e. this mode of operation can be used immediately after separation from the launcher. This concept of a single mode of operation saves a remarkable amount of complexity and can significantly reduce the mass and cost of the attitude-control system.

That the Sun is occulted during eclipse is compensated for by the fact that the disturbance torques disappear as well. The momentum wheel maintains passive stability during this period.

Should the attitude control break down temporarily, the worst that can happen is that the satellite starts counter-rotating about the (Sun-pointing) momentum-wheel axis. Hence, although the communications link to the Earth is lost, the satellite will remain passively stabilised towards the Sun so that its power supply and thermal control remain unchanged.

The satellite service module can be stabilised in a Sun-oriented system with high precision. To ensure that the payload module tracks the Earth rather than the Sun, the BAPTA can be pulsed in open loop with a step size of 1 arc min. Once per day a zero reference signal will confirm that no pulse has been lost. For very high precision applications, an RF sensor would be used in any case.

The mass saving in the AOCS domain is more than 20 kg.

Detailed design

The exploded view in Figure 4 presents the final configuration that was elaborated in the study contract. It shows, in comparison with Figure 3, that the main structural element, i.e. the central tube including the propellant tanks, has been maintained unmodified. The solar arrays have been combined essentially into a single rigid solar array, which serves at the same time as a thermal shield for the service module. The three previously separate payload panels have been merged into a single disc-shaped payload platform, which can 'grow' in diameter, up to the launcher shroud diameter if necessary.

The heat-producing elements of the payload, i.e. the travelling-wave-tube amplifiers and power conditioners are arranged in a ring configuration on the lower side of the payload platform. They are thermally isolated from the service module and can radiate in the northerly direction through second surface mirrors. The channels are interconnected in a ring redundancy scheme before they are combined and fed to the antenna feed assembly.

The payload that has been selected as a representative example consists of eighteen active 30 W channels plus nine spares for transmission in the Ku-band frequency range. Full eclipse operation for 10 years is envisaged. The antenna configuration is designed to produce shaped beams for European coverage and parts of Europe.

As shown in Figure 5, all elements of the service module are mounted directly on the central tube:

- 2 × 3 thrusters firing in the direction of the apogee motor to stabilise the satellite during apogee firing and to perform north/south station-keeping manoeuvres
- 2 × 2 thrusters firing in the anti-Sun direction to perform east/west station-keeping manoeuvres
- a fixed momentum wheel (plus a redundant unit)
- a single avionics rack containing all the electronics for the service module
- battery cells mounted directly on the central tube (see Fig. 4)
- a two-axis Sun sensor mounted on the solar array (see Fig. 6)
- a star sensor (white) close to the avionics rack (see Fig. 5).

Figure 6 shows the satellite in its launch configuration. The upper ring of the central tube is rigidly connected with the payload platform by a marmon clamp to avoid stressing the BAPTA during launch.

The mass budget of the service bus in its proposed configuration is as follows (excluding solar arrays and payload batteries):

Structure	30	Structure	30
Reaction control	75	BAPTA	5
Avionics rack	25	Power control	10
Momentum wheels	15	Payload TTC	10
Service-module batteries	10	Harness	10
Thermal control	10	Thermal control	20
Total Service Module	165 kg	Total Payload Module	85 kg

Total Service Bus: 250 kg

Figure 6 — Launch configuration for DFS-B

Figure 7 — Full-scale demonstration model of DFS-B

It shows that the dry mass of the service bus can be significantly reduced, so that without increasing the overall mass of the satellite the mass of the payload and the associated power supply (solar arrays and batteries) can be increased by ca. 100 kg to accommodate a payload in the 500 W RF class.

The solar arrays are sized to provide 2 kW at the end of 10 years. 1.6 kW can be used as DC power to the payload. Full eclipse capability is assured by a sufficient increase in battery capacity.

Demonstration model

As the advantages of the reconfiguration became apparent, MBB/ERNO decided to build a scale 1 : 1 demonstration model in order to substantiate the performance of this design concept. A photograph of this model is shown in Figure 7. In general, elements that are re-used from the DFS-Kopernikus programme without modification are modelled in wood or similar material; areas that involve major design changes are modelled as representatively as possible.

For example, the star sensor and the avionics rack are fully equipped, functional and representative in terms of mass, power and dimensions. The electrical harness is also fully representative. The wheel and the Sun sensor are flight standard.

This demonstration model is important for the following planned activities:

- design verification, deployment manoeuvres, avoidance of physical or optical obstruction, compliance with launcher envelope
- electrical performance verification
- dynamic simulation of the control loops
- establishment of integration and test sequences and procedures.

MBB/ERNO is planning to replace as many elements as possible by more realistic hardware so that the model can grow towards a thermal or structural model which can be subjected to thermal-vacuum or vibration testing.

Summary

The concept of a Sun-oriented communications satellite has been considered so far as one potential solution for future, probably larger, satellite concepts. The present study has demonstrated, on a representative example, that existing satellite designs could also benefit from such a reconfiguration and that their payload efficiency would be increased.

In the case of the DFS-Kopernikus design, the payload mass (including payload power generation) could be increased by 100 kg without affecting the satellite's overall dry mass (700 kg), its propellant budget, or its launch vehicle.

Once the reconfiguration has been introduced, a further increase in payload can be achieved by scaling up the satellite itself. However, due to the performance increase already achieved with the reconfiguration, in many cases this will not be necessary.

Exosat Probes the Remnants of Dead Stars

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

Some of the most impressive results to date from the Exosat X-ray observatory have been in the study of the remains of dead stars. These clouds of hot gas provide an insight into the nature of the original star and the physical and chemical properties of the surrounding interstellar medium, which has been enriched by heavy elements, such as sulphur and iron, as a direct result of the stellar explosion.

Exosat, launched in May 1983, has now been operational for approximately eight months and has performed over 700 observations of objects as diverse as planets (Jupiter), stars, black holes, galaxies and quasars. Already these results will engage astronomers for many years to come, as well as providing theoreticians with further food for thought. The observations of stars at the end of their evolution have been particularly rewarding. The observatory has studied many stars that have evolved into neutron stars, extremely high density objects of the order of only 10 km in diameter with masses typically the same as that of the Sun. It has measured their rotation rates, orbital periods and temperatures.

Some of the most spectacular results to date have, however, come from the study of supernova remnants (SNR). An SNR is the remains of a star which, as it reaches the end of its evolution, explodes due to a lack of fusion fuel. The explosion heats up the material thrown out from the star as well as the surrounding interstellar medium to many millions of degrees. At these temperatures the material cools through the emission of X-rays. The Exosat observatory can image this radiation, as well as determine the spectrum (colour) of the X-rays.

Figure 1 shows the Exosat image of such a remnant (Tycho) at energies below 2 keV (<6 Å). The Tycho supernova explosion was observed by Tycho Brahe in 1572. The star, which is 900 light years from Earth, seems to have been completely decimated by the explosion. The surrounding interstellar medium has been warmed to about 10 million degrees and enriched with heavy elements. The energy spectrum as observed by the gas-scintillation spectrometer on Exosat indicates the richness of sulphur in this medium. Analysis of these images, coupled with the spectra, should provide information on the temperature and density variations throughout the remnant and the inhomogeneities in the surrounding interstellar medium. The spectra are particularly crucial in such young remnants for establishing the degree of thermal and ionisation equilibrium.

A 'middle-aged' remnant is shown in Figure 2. This is the supernova remnant RCW 86, the remains of a star that exploded in AD 185 about 8000 light years from Earth. The image shows a shell of emission about 90 light years (30 arc mins) in diameter. Clear asymmetries in the shelf profile indicate the inhomogeneities in the surrounding interstellar medium. Due to the extent of the remnant, Exosat has been able to perform the first crude mapping of a supernova remnant in the heavy-element iron by means of its medium-energy and gas-scintillation-spectrometer experiments.

In still older remnants, the stellar material has dispersed into the interstellar medium and the blast wave from the explosion has propagated much further. An example of such a remnant is Puppis-A. This is the remains of a star about 6000 light years from Earth, which exploded 10 000 years ago. The Exosat high-resolution camera (CMA) image is shown in Figures 3a,b. The

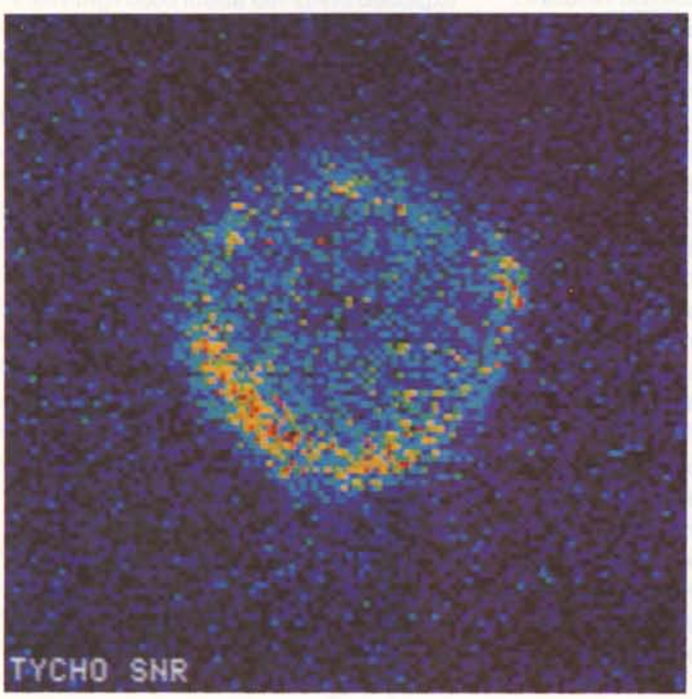


Figure 1 – The Exosat channel-multiplier-array (CMA) image of the Tycho supernova remnant. The data is colour coded as a function of intensity

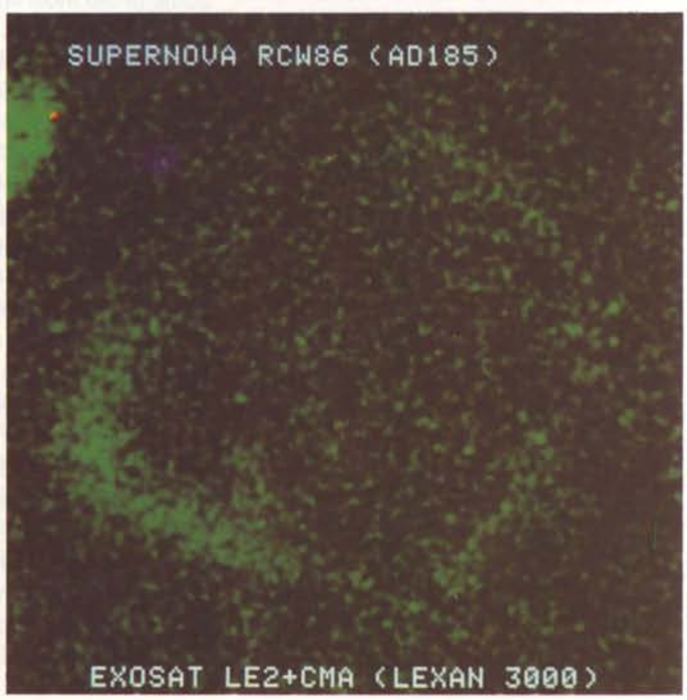


Figure 2 – The Exosat CMA image of RCW 86

remains of the explosion cover a region of 75 light years (6×10^{12} miles). The bulk of the X-ray emission observed by the Exosat telescope originates from the shock-heated interstellar medium. Therefore, study of the image profile and the intensity and spectral distribution tells us primarily about the large- and small-scale variations in the interstellar medium as the shock wave propagates through it.

Figure 3c shows the same remnant as seen by the position-sensitive proportional counter (PSD). This counter has a cruder imaging capability, but better colour discrimination than the CMA. The observations from this recently successfully reactivated detector will provide data on the temperature variations throughout the remnant.

Not all stars that undergo a supernova explosion are completely destroyed. Figure 4 shows the Exosat image of the Crab nebula, the most famous of supernova remnants. This remnant is the remains of a star that exploded in approximately 1054 AD, recorded by ancient Chinese astronomers as a 'Guest Star'; a dying star would have been more appropriate. This remnant contains at its centre the remains of the original star, which pumps high-energy electrons into the nebula. The star that was left over after the explosion is a neutron star which rotates some 30 times per second. The nebula and neutron star have been extensively studied by Exosat, which has provided the first energy-dependent morphological study at X-ray wavelengths. From these studies it may be possible to establish the influence and interaction of the neutron star with the nebula.

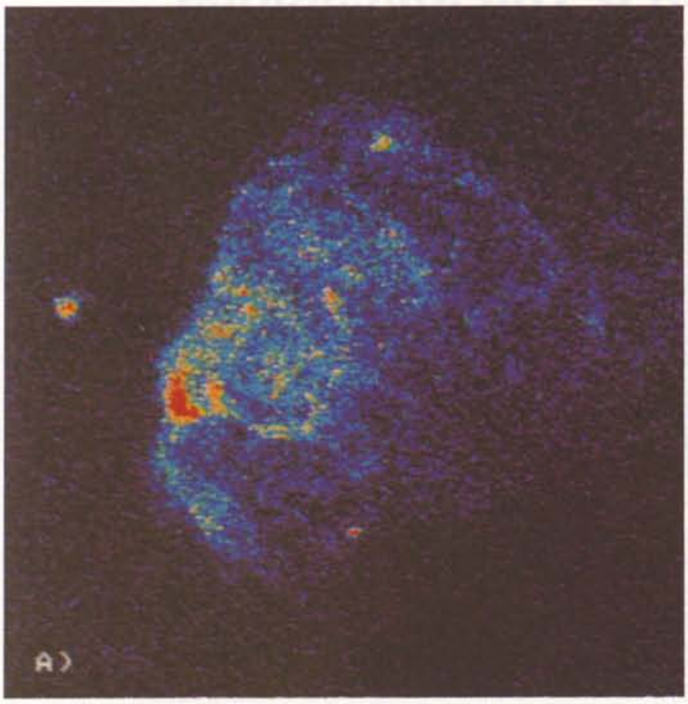
Many other supernova remnants with a wide age range have been observed by Exosat. The essential questions we are attempting to answer can be summarised as follows:

- What factors control the total disruption of a star?
- What controls the production of neutron stars?
- What remnants are powered by neutron stars?
- What are the abundances of heavy elements in remnants which ultimately enrich the interstellar medium?
- What are the inhomogeneities and chemical composition of the interstellar medium?

Acknowledgements
The author would like to express his thanks to Dr. B. Aschenbach of the Max Planck Institut für Extraterrestrische Physik, for permission to reproduce the Exosat images of Puppis-A and the Crab nebula.

Figure 3 – The Exosat CMA image of the older supernova remnant Puppis-A observed with the thin lexan (a) and boron (b) filters to provide a limited wavelength (colour) discrimination. (c) is the PSD image of the remnant

Figure 4 – The Exosat CMA image of the Crab nebula



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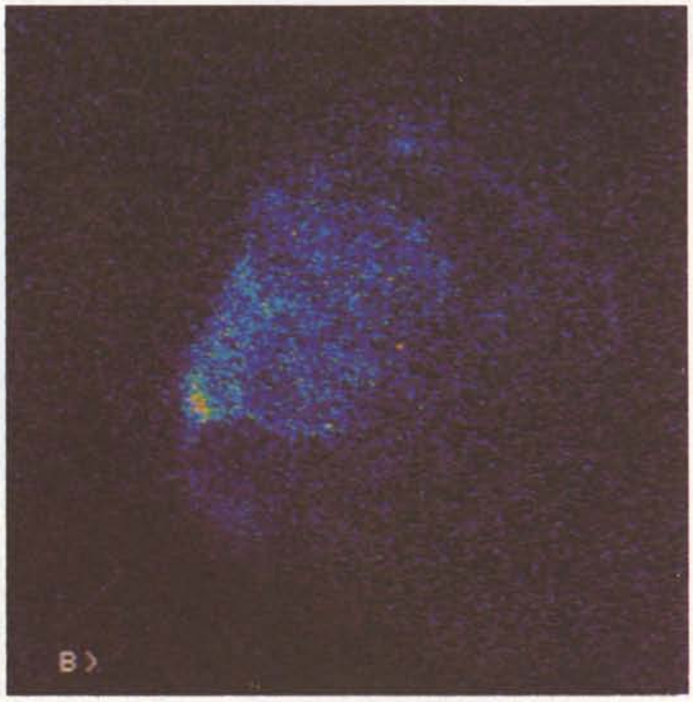
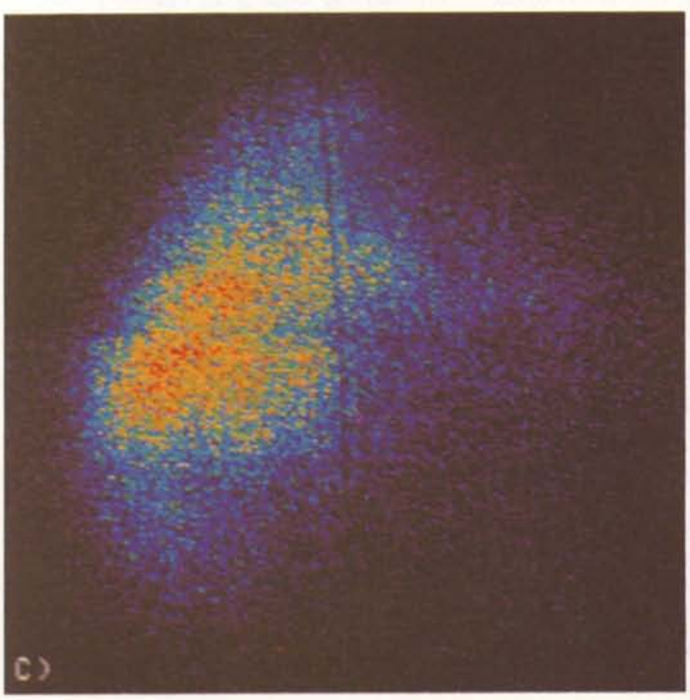


3b

3c



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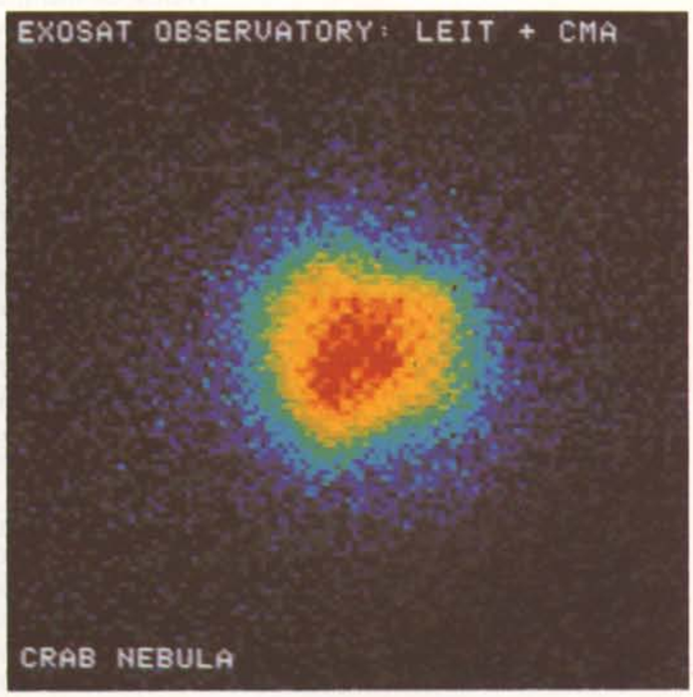


ESRO + ELDO = ESA: The Men & The Milestones

B. Battrick, ESA Scientific & Technical Publications Branch, ESTEC, Noordwijk, The Netherlands

The births of the European Launcher Development Organisation (ELDO) on 29 February 1964 and the European Space Research Organisation (ESRO), just three weeks later, on 20 March 1964 marked the beginnings of the European endeavour in space. The European Space Agency, formed on 30 May 1975 by the merger of ESRO and ELDO, is the legacy of the handful of European 'space pioneers' whose farsighted endeavours brought those two Organisations into being in the early sixties.

ESRO's early years

The birth of the European movement towards cooperative space research can be traced back to August 1959, when Prof. Edoardo Amaldi of Italy and Prof. Pierre Auger of France talked together in the Luxembourg Gardens in Paris about collaborating on artificial Earth satellites. The following January, at a Committee on Space Research (COSPAR) Meeting in Nice, further discussions on the possibilities of a cooperative European venture in space research were held with other scientists, and the first clear concept for a European organisation was born. In April 1960, at the invitation of the Royal Society, a more formal meeting in London was attended by scientists from ten European countries (Belgium, Denmark, France, Germany, Italy, The Netherlands, Norway, Sweden, Switzerland, and the United Kingdom).

These various discussions culminated, in June 1960, in the formation in Paris of a study group known as the Groupe d'Etudes Européennes pour la Recherche Spatiale (GEERS). Sir Harrie Massey (UK) was elected Chairman and Prof. Pierre Auger was appointed Executive Secretary. The group's brief was to consider the establishment of a Preparatory Committee to investigate a joint European programme for space research and the terms of reference for such a Committee.

As a result of the study group's work, an Intergovernmental Conference was convened at the premises of CERN in Meyrin, near Geneva, on 28 November 1960. It was attended by officials from the 10 nations that had taken part in the earlier discussions, plus Spain, with Austria present as an Observer. On 1 December 1960, the last day of the Conference, the 11 participating nations signed the 'Meyrin Agreement', setting up a 'Preparatory Commission to study the possibilities of European collaboration in the field of space research' (COPERS)*.

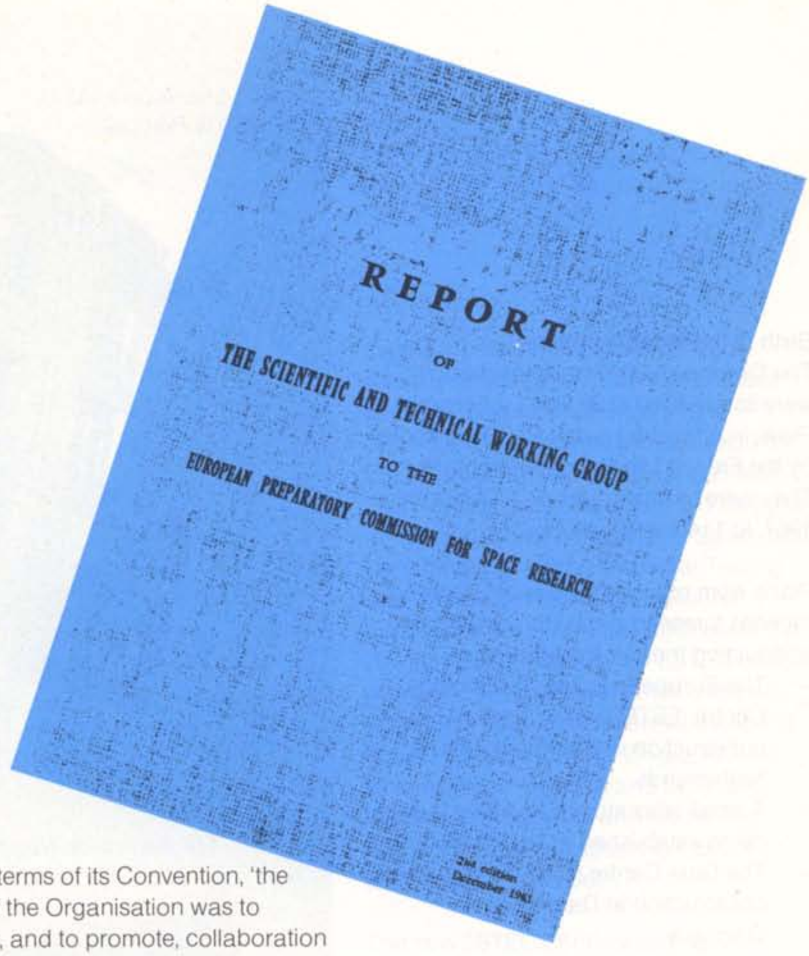
COPERS' primary function was to draft a convention, a scientific and technical programme, a budget, financial rules, staff regulations and agreements with other organisations interested in space research, and to prepare for an intergovernmental meeting to establish the Organisation.

The Meyrin Agreement on COPERS entered into force on 27 February 1961, with the approval of six 'Member States', whose financial contributions constituted the necessary 70% of the proposed first-year budget of $ 192 838. Although originally intended to last only one year, the Agreement was extended several times and COPERS continued to function until the European Space Research Organisation (ESRO) came into being on 20 March 1964.

The officers of COPERS were: Sir Harrie Massey (UK), Chairman; Prof. Luigi Broglio (Italy) and Prof. Henk van de Hulst (The Netherlands), Vice-Chairmen; and Prof. Pierre Auger (France), Secretary General.

* Commission Préparatoire Européenne de Recherches Spatiales

The 'Blue Book'



The Commission established two principal working groups: the Scientific and Technical Working Group (STWG), under the Chairmanship of Prof. Lamek Hulthen (Sweden), and the Legal, Administrative and Financial Working Group (AWG), under the Chairmanship of Dr. Alexander Hocker (Germany). These two groups in turn set up a number of specialised subcommittees and ad hoc groups to study various scientific, technical and administrative problems associated with ESRO's birth. One of these was the Launching Programmes Subcommittee, chaired by Dr. Reimar Lüst, charged with proposing the scientific compositions of the first satellite and sounding-rocket payloads.

It was the STWG that drew up the so-called 'Blue Book', a report to COPERS in which it formulated, inter alia, the scientific and technical programme to be pursued by the new Organisation. The second edition of this book was issued in December 1961.

Further meetings of Member-State representatives were held in Paris (February 1962) and Rome (May 1962).

On 14 June 1962, at a Conference of Plenipotentiaries, the 'Convention for the Establishment of a European Space Research Organisation' was signed by: Belgium, France, Germany, Italy, The Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Denmark also signed in December 1962, and Norway and Austria were granted Observer status. The ESRO Convention entered into force on 20 March 1964, after ratification by all of the signatories except Italy, which subsequently ratified the agreement in March 1965.

The first session of the ESRO Council took place on 23–24 March 1964. Sir Harrie Massey was elected Chairman, Dr. Alexander Hocker and Prof. Henk van de Hulst were nominated Vice Chairmen; Prof. Pierre Auger was designated Director General.

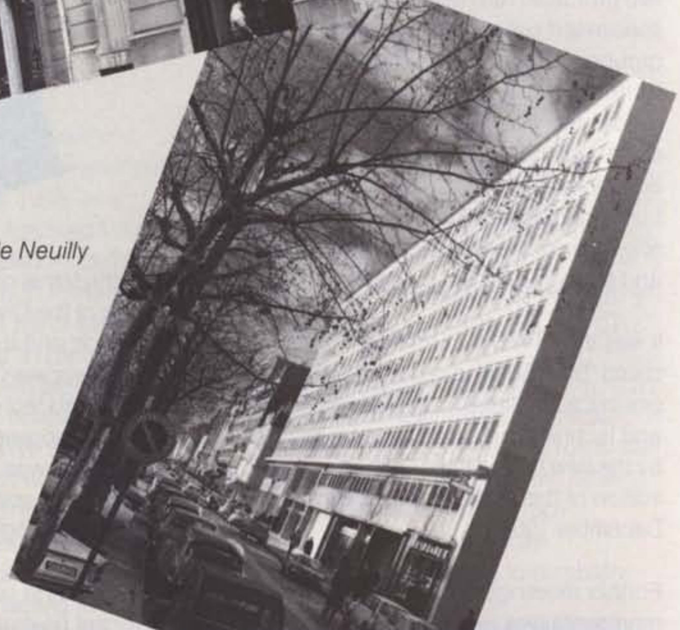
Under the terms of its Convention, 'the purpose of the Organisation was to provide for, and to promote, collaboration among European States in space research and technology, exclusively for peaceful purposes'. To fulfil this role, the Organisation was to carry out a programme of scientific research and related technological activities, in particular to:
- design and construct sounding-rocket payloads, satellites, and space probes, to carry instruments provided by the Organisation or its Member States
- procure launch vehicles and arrange for their launching
- provide means for the reception, collection, reduction and analysis of data
- support research and development, as required for its programme
- promote and provide for contacts between scientists and engineers, their interchange and advanced training
- disseminate information among Member States
- cooperate with research institutions in the Member States and assist in the coordination of their efforts
- make contractual arrangements for the use of launching ranges for rockets and satellites and other facilities available in Member or other States.

The Convention also authorised the Organisation to establish and operate the facilities necessary for its programme, specifying to meet initial requirements:
- a European Space Technology Centre to undertake or arrange for the Organisation's activities and take part in advanced technological research
- a research laboratory near the above Centre to undertake joint research programmes 'on the minimum scale deemed necessary by the Council to complete or complement the scientific studies carried out in the Member States'
- sounding-rocket launching facilities
- data centre and telemetry, tracking and telecommand stations.

A protocol to the Convention was the 'Protocol concerning the financing of ESRO during its first eight years of existence'. Based on 1962 price levels, it set the expenditure for the first eight years at $306 million, $78 million of which was to be available for the first three-year period. There was a proviso that the Council could, by a unanimous decision, adjust this eight-year level of expenditure in the light of major scientific or technological developments.

36 Rue la Pérouse

114 Avenue de Neuilly



8-10 Rue Mario Nikis

Birth of the Establishments

The Organisation's first Headquarters were established at 36 Rue La Pérouse, in Paris, in a building put at ESRO's disposal by the French Ministry of Foreign Affairs. They were to move later, on 1 December 1967, to 114 Avenue de Neuilly.

Plans were soon in hand to set up the facilities foreseen in the Convention for conducting the initial programme:

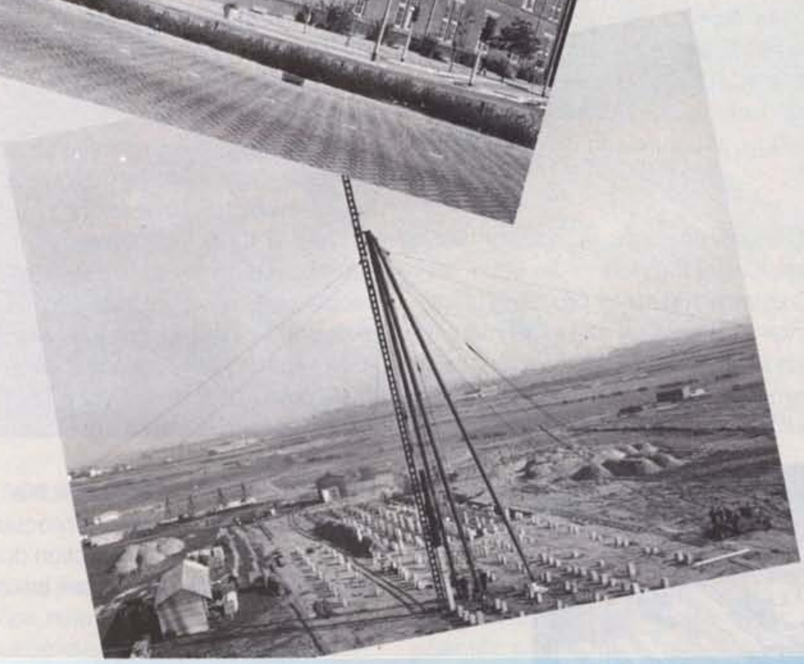
- The European Space Technology Centre (ESTEC) was under construction in Noordwijk, The Netherlands.
- A small laboratory (ESLAB) was also being established at Noordwijk.
- The Data Centre (ESDAC) was under construction at Darmstadt in Germany.
- A worldwide network of stations for tracking and telemetry was in the process of being set up.
- The Research Institute (ESRIN) was to be set up near Rome.
- The Organisation's own launching site (ESRANGE) was under construction at Kiruna, in Swedish Lapland.

ESTEC

ESTEC's first home was in buildings loaned by the Technische Hoogeschool at 11 Mijnbouwplein in Delft, pending the construction of more permanent facilities in Noordwijk. On 31 December 1963, ESTEC had 95 staff members; by December of the following year the total had risen to 270. ESTEC's first Director was Dr. Alfred ('Freddie') Lines.

The Dutch Government's offer of the Noordwijk site was accepted at an Extraordinary Meeting of Council on 22 October 1964, after the first site offered, in Delft, had been deemed unsuitable. By May 1965 prefabricated buildings with a floor space of 3000 m² had been erected on the site and an additional area of 600 m² was to be occupied by ESLAB. The first of the 1776 concrete piles for the foundations of the permanent ESTEC building was sunk on 1 March 1965.

11 Mijnbouwplein, Delft



ESTEC, Noordwijk

On the night of 14/15 October 1966 disaster struck the endeavours of these early pioneers when a watchman discovered that the prefabs occupied by ESLAB and part of ESTEC were ablaze! This building, which was totally destroyed, at that time housed the ESTEC Spacecraft Department and Environmental Testing and Applied Mathematics Divisions, totalling some 200 staff, in addition to the 26 members of ESLAB. The ESTEC staff were obliged to evacuate their offices to Hotel Huis ter Duin in Noordwijk, and the ESLAB staff to the Hotel Zinger. At this time the Administration and Sounding-Rockets Departments and part of the Applied Research Department and the Library were still in Delft.

The new ESTEC Centre was finally completed on 1 December 1967, though parts of the building were in fact occupied before then. ESTEC was formally inaugurated on 3 April 1968 by HRH Princess Beatrix of The Netherlands.

ESLAB

ESLAB began life in the Hotel Helmhorst in Noordwijk, awaiting the construction of the temporary accommodation on the ESTEC site. Then, as a result of the fire, in which all of ESLAB's initial equipment and documentation was destroyed, it was moved first to the Hotel Zinger in Noordwijk and later to further temporary premises, at 's-Gravendamseweg 16c, in Noordwijkerhout. The start of ESLAB's scientific activities – in particle, ionospheric and surface physics – was seriously delayed by the fire, and the Laboratory was really only fully operational from the summer of 1967.

ESDAC/ESOC

The staff of the European Space Data Centre (ESDAC) were also originally housed in temporary premises, at Havelstrasse 16 in Darmstadt, near Frankfurt, pending building of the new ESDAC Centre. The Darmstadt site, offered by the German Government, was formally accepted by COPERS on 9 April 1963 for the ESRO data centre. Whilst awaiting completion of their new offices and the installation of their new IBM 360, model 50H computer, the ESDAC staff used the facilities of the nearby Deutsches Rechenzentrum.

The ESDAC foundation stone was laid on 12 November 1965 and the first buildings housing computer and administration facilities took about eighteen months to complete. The new buildings were inaugurated on 8 September 1967, in the presence of Germany's Federal Minister for Scientific Research, Dr. G. Stoltenberg. ESDAC's first Director was Dr. Stig Comét.

ESRIN
The establishment of ESRIN as an institute 'to undertake laboratory and theoretical research in the basic physics and chemistry necessary to the understanding of past, and the planning of future experiments in space', was proposed when the Conference of Plenipotentiaries met on 14 June 1962 to adopt the ESRO Convention. The study of proposals for the laboratory proved to be a long process and the decision that ESRIN should be established in the Rome area was finally taken at the sixth session of the ESRO Council in March 1965. At its seventh session in July 1965, it approved the budget, structure and programme for ESRIN.

ESRIN began operating in January 1966, to complement the work of the other ESRO establishments by providing expertise in theoretical and experimental physics and chemistry related to space experiments.

The initial staff of five scientists, six technicians and four administrative personnel, plus one Research Fellow, were led by ESRIN's first Director Dr. Hermann L. Jordan. Their first accommodation was in the former Park Hotel in Frascati, rented from the Bishopric of Frascati. The first of the permanent buildings on today's site was not occupied until 1968.

ESRANGE
Construction of the Organisation's European Space Range (ESRANGE) at Kiruna in northern Sweden began in the summer of 1964. It was officially inaugurated on 24 September 1966, and it became fully operational at the end of that year. The first launch took place on 20 November 1966. By early 1968, more than 20 rockets, mainly Centaures, had been launched from Kiruna.

The range was originally under the control of ESTEC, but was subsequently placed under ESOC's jurisdiction during the reorganisation in 1967 (see below).

ESOC, Darmstadt

ESRIN, Frascati

ESRANGE, Sweden

During the first years of the Organisation's existence, responsibility for carrying out Council policy was in the hands of the Director General and three Directors (scientific, technical and administrative), all of whom were located in Paris. It became increasingly apparent, however, that although this arrangement had been adequate during ESRO's buildup phase, it was not likely to prove the most efficient in the longer term.

In July 1966, the Council therefore set up a Committee of Experts, under the Chairmanship of Mr. J.H. Bannier (The Netherlands) to examine the Organisation's structure, procedures and working methods. The report prepared by this Committee and the Director General's proposals regarding its implementation were considered by the ESRO Council in April 1967. The recommendation that the Organisation's internal structure be modified was approved and the first steps to put into effect the 'Bannier Report' proposals were taken at the beginning of 1968.

The main changes brought about by the reorganisation were that: the former scientific and technical directorates were replaced by a Directorate of Programmes and Planning; a new establishment, the European Space Operations Centre (ESOC) was created, to include the Data Centre (ESDAC) already in Darmstadt and the Control Centre, transferred from Noordwijk, and with control of the sounding-rocket range (ESRANGE) in northern Sweden; ESLAB was incorporated within the Space Research and Technology Centre (ESTEC), and the Space Research Institute (ESRIN) was placed under the control of ESRO's Director General.

The mid-sixties were not without their budgetary and programme-decision difficulties for ESRO. In 1966, for example, the Council was unable to reach a unanimous decision on the level of resources for 1967, 1968 and 1969 and the Organisation's activities were therefore thwarted by the statutory requirement that all decisions of a financial nature required unanimity. In November 1968, however, the ESRO Council did unanimously vote a level of resources to be made available to the Organisation during the three-year period 1969–1971. Moreover, from 1969 onwards budgetary decisions, like the other decisions governing ESRO's running, needed only a two-thirds majority vote for implementation.

Prof. Hermann Bondi, ESRO's Director General at the time of this procedural change, was moved to comment: 'Now, with a real future assured for space science, and a start made on space applications, the stage has been set for a real advance into the future.'

By the end of the 1960s there were 211 staff at Headquarters, 722 at ESTEC, 311 at ESOC (incl. ESRANGE) and 70 at ESRIN.

The ESRO programme

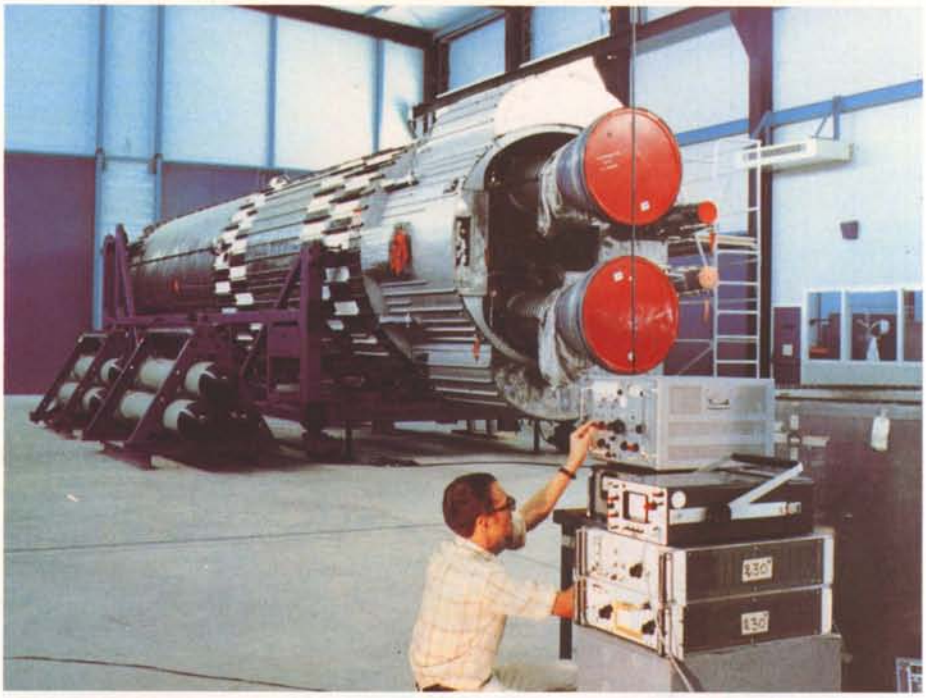
The Organisation's early sounding-rocket and scientific satellite programmes have been described in detail in earlier issues of the ESRO/ESA Bulletin, in the Organisation's Reports to COSPAR, and in particular in ESA Special Publication SP-1013*.

ELDO's early years

Following its decision in early 1960 to halt development of the Blue Streak missile, the British Government invited a number of European countries to cooperate in a European organisation for the joint construction of a heavy satellite launcher, which would use Blue Streak as a first stage. In January 1961 the UK authorities submitted more detailed proposals to the European States, in answer to which France suggested that a French rocket be used as the second stage of the planned vehicle. Subsequently these two Governments invited Belgium, Denmark,

* Available from ESA Scientific & Technical Publications Branch, price 90 French francs, or equivalent.

Blue Streak



Italy, The Netherlands, Norway, Spain, Sweden and Switzerland to discuss the setting up of a European organisation. As a result, a conference was held from 30 January to 2 February 1961 in Strasbourg, under the Chairmanship of the British Minister of Aviation, Mr. Peter Thorneycroft. Austria, Canada, Greece and Turkey attended as Observers.

A number of basic principles were established for the Organisation's activities:

- the Organisation's initial programme would be to develop a three-stage launcher and an initial series of satellite test vehicles. The first stage would be built by the UK, the second by France and the third stage and the test satellite by the other members. Test firings would take place from Woomera in Australia
- the Organisation would work solely for peaceful purposes
- the expertise already acquired by the UK and French Governments would be put at the Organisation's disposal free of charge.

After the Strasbourg Conference, the British and French Governments went ahead with the drafting of a Convention, and this led to the convening of a Conference at Lancaster House in London on 30 October 1961. This was attended by representatives from Australia, Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain and the United Kingdom. Norway, Sweden and Switzerland sent Observers.

It was decided at the Lancaster House Conference that the development and construction of the third stage of the proposed launcher would be carried out under German leadership. The first series of satellite test vehicles would be Italy's responsibility, while the down-range guidance system would be supplied by Belgium. The long-range telemetry links and auxiliary ground equipment were to be provided by The Netherlands.

The estimated cost of the initial programme was £70 million, and there was considerable discussion as to whether this was to be regarded also as a strict ceiling.

The Convention for the Establishment of a European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO) was eventually opened for signature in London. On 29 March 1962 seven countries signed the Convention: Australia, Belgium, France, Germany, Italy, The Netherlands, and the United Kingdom. Denmark was granted Observer status.

It was recognised that ratification of the Convention would take many months and it was recommended that a body be set up to make detailed plans for the Organisation's activities and to coordinate work already in hand or capable of being started. A Protocol establishing a Preparatory Group was therefore also signed at the same time as the Convention.

The ELDO Convention entered into force on 29 February 1964. On 5 and 6 May 1964 the ELDO Council met for the first time in Paris. Prof. Gunther Bock (Germany) was elected Chairman, Sir Allen Brown (Australia) and M. Paternotte de la Vaillee (Belgium) Vice Chairmen. Ambassador Renzo Di Carrobio (Italy), who had been Secretary General of the Preparatory Group, was appointed Secretary General.

ELDO's Headquarters were established in Rue La Pérouse in Paris (moved later to 114 Avenue de Neuilly) and it relied for its development programme on national facilities made available by its Member States, including the Woomera facility. It was not until 1966 that ELDO decided to proceed with its own base at the French Space Centre in Kourou (French Guiana).

The ELDO programme

The goal of the initial development programme was the construction of the three-stage launcher, called 'Europa I', with Britain's 'Blue Streak' as its first stage, France's 'Coralie' rocket as its second, and Germany's 'Astris' as the third.

In 1966 the Ministers of the seven Member States met to review the initial programme and decided that Europa I's performance should be upgraded by the development of a four-stage Europa II, more suited to the needs of potential users.

The early development programme had four distinct phases:

- The first covered three firings of the first stage, Blue Streak, alone in June 1964, October 1964, and March 1965. All were successful.
- The second stage covered the firings of the complete three-stage Europa I launcher. The F4 and F5 vehicles, with inert upper stages and satellite test vehicle, were successfully launched in May and November 1966. The next F6/1 and F6/2 vehicles, with live first and second

stages and an inert third stage, in August and December 1967, were only partially successful.
- The third phase covered a series of launchings of Europa I with all live stages in November 1968 (F7), July 1969 (F8), and June 1970 (F9), all of which were only partially successful.
- The fourth phase had as its goal the qualification of the Europa II launcher, to be launched from French Guiana.

The F9 launch was the last to be undertaken from Woomera, and the ELDO installations there were subsequently dismantled for transfer to French Guiana. This new launch site was commissioned in May 1971.

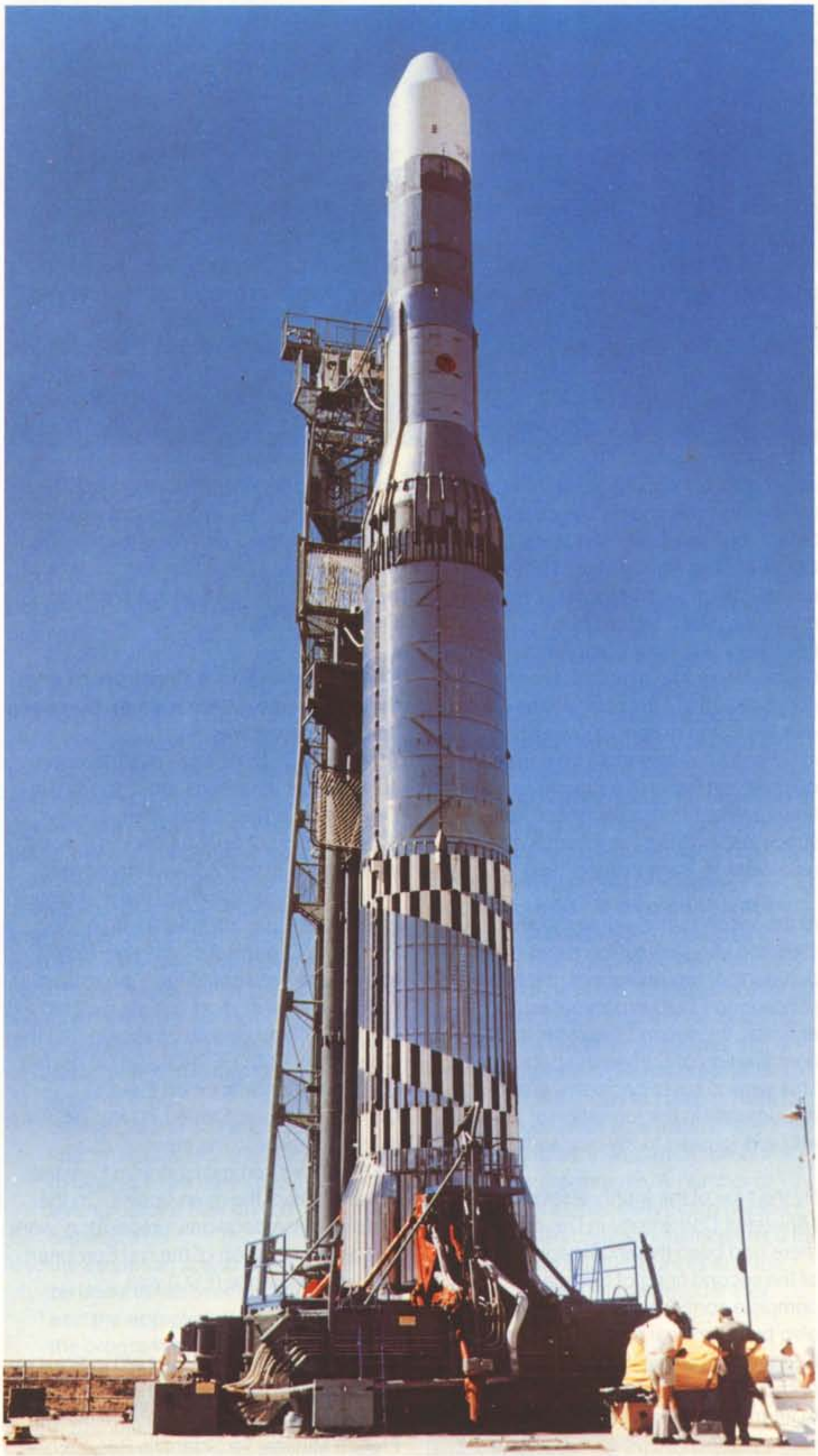
The aim for Europa II was to be able to launch satellites weighing up to 170 kg into geostationary orbit from the equatorial launch base.

In May 1970, the ELDO Council had selected a configuration for a two-stage Europa III vehicle to follow Europa I and II and provide an independent European capability for launching commercial applications satellites weighing up to 700 kg in geostationary orbit. The vehicle's first operational flight was planned for the beginning of 1979, with an envisaged rate of two launches per year.

ELDO's budgetary difficulties
As a result of the financial problems that arose out of the expected overspend of the original £70 million, intergovernmental consultations were deemed necessary as early as January 1965. At this Conference of Ministers a whole series of problems arising from the continuance of the initial programme and the orientation of further programmes were reviewed. The cost to completion of the initial programme was re-estimated, and accepted, as 400 MMU*

* Million Monetary Units (1 MU = ± 1 US $)

Europa I at Woomera



and the various cost estimates for future programmes were scrutinised. A working group was set up to review the overall activities of the Organisation. Its recommendations were examined at a second session of the Conference in April 1965, where it was unanimously agreed to continue with the initial programme.

In February 1966, in anticipation of the next Ministerial Conference, set for April, the British Government sent the other ELDO Member States a memorandum in which it expressed misgivings about the magnitude of the Organisation's expenditure and doubts about the value of the ultimate return. The UK's concern about the cost escalations and slippages turned out to be shared by other Member States. As a result, the Ministerial Conference in Paris in April 1966 was devoted to an exchange of views on questions raised by the UK's memorandum, future programmes of the Organisation and possible steps for the coordination of European space policy. It was felt by the majority, however, that the initial programme should be completed. A number of measures for improved management and cost control were suggested and the Conference decided to reconvene in Paris in June 1966.

At the second session in June and July 1966, the Ministers took a series of positive decisions of two categories, the first concerning ELDO programmes and activities, the second the wider question of coordination of European space policy. This second set of decisions was to prove instrumental in the formation of ESA, as will be discussed in the next section.

By the time of the fourth session of the Ministerial Conference in December 1966 there had been the encouraging success of the second firing of Europa I in complete configuration. However, it had also become clear that the proposed budget for 1967, while within the approved ceiling, would not be sufficient to finance successful completion of the year's planned activities.

At the beginning of 1968 it became apparent that the financial ceiling of 626 MMU fixed by the ELDO Ministers could not be maintained. The Ministers met again in July 1968 and were unable to reach a unanimous decision on a plan to serve as a basis for continuing the Organisation's activities. At the next meeting, in October 1968, the Chairman on that occasion, Mr. Théo Lefèvre, again stressed the need for ELDO's activities to be placed in a wider context. The deliberations at Ministerial and Council level were set to continue into the early 1970s.

At the same time as this crisis was being considered within the framework of the ELDO Ministerial Conference, it was also being considered within the framework of the European Space Conference, which had met for the first time in Paris in December 1966.

The European Space Conferences and the first steps towards a single European space organisation

At the ELDO Conference of Ministers in July 1966, at the instigation of the Italian Delegation, a Resolution titled 'Coordination of Space Policy in Europe' was passed in which it was stated that, owing to the complexity of the problems involved, the possibility of a single European Organisation coordinating space activities should form the subject of further studies and consultations. The ELDO Conference also proposed that the Councils of ELDO, ESRO, and CETS (the European Conference on Satellite Communications, formed in May 1963), be invited to agree to the creation of a coordinating committee drawn from the Secretariats of the three bodies. On the basis of these decisions, preparatory work for the convocation of the first European Space Conference (ESC) was undertaken.

The first ESC meeting was held in Paris on 13 December 1966, under the Chairmanship of Mr. Alain Peyrefitte, the French Minister for Scientific Research. In its first Resolution, the Conference recognised the need to coordinate effectively the use of the resources available to the European States for scientific and technical research in the space field. A working group on programmes, the 'Bignier Group', was created and charged with the making of an inventory of the programmes in progress or envisaged by each of the existing space organisations and their Member States, together with an economic assessment of the advantages likely to accrue therefrom.

The studies requested by the first meeting of the Conference were carried out sufficiently quickly to enable the second meeting to take place on 11 – 13 July 1967 in Rome, under the Chairmanship of Mr. Leopoldo Rubinacci, the Italian Minister for Scientific Research. All the Member States of ELDO and ESRO participated, as well as Norway and the Vatican. There were also Observers from Austria, Canada, Greece, Ireland, Monaco and Portugal.

Given the resources available to European Member States, on the basis of the working group report, it was thought that no comprehensive European programme could be undertaken at that moment. It was therefore decided to create an Advisory Committee on Programmes to formulate propositions with the aim of establishing a coordinated European space policy for adoption at the next meeting. The Conference nominated Mr. J.-P. Causse of France as Chairman of the Advisory Committee.

The Advisory Committee's report, known as the 'Causse Report', was made available at the beginning of January 1968. It presented a proposed European Space Programme to cover a period of seven years, based on a division of economic and technical resources between scientific research and applications satellites and the construction of space vehicle launchers. The Committee of Alternates did not unanimously accept the

Final meeting of the European Space Conference in Brussels on 15 April 1975

recommendations of the 'Causse Report', but a working group on institutions chaired by Mr. J.H. Bannier was invited to make a detailed investigation of possible ways of implementing the Report's proposals.

The determination of Germany, Belgium, France, Italy and The Netherlands, at the ELDO Ministerial Conference, to include a launcher capability in a common programme in which priority would be given to applications satellites was something of a surprise to the non-ELDO members at the European Space Conference's third meeting, in Bad Godesberg, in November 1968. With the complexity of the situation thus created, it took all the resources of the Chairman, Dr. G. Stoltenberg, German Federal Minister for Scientific Research, to achieve any results whatsoever. Agreement was reached, however, on the principal objectives for a basic European space programme. They would be:

- to construct, launch and put into operation a synchronous satellite capable of retransmitting television programmes to individual receivers
- to develop a scientific research programme to carry out missions that surpassed national capabilities, maximum possible use being made of the results of the scientific programme for the applications programme and vice versa.

The Conference also decided, in order to facilitate the amalgamation of the existing organisations, to establish a Committee of Senior Officials to draft the text of a Convention for the single Organisation, by 1 October 1969. This Committee, under the Chairmanship of Prof. G. Puppi (Italy), was to take into account the content of the Causse Report, the Bannier Report and the report to the ELDO Conference of Ministers known as the Spaey Report.

The Committee of Senior Officials completed its report to the ESC in June 1970, including a report by a working group on programmes chaired by Mr. Spaeth of Germany and one on institutions chaired by Prof. J.F. Denisse of France. Difficulties still stood in the way of a coordinated European space policy, not the least of which was 'the launcher problem'.

The fourth meeting of the ESC was held in Brussels from 22 to 24 July 1970, under the Chairmanship of Mr. Théo Lefèvre, then Belgian Minister for Scientific Policy and Planning. It was evident from the outset that the recent change of government in the United Kingdom and the ministerial crisis in Italy would not allow the participating countries to reach final decisions and that a further meeting would be necessary before the end of 1970. Nevertheless, a number of key issues were discussed, including:

- consideration of possible European participation in future US programmes
- amalgamation of the European space organisations and transitional measures to be taken pending the setting up of a new unified organisation
- the European space programme to be undertaken over the next decade and the approval of the first slices of the programme.

All of these questions had been studied by the Committee of Senior Officials set up in Bad Godesberg in November 1968, and by the Committee of Alternates chaired by Mr. E.A. Plate of The Netherlands.

The Ministerial Meeting approved the Senior Officials' proposals for the creation of a unified European Space Organisation to replace the ESC, CETS, ELDO and ESRO and at the same time defined the principles by which this Organisation should be governed. It was agreed that the text of a Convention to be prepared to this end would be drafted and submitted to the Member States in November 1970. Efficient management of space programmes was to be sought, with the formation of international industrial groups for their execution. The new Organisation was also to direct its efforts to the harmonisation of the national and international space programmes of the Member States. The Conference also decided unanimously to press on with studies undertaken as a result of the American invitation to participate in the post-Apollo programme. A number of transitional measures were also decided, which included common memberships for the ELDO and ESRO Councils and the appointment of a single President for both.

At the end of this third ESC, while no final decisions on programme proposals had been possible, there were signs of determination on the part of many

The signing of the ESA Convention in Paris on 30 May 1975

Members to pull European space activities out of the rut in which they had, by this time, been trapped for several years. It was hoped that this concerted will would allow decisions of a more permanent nature to be taken at the Conference's next session in November 1970.

The second session of the Fourth ESC opened in Brussels on 4 November 1970, under Théo Lefèvre's Chairmanship once again. Despite the Chairman's exhortations that the participants should strive to be conclusive on this occasion, this meeting broke up far from achieving the unified international programme of European space activities that had by this time been the subject of four years' labour.

The two ESC meetings in 1970 had shown that a number of States were prepared to undertake an applications satellite programme, but the problem of how to launch these and the other satellites remained. Europe was finding it difficult to renounce its own launcher programme in order to make a more significant contribution to the post-Apollo programme.

Further meetings and deliberations took place in 1971, but it was not until the Ministerial meeting in Brussels on 20 December 1972, chaired again by Belgian Minister of State Théo Lefèvre, that they managed to reach binding agreement on the setting up of a single 'European Space Agency', with responsibility for building a heavy launcher for Europe, Spacelab for the post-Apollo programme and the pursuit of a rationalised set of European satellite programmes.

This meeting at the Palais d'Egmont was a major turning point in European space history. Widely diverging views had caused Théo Lefèvre to postpone this Conference twice from its originally scheduled date in July 1972. With general approval for the two major projects on which positions had long seemed irreconcilable – the European launcher and the space laboratory – Mr. Lefèvre was able to report the Conference's general approval for ESA to be formed, if possible by 1 January 1974.

As a result of the decisions taken by the ESC on 20 December 1972, the ELDO Council decided: firstly, not to embark on the development phase for Europa III, and thence to terminate this programme on 1 January 1973; and secondly to halt the Europa II development and construction programme, terminating it from 1 May 1973.

Further meetings of the ESC in Brussels on 12 and 31 July 1973, under the Chairmanship of Minister Charles Hanin, produced general agreement on the outline programme for ESA, though it was not finalised in detail until 20 September 1973 at a Committee of Alternates Meeting. On 24 September 1973, an Agreement between Europe and the USA on the construction of Spacelab was signed in Washington. Agreements between the European countries on the new programmes, including the Ariane launcher, were signed in the following months.

The formal proposal for the establishment of ESA, based on a revised version of the ESRO Convention, was submitted to a final meeting of the ESC in Brussels on 15 April 1975. This ESC, chaired by Mr. Gaston Geens, Belgian Secretary of State responsible for Scientific Policy, marked the end of the European Space Conferences per se, as the future forum for Ministerial meetings was to be provided through ESA's Council.

On 30 May 1975 a Conference of Plenipotentiaries met in Paris to sign the 'Convention for the Establishment of the European Space Agency'. Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Sweden, Switzerland and the United Kingdom signed on that day. Ireland signed later, on 31 December 1975. The final ESC had expressed the wish that ESA should begin functioning 'de facto' before final ratification of the Convention, and it did so from 31 May 1975.

The Workload of European Space Industry: Current Situation and Foreseeable Trends

G. Dondi, Directorate of Administration, ESA, Paris

M. Toussaint, Eurospace, Paris

A study on the workload of European space industry was undertaken in the Spring of 1983 with the help of Eurospace, with the following aims:
- **to conduct a 'grass-roots' verification of European space industry's workload and of the part played by ESA's programmes in European space activities**
- **to solicit industry's point of view on the foreseeable workload in the medium term as an input for the preparation of ESA's Medium-Term Programme.**

The space industry is relatively young, only recently being recognised as a separate endeavour and no longer just the promising offspring of aeronautical or electronics activities. It is therefore understandable that statistical information on the space industry is scarce. Consequently, ESA has an interest in seeking replies to such questions as:
- How many people work in space-related industries in Europe?
- Are space activities creating employment?
- Is space industry still predominantly dependent on ESA for its workload?
- For what kinds of workload is European space industry preparing itself in the medium term?

The help of Eurospace in conducting this study was deemed necessary in order to gain access to information concerning non-ESA activities normally considered commercial/confidential by individual firms, but which is an indispensable input for a statistical study of this type.

A representative sample of the firms active in the space domain in Europe was selected (51 firms in 12 countries; see Table 1) and a questionnaire was sent to each outlining the information sought. In order to begin with a reasonably uniform working hypothesis, each firm was provided with some forecasts, worked out jointly by ESA and Eurospace, on ESA's future programme and the foreseeable space market accessible to European industry.

A series of industrial visits was made to complement the replies received with more in-depth information.

The findings of the study have been compiled in two reports, the first of which, containing the summary information, is freely available; the second containing the

Table 1 — Firms contacted for the workload study

BELGIUM
BTM
ETCA
FN
SABCA

DENMARK
ROVSING
TERMA

FRANCE
AEROSPATIALE
AIR LIQUIDE
CROUZET
ESD
INTERTECHNIQUE
MATRA
SAT
SEP
THOMSON-CSF

GERMANY
AEG WEDEL
ANT
DORNIER
MAN
MBB-ERNO
SEL
SIEMENS

ITALY
AERITALIA
BPD
FIAR
GALILEO
GTE
ITALSPAZIO
LABEN
SELENIA SPAZIO
TELESPAZIO

THE NETHERLANDS
FOKKER
HSA

SPAIN
CASA
INTA
SENER

SWEDEN
LM ERICSSON
SAAB SPACE
VOLVO FLYGMOTOR

SWITZERLAND
CIR
CONTRAVES

UNITED KINGDOM
BAE
FERRANTI
LOGICA
MARCONI COMMUNICATIONS
MSDS
PLESSEY

NORWAY
EB

AUSTRIA
ORS
ELIN

ARIANESPACE

detailed 'grass-roots' data, is considered confidential and its distribution was restricted to ESA's top management.

Summary findings

Space industry organisation

In 1983, the merger of major aerospace firms (or departments involved in space activities) affected space activities in several major European countries:

- In the United Kingdom, British Aerospace, Space & Communications Division consolidated administratively the merger initiated in 1980 between HSD and BAC.
- In Germany, the merger between MBB Space Division and ERNO was in progress.
- In Italy, Selenia Spazio was created, bringing together the Selenia Space Division, the Italtel space activities (ground-station hardware), STS's activities (telecommunications ground-station systems), and CNS's activities (communications satellite integration).

At corporate level, quite a number of other major space firms were undergoing an internal reorganisation, reflecting in some cases the recognition of space activities within the corporate structure by making previous departments or groups the nucleus of an independent company or profit centre, in others geographical or corporate regroupings imposed by the growing importance of space activities:

- In France, the reorganisation of Thomson-CSF; and the moves to Toulouse affecting Matra and Thomson-CSF.
- In Germany, the reorganisation of AEG-Telefunken, with the separation of ANT (previously AEG Backnang) and the restructuring of AEG Wedel. Dornier also underwent a minor reorganisation.
- In Italy, the restructuring affecting BPD and Aeritalia.
- In Sweden, the restructuring of Saab (with Saab Space now an independent company) and L M Ericsson (creation of Ericsson Radio System incorporating the space activities of L M Ericsson and SRA).
- In Switzerland, the restructuring of Contraves.

Finally, there was an evolution in the industrial consortia of the 1970s, in two respects:

- on the one hand, the consolidation of past preferential links into joint companies or GIEs (Groupements d'Intérêts Economiques) more adapted to the undertaking of commercial space activities, examples being Arianespace, Eurosatellite, Satcom, etc.
- on the other, the proliferation of ad-hoc commercial agreements between European and US space firms with a view to facilitating entry to specific markets.

We have attempted to summarise these developments in a simplified manner in Figure 1.

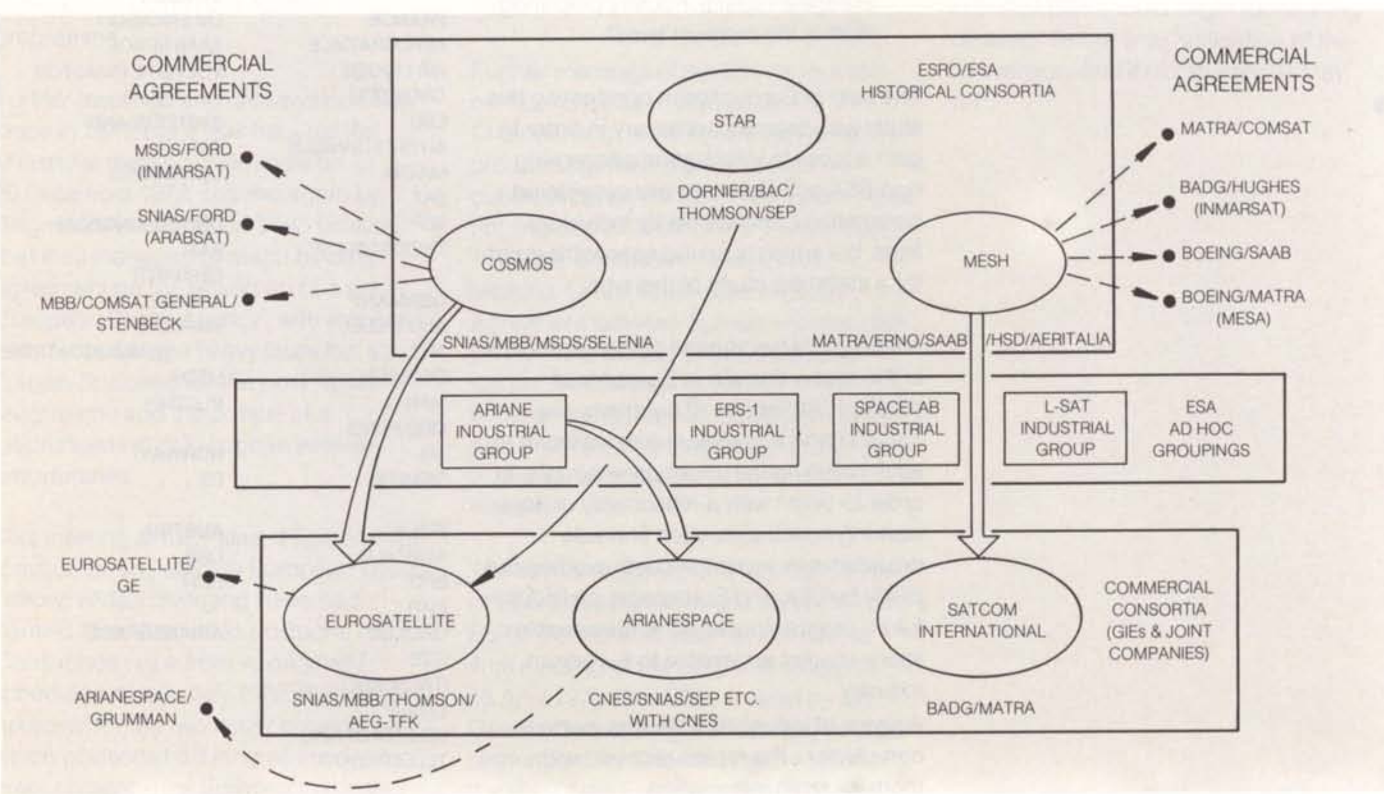


Figure 1 — Evolution in industrial groupings of European space firms (excluding national groupings)

Personnel employed on space activities

Table 2 lists the personnel working in the sample of firms considered in the study.

To give a more complete idea of the number of people directly involved in space activities, some extrapolations have been made:

In Europe, in 1983, about 31 000 people were concerned with space activities. Of this number:

- 51%, about 16 000 people, worked in large space companies (i.e. the companies in the sample used in the study)
- some 20%, about 6000 people, worked for other companies or as consultants
- some 17%, about 5000 people, worked for institutions such as ESA, CNES and DFVLR
- some 12%, about 4000 people, worked in universities and laboratories.

These figures do not include personnel working on space activities in customer organisations (meteorology, post and telecommunications, television), or in banks and insurance companies.

Recruitment problems

It was one of the surprises of the study to discover that, in a world so preoccupied with unemployment, so many space companies have difficulties in finding personnel. The difficulty in recruiting good young space engineers and technicians was mentioned by several companies in all countries. However, many firms have established good contacts with universities and thereby found a satisfactory solution to their problem.

It is even more difficult to find qualified engineers and technicians. A number of years (three is the figure often quoted) are necessary before a newly recruited engineer or technician is fully operational on space programmes (on the job training is usually the rule). With the increase in the market in such sectors as communications, qualified staff are becoming a scarce commodity in Europe.

In addition, the period for which an engineer or a technician with a particular skill is professionally useful is becoming shorter than a few years ago, due to the accelerated replacement of technologies. Consequently, a continuous stream of newcomers must be recruited and trained.

Turnover and added value per employee

The 'internal' turnover figures of the various companies, i.e. the value of the space-activities contracts obtained by these companies minus the value of the subcontracts given to subcontractors having full responsibility at subsystem level, have been grouped by country in Table 3.

It was not possible to obtain detailed figures from all companies even for recent years, and so some approximations have had to be made.

The average financial turnover per employee varies widely from company to company – between 40 and 120 kAU per staff member in 1983 – due to the very different situations of individual firms. Certain companies use the services of other 'captive' companies that are not subcontractors with responsibility at subsystem level. Also for certain companies the cost of components is

Table 2 – Numbers of personnel working on space activities in the companies considered for the study

	1977	1983	1988
Belgium	297	358	384
Denmark	71	144	205
France	3 833	5 559	7 449
Germany	3 130	3 680	4 230
Italy	777	1 793	2 493
The Netherlands	211	270	359
Spain	344	430	585
Sweden	130	570	1 010
Switzerland	97	12	112
United Kingdom	1 517	2 532	3 115
Ireland	5	15	20
Norway	–	100	140
Austria	–	25	75
Arianespace	–	145	175
Total	10 441	15 731	20 407

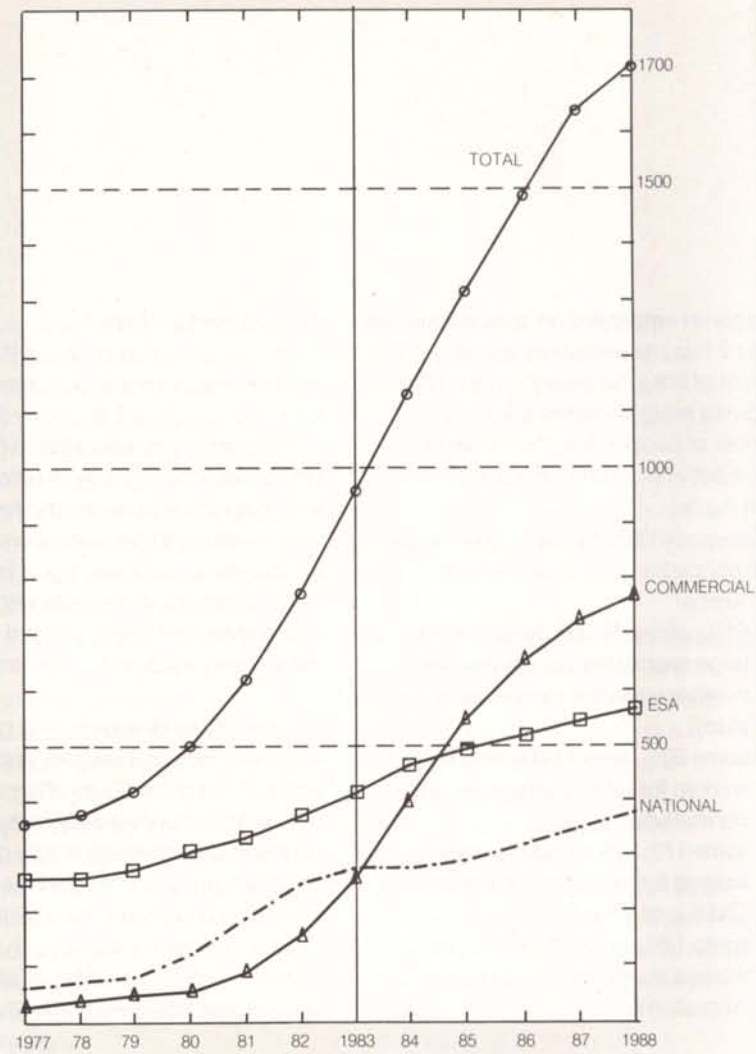
* Average growth rate 1977 – 1983: about 7% per year
Average growth rate 1983 – 1988: about 5% per year (estimated)

Table 3 – Space-activities turnover in firms of the sample grouped by country (development contracts in current MAU)

Country / Year	1978	1979	1980	1981	1982	1983	1984*	1985	1986	1987
Belgium	14.8	18.5	17.6	17.8	19.7	20.9	21.6	21.9	22.9	23.6
Denmark	3.5	3.9	4.7	5.2	6.7	8.2	11.3	14.3	16.7	17.4
France**	119.4	112.3	144.4	206.9	263.4	333.1	386.9	416.0	452.2	507.3
Germany	128.4	145.8	158.9	169.8	195.3	225.0	240.6	265.0	288.0	307.0
Italy	31.2	36.8	47.1	57.8	72.9	121.4	145.5	189.3	202.5	240.0
The Netherlands	14.3	14.5	11.4	12.8	21.1	22.0	23.2	28.0	29.6	30.7
Spain	19.5	19.5	21.1	20.6	22.5	24.1	29.6	30.4	31.1	31.4
Sweden	8.0	7.4	8.2	12.9	23.1	25.4	28.1	38.6	43.9	49.6
Switzerland	4.6	7.0	6.4	8.1	8.9	10.3	9.5	9.9	10.1	9.1
United Kingdom	33.6	51.8	83.2	105.5	141.9	165.1	187.4	209.9	245.4	270.5
Ireland		0.2	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.9
Norway	2.0	2.6	2.8	2.5	3.0	4.0	5.0	5.8	6.5	7.0
Austria						0.7	2.5	3.4	3.4	6.2
Arianespace (main sub-contractors)							57.0	96.0	140.0	140.0
Total	329	420	506	620	779	961	1149	1329	1493	1641

* 1983 conversion rates for the year 1984 and beyond
** Thomson-CSF ground station excluded

Figure 2 — Global space-activities turnover of the companies surveyed (in MAU)



high. For the space electronics industry in particular, the cost of components has increased sharply in recent years.
An alternative means of measuring the output of a firm's personnel is through reference to the concept of 'added value', i.e.

> the turnover of the company (excluding subcontractors), minus material, equipment and minor work supplied by other companies, plus the yearly increase in the value of the company's stock.

Unfortunately, it was possible to obtain these figures only from a subset of the companies studied, but the figures obtained show that the 'added value per employee' varies much less from company to company than turnover. It is usually between 35 and 60 kAU per employee. It is not really connected with the nationality of the company, nor is it too dependent on the relative importance of production work compared with development work. This is due to the fact that the investment in machine-tools, etc. for every production job is so great that its amortisation cost compensates for the difference in salary between production workers and engineers.

The evolution of added value with time is linked to the increase in productivity, and the effects of inflation. Table 4 illustrates general trends by means of two specific examples: the first relates to a French firm, the second to a German firm.

Table 4 — Evolution in added value per employee

Year	Added value per employee (kAU) French firm	German firm	Inflation factor for space procurements
1976		24.5	100
1977	17.7	30	108
1978	16.1	35	116
1979	16.5	39	127
1980	27.4	42	141
1981	34.1	44	155
1982	37.7	50	167
1983	40.6	55	
Average growth	14.8%/year	12%/year	8.9%/year

Investment
Due to the growth of the space-related market, new investments have recently been made by several companies to cope with the expected future workload. Three categories of investment can be distinguished:
- large investments in the form of buildings or large integration and testing facilities
- investments in technology (e.g. development of carbon-fibre products)
- investments in products (e.g. development of special satellite platforms for the commercial marke

Due account has also to be taken of investments made for the training of specialised personnel.

The number, size and quality of the new integration and test facilities that have recently become operational in Europea industry (or will become operational shortly) is particularly impressive. A number of firms that have so far concentrated on the development of subsystems as subcontractors, now see determined to play a role at system level

Market trends
Figure 2 shows the growth in total turnover of the companies surveyed between 1977 and the present and their projections until 1988. The evolution in t ESA, national and commercial components is also included. This turnover corresponds to development contracts.

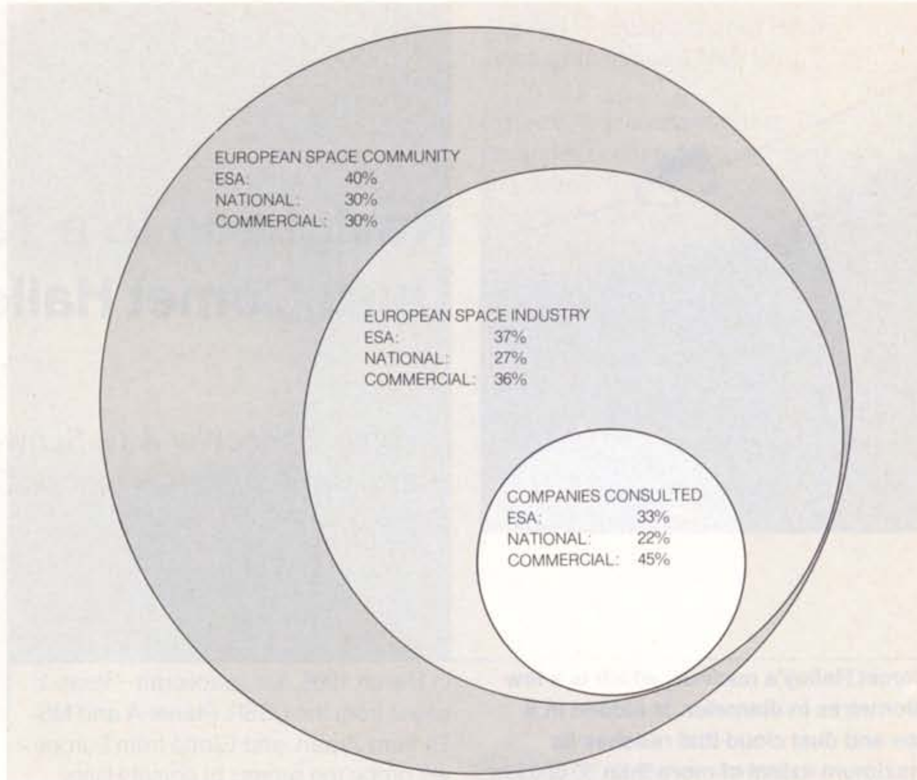


Figure 3 – ESA, national and commercial shares of
- *European space community expenditure*
- *European industry turnover*
- *turnover of the companies consulted*

The growth in total turnover amounts to an average of 15.2% per year; 16.7% for the 1977–1983 period, and 12.3% for the 1984–1988 period, which tends to indicate that the company forecasts are rather realistic. It is due to:
- a moderate growth in ESA contracts (7% per year)
- a more rapid growth in national markets, especially during recent years (27% per year between 1977 and 1983, 6.5% foreseen between 1984 and 1988, 16% per year on average)
- a considerable growth in the commercial market (44% between 1977 and 1983; 23.4% foreseen for the 1984–1988 period; 34.5% on average for the 1977–1988 period).

Overall, the structure of the market for the European space companies consulted is changing radically. In 1977, ESA contracts represented 70% of their turnover and the commercial market 10%. In 1988, the expected percentages are 33% and 45%, respectively. In 1983, these percentages were already 43% and 28%. By comparison, the national market has remained stable: 20% in 1977, 22% expected in 1988, with a peak of 29% in 1980–1983.

By making some simple computations, it was possible to extrapolate (Fig. 3) the distribution of ESA, national and commercial space expenditures foreseen for 1988:
- for the European space community as a whole, including the institutions and universities (in this case, the ESA and national space expenditures are assumed to equate to the budgets of the space institutions, while the commercial market is assumed to be the commercial market accessible to European space industry)
- for the entire European space industry, including companies not consulted in the study (in this case, the ESA market has been assumed to represent 85% of the Agency's expenditure, and the national market 65% of the national space expenditure).

It is clear that the commercial market is expected by the companies consulted to represent the most important component of their turnover in 1988. If one looks at the whole European space community, however, the activities financed by ESA will still be more important in financial terms than the activities originated in the commercial market itself.

Differences per country and per company

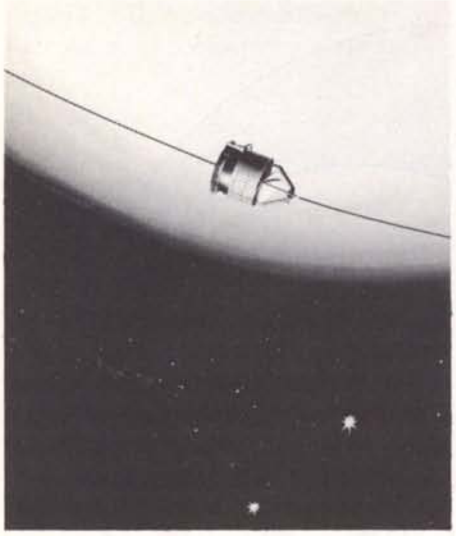
The global data given above encompass a wide variety of situations. National activities are not distributed evenly among the companies of the countries with a sizeable national programme. In the case of France, for example, national contracts represent less than 15% of the turnover of some companies and more than 60% for others. Commercial contracts show an even greater spread between companies. ESA contracts have increased by 7% per year since 1977, but their number and distribution have created problems in some cases in terms of continuity of work (especially when a firm is active in only a limited number of technological areas) and irregular workload.

Conclusions

The space programmes that were decided upon at the beginning of the sixties have stimulated the provision of investment for space infrastructures, sustained a robust growth in turnover for European space industry and, more generally, allowed this industry to mature.

During the implementation of these programmes, a number of structural changes have taken place:
- A sizeable commercial market has emerged in addition to the traditional ESA and national space markets. This market is still young, and its further development depends on the continuation of a sustained effort, at ESA and national level, for developing the next generation of space products. Its effects on the prosperity and efficiency of the European companies are, however, already considerable.
- Industry has restructured itself, by recognising space activities at corporate level, and by creating new cooperative structures to cope with commercial activities.

If European space industry is to continue to prosper and grow, it is now time for Europe to implement a new series of programmes aimed at developing the new technologies and infrastructures that will be needed for the future missions to be undertaken not only by Europe but also by the rest of the world.



Navigation to a Target Hidden in Dust: Comet Halley's Nucleus

J. Fertig, F. Hechler & G. Schwehm, Orbit Attitude Division, European Space Operations Centre (ESOC), Darmstadt, Germany

Comet Halley's nucleus, which is a few kilometres in diameter, is hidden in a gas and dust cloud that reaches its maximum extent of more than 50 000 km around the comet's closest approach to the Sun. The invisible nucleus is the reference point for the targeting of the Agency's Giotto spacecraft. Modelling of the outgassing nucleus and its environment will provide the mathematical basis for the targeting process.

In March 1986, five spacecraft – Vega-1 and 2 from the USSR, Planet-A and MS-T5 from Japan, and Giotto from Europe – will probe the secrets of comet Halley. With its period of 76 years, Halley still displays the full range of phenomena of 'fresh' comets: an extended coma, a dust tail, and an ion tail. It therefore presumably consists of unprocessed material similar to that present in the early stages of our solar system.

The Giotto mission, ESA's contribution to the comet's exploration, will provide in-situ measurements of comet Halley and the first high-resolution images of its nucleus. Giotto should fly by the comet more closely than the other spacecraft and will penetrate deep into the cometary coma. Unfortunately, Halley's orbit is retrograde, i.e. its direction of rotation around the Sun is opposite to that of the Earth and Giotto's heliocentric orbit. This precludes a long rendezvous and means that the spacecraft will be able to spend only a few minutes inside the cometary region of greatest scientific interest.

The targeting and navigation of Giotto are challenging tasks because of the exacting goal of a close flyby of the tiny nucleus hidden in the coma, and the very short encounter time. This challenge has to be met by sophisticated modelling, reflecting today's best available cometary knowledge.

Target characteristics

The often spectacular, visible parts of a comet are its head and tail (Fig. 1). These very tenuous and evanescent elements occupy a huge volume, comparable to that of the Sun, but weigh no more than 10^{-22} solar masses. According to Fred Whipple's icy-conglomerate model, the source of this material is a chunk of dirty ice a few kilometres in diameter, known as the 'nucleus'. This nucleus is the physically and cosmogonically most relevant part of the comet. The various phenomena and scales involved are shown in Figure 2.

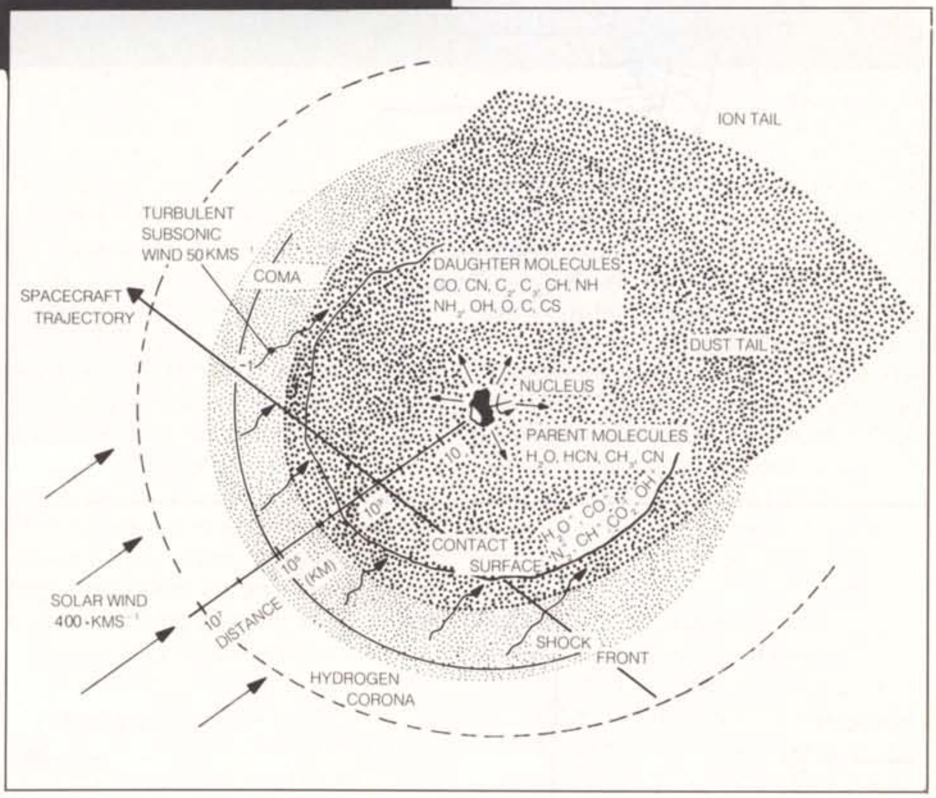
At the time of its latest recovery by Mount Palomar in October 1982, comet Halley was faint and starlike. As the heliocentric distance decreases, sublimation of the volatile constituents starts to drag away dust from the nucleus' surface and the coma totally 'outshines' the nucleus. Initially the coma is spherical but, as the comet moves still closer to the Sun, radiation pressure gives rise to a repulsive force in the Sun – comet direction, causing the dust tail and the ion tail to appear.

The motion of small particles in the coma can be described by the 'fountain model', which explains the coma's parabolic shape (Fig. 3), but neglects the influence of the comet's orbital motion on the dynamics of larger dust particles. Surface inhomogeneities on the nucleus lead to locally enhanced dust production, visible as jet-structures in the coma. Images of Halley taken in 1910 indicate that the spatial densities of gas and especially dust in these jets might be orders of magnitude higher than in the surrounding coma.

The continuous loss of mass results in a force on the nucleus which may be

Figure 1 — Head of comet Halley, photographed on 8 May 1910

Figure 2 — The comet coma. The distances of contact surface and bow shock from the nucleus correspond roughly to estimates for Halley at 1.5 AU heliocentric distance



significant for comets. Beginning with Bessel's studies on the 1835 apparition of comet Halley, it became apparent that cometary orbits may undergo substantial nongravitational perturbations due to this rocket-like outgassing effect. Again the icy-conglomerate model provided the firm theoretical basis to explain these nongravitational effects (Fig. 4).

The operational challenge

The Giotto spacecraft must reach its target, a small window about 500 km to the sunward side of the comet's nucleus, at a preselected time to ensure ground-station coverage throughout encounter. For operational reasons, the necessary trajectory-correction process must be completed about 1 day prior to the flyby. The target is specified with respect to the comet's centre of mass and hence can only be achieved satisfactorily if the ephemeris of the comet's nucleus is known rather precisely.

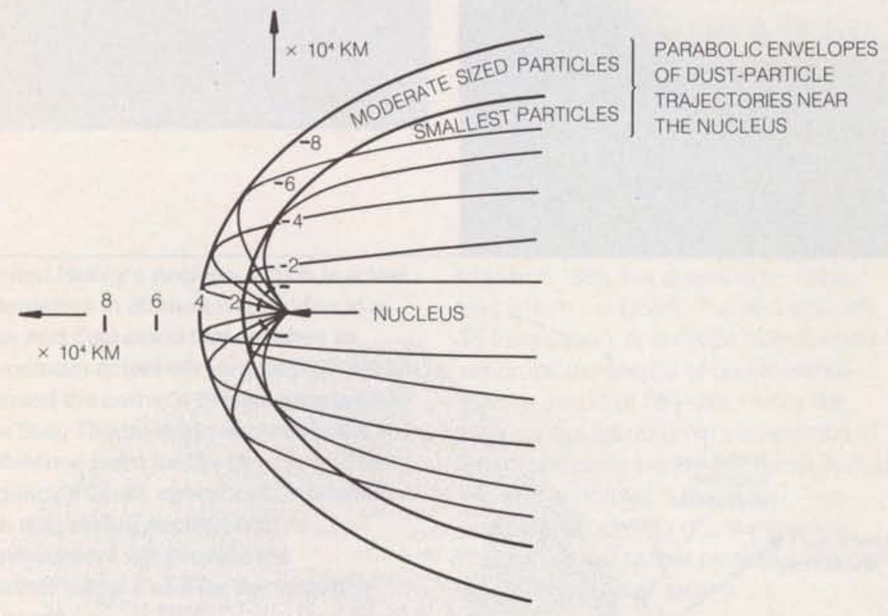
The ephemerides of comets are determined, like those of planets, from astrometric data, i.e. from the directions of the celestial body as seen from Earth-bound observatories. Unfortunately, our target is a nucleus hidden in a huge coma, which makes it invisible throughout the mission. The coma is at its most extensive around the time of the encounter. The accuracy of the ephemeris depends on the quality of the astrometric data. In our case, this quality largely depends on the accuracy with which the nucleus can be localised in the coma and this is partly a function of observation techniques and hardware (e.g. exposure times and plate material). Studies have revealed that the orbit determination for Halley must take into account astrometric data collected during previous apparitions back to at least 1835, so that our targeting accuracy also depends on 'historical' decisions on the position of the comet's hidden nucleus.

The ephemeris accuracy also depends strongly on uncertainties in the force model. Gravitational forces like planetary attraction are well known, but outgassing forces on the cometary nucleus are a dominant error source in the orbit-determination process. These forces may induce transitory and secular phenomena in the comet's motion, such as its well-known variation in orbital period by roughly 4 days, which can only be explained by nongravitational forces.

Given the above uncertainties, mission analysis presently predicts a 40% probability of missing the target by more than 500 km, which could cause an

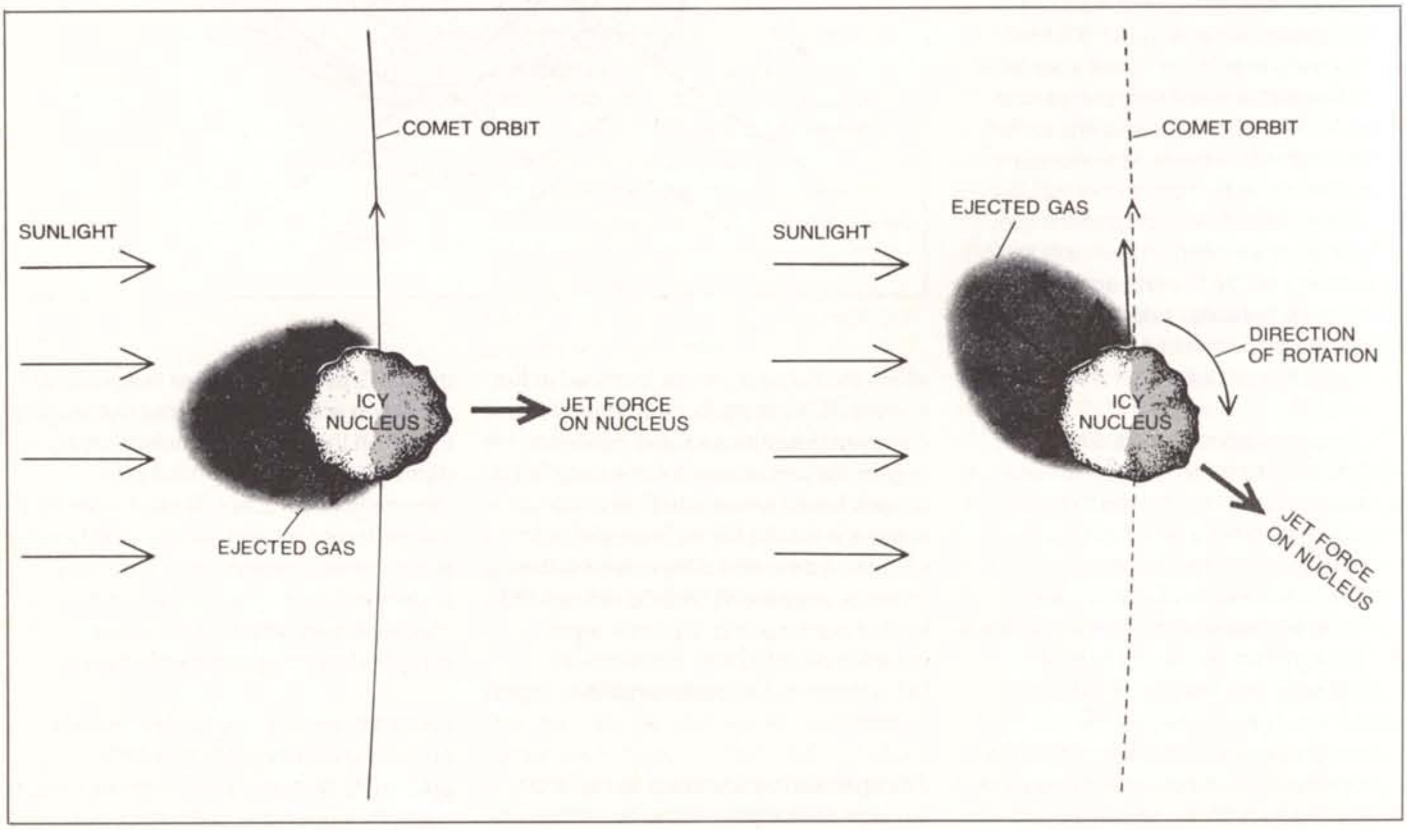
Figure 3 — Principal particulate features of a typical comet derived from the fountain model

Figure 4 — The thrust exerted on the nucleus by volatilised gases (from F.L. Whipple, 'The Spin of Comets', Scientific American, March 1980)

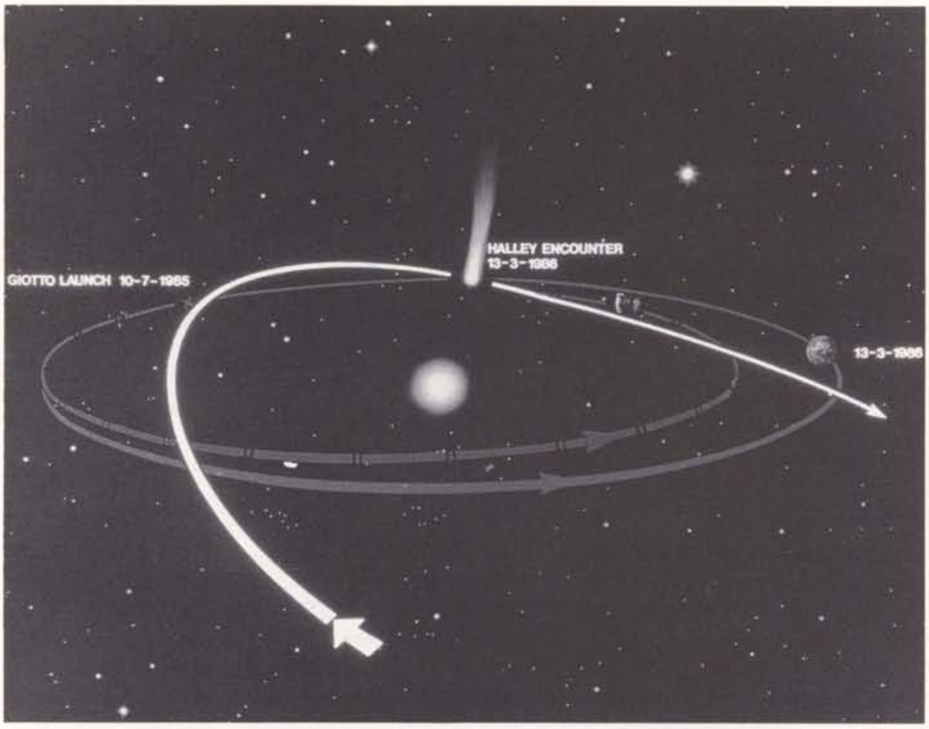


undesirable flyby on the dark side of the nucleus. Careful modelling of nongravitational forces and of optical phenomena for different observation periods and techniques is therefore a prerequisite for improvement of the targeting accuracy.

After the Giotto spacecraft has been manoeuvred successfully towards its target, it has to traverse the cometary dust cloud for the final 50 000 to 100 000 km of its approach to the nucleus. Dust particles will impinge on the spacecraft at the flyby velocity of 68 km/s. At this enormous velocity, a dust grain weighing only 0.1 g could penetrate up to 8 cm of solid aluminium. The spacecraft will therefore be protected by two shields against structural damage and its attitude during encounter will be chosen such that the dust grains impact the front shield only. The spacecraft's spin axis will thus be aligned with the spacecraft—comet relative velocity vector.



In addition, large-particle impacts may result in loss of ground contact with the spacecraft, because they are likely to cause attitude perturbations that exceed the high-gain-antenna beamwidth of 0.5°. The impact of a 0.1 g particle on the outer rim of the shield, for instance, would shift the spacecraft's spin axis by more than 2°. Fortunately, the probability of encountering particles that large is low.



Nevertheless, the need for operational predictions of the probability of survival to or beyond closest approach is clear. These predictions are required during final targeting operations as one of the criteria for aiming-point selection. They are derived from a detailed numerical model for the cometary dust environment. Emphasis must be placed on the modelling of the spatial distribution of the large dust grains as they constitute the main hazard to the spacecraft.

Fortunately, additional information on both the cometary dust environment and the nucleus position will be available for Giotto, based on the earlier flybys of the two Vega probes. Precise measurements of the position of the nucleus (the 'Pathfinder Concept'; see page 90 of this Bulletin) should allow greater accuracy in the comet-ephemeris prediction and the experience of the dust environment gained with these probes can be applied for Giotto's targeting. Should the Vega data show that the dust hazard is far outside its expected boundaries, late optimisation of Giotto's flyby distance will be possible.

Target-environment modelling

Up to now, only remote observations of comets are available. Images of Halley show the gas and dust coma, while the nucleus itself remains inaccessible to direct studies. Because the local properties of nucleus and dust coma cannot be measured in situ, they have to be derived from theoretical models that fit the available macroscopic ground-based observations.

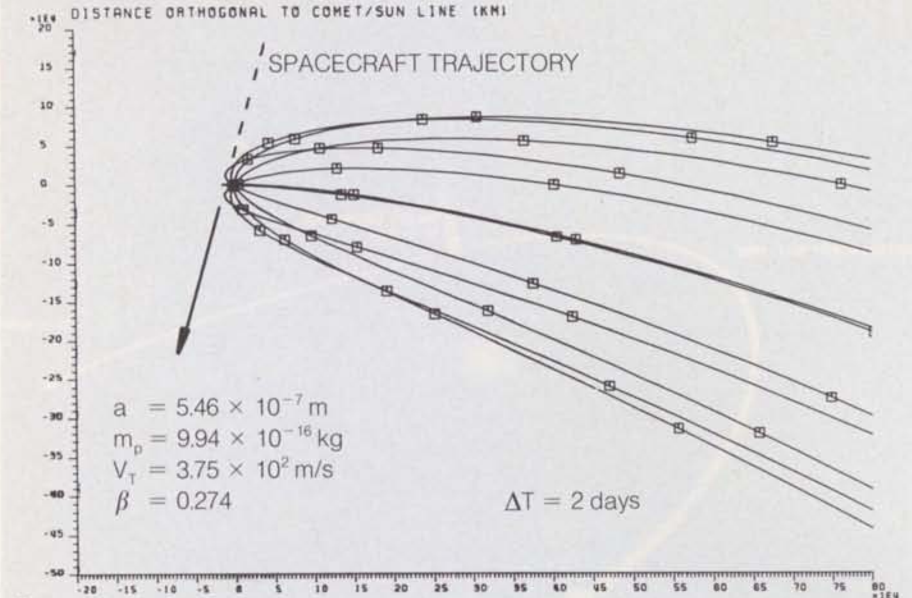
The *nucleus model* has to reflect the physical and chemical processes occurring as the icy nucleus approaches the Sun. The nonuniform temperature distribution on the surface of the rotating nucleus and active areas that are switched on and off once per revolution (depending on temperature) account for the anisotropic emission of gas and dust. The resulting dust jets are observable in cometary images. Light scattered by the cometary dust cloud will lead to a more uniform heating of the nucleus surface. Close to perihelion, the total gas and dust production will increase with temperature, but the resulting optically thicker coma will, in turn, shield the nucleus more efficiently from solar radiation. Thus, a feedback mechanism between incoming radiation and gas and dust production has to be considered.

For a given size and chemical and physical properties of the nucleus, the above processes can be translated into a *nongravitational forces model* along the trajectory. Model parameters reflecting the uncertainties in the assumptions have to be calibrated by fitting the astrometric data.

In addition to the nongravitational forces, the nucleus model provides us with input parameters for the *dust environment model*, e.g. the gas and dust production rates and the dust terminal velocities. A dust grain reaches terminal velocity when it leaves the sphere of influence of the accelerating gas. Active areas on the nucleus may produce local dust concentrations that differ by orders of magnitude from the values expected for a homogeneous nucleus. Information on the locations and production rates of active areas on the nucleus is an essential prerequisite for the force and dust modelling. The period and direction of dust outbreaks is influenced by the spin period and spin-axis orientation of the nucleus.

Given these input parameters, the dust model predicts the spatial dust density in the coma as a function of position and particle size. Operationally, the dust model is used to estimate the dust density along the flyby trajectory, in order to assess the spacecraft's probability of survival. In addition, it provides information on the position of the nucleus with respect to the visible dust cloud and will thus be used to remove a significant bias from astrometric observations.

The 'fountain model' neglects the influence of the comet's orbital motion on the dust-particle dynamics. This simplification is valid for small particles ($M_p \lesssim 10^{-8}$ g), which are strongly accelerated by solar radiation pressure. As a consequence, the trajectories of small particles in a comet-fixed coordinate system are well approximated by parabolae and the entire cloud of these



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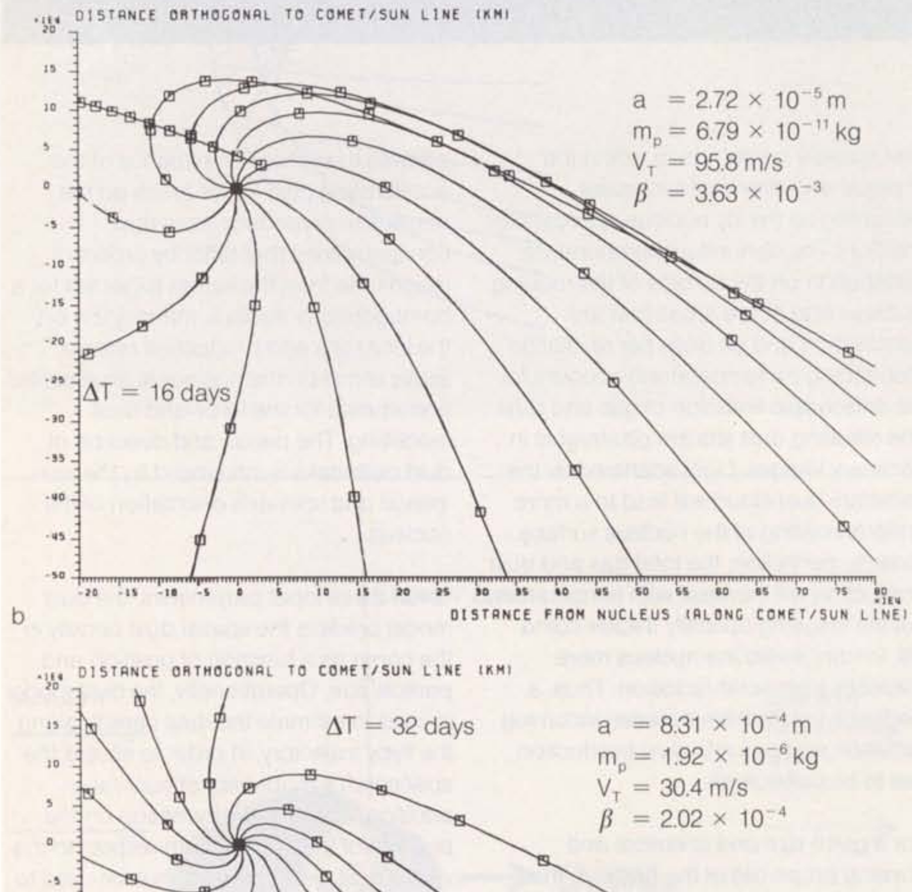

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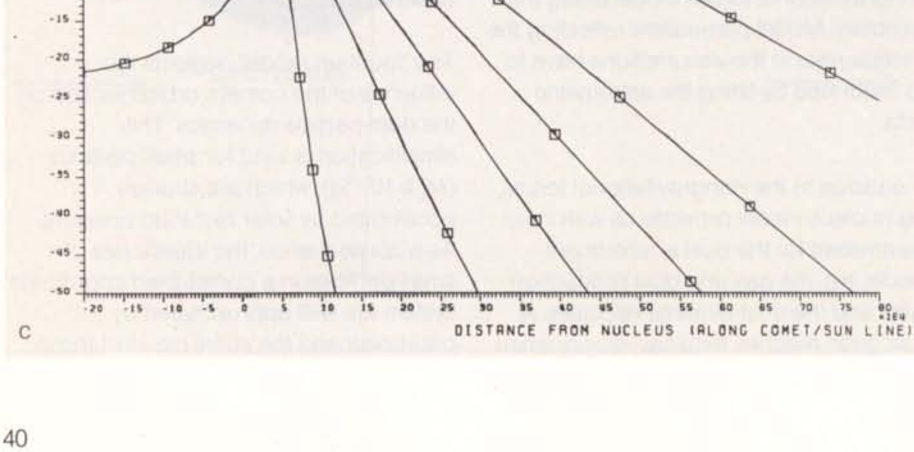

c

Figures 5a – c — Trajectories of dust particles in the plane of the comet orbit (cometo-centric system). The azimuth of ejection is varied in steps of 30°. Three particle masses are considered; the respective radii a, masses m_p, terminal velocities V_T, and radiation-pressure force/gravitational-attraction ratios β are noted in the figures. The locus of simultaneously emitted particles after T=2, 16 or 32 days is shown. The Giotto trajectory is inclined by 8° with respect to the plane of the figure.

particles is confined within a paraboloid of rotation, the 'dust envelope' (Fig. 3).

Figure 5 shows the drastic difference in dust-cloud geometry for small (a), intermediate (b) and large (c) particles. The comet nucleus is at the origin and the comet – Sun line is parallel to the abscissa; the plane of the drawing is the comet's orbital plane. In each case 12 trajectories are considered and the particles are assumed to be ejected at perihelion. The initial-velocity vectors are at azimuth intervals of 30° in the orbital plane. The locii of the particles at 2, 16 or 32 day intervals are indicated in the figures.

Simultaneously ejected lightweight particles can be thought of as located at the surface of a sphere which is expanding with the dust terminal velocity, while its centre is accelerated in the antisunward direction by solar radiation pressure. For large particles, these spheres are distorted into ellipsoids and, more importantly, their velocity of expansion may become larger than the velocity at which the centre moves. Thus, while these heavy particles are still confined to a limited area around the nucleus due to their low terminal velocity, the shape of the overall particle cloud deviates greatly from a paraboloid of rotation.

In the dust model established at ESOC, the number density of particles is derived as a function of particle mass, time and position in the comet-fixed coordinate system. As a first step, we calculate the departure time and initial velocity of all particles that reach a given position at the specified time. This mathematical problem is solved in its linearised form by expressing the particle trajectory relative to the nucleus as a linear function of the dust departure velocity vector and of the effective change in solar gravity constant due to radiation pressure. This simplification provides a highly efficient algorithm, while it does not noticeably curtail the accuracy. Given departure time and direction, we find the particle density from the local emission characteristics (obtained from the nucleus model) and from the transformation of a unit volume element at the departure point to the position in question. The dust terminal velocity and the radiation pressure efficiency factor are both used as inputs to our program in tabular form as a function of particle size. Our model accounts for discrete emission areas.

When selecting the target point for the Giotto spacecraft, the risk of losing ground contact must be assessed as a function of aiming point and time from closest approach. This requires a functional translation of the dust spatial density along the reference trajectory (obtained from a numerical dust-environment model) into a suitable, numerical measure of the *hazard to spacecraft structure and attitude*. The expected value for the attitude offset has been selected as this measure in earlier studies.

Model calculations for the current reference trajectory, with an aiming point 500 km to the sunward side of the cometary nucleus, have shown that the spacecraft spin axis will remain within 6° of its nominal direction with 95% probability. This result seems to imply that the ground link will almost certainly be lost during closest flyby. This is possibly overly pessimistic because the impacts of large particles would lead to an enormous attitude disturbance, but are very unlikely to occur. For example, the probability of encountering any particle heavier than 0.1 g along the reference trajectory is less than 2%. On the other hand one must bear in mind that these calculations have been performed assuming a homogeneously emitting nucleus. In reality the dust coma will exhibit a jet structure and the probability of spacecraft survival will depend greatly on whether the probe has to traverse jets or a regime of low particle density.

It will therefore be important in the final target-point selection to include the most up-to-date information on the cometary emission characteristics in the dust model.

The modelled spatial densities and related size distributions of the dust grains in the vicinity of the nucleus enable us to simulate the visual appearance of the comet. The scattering properties are derived either from analytical models or from laboratory measurements. Given the above information, we can calculate the brightness distribution in images of the dust coma for different viewing geometries and instrument resolutions. This will allow us to model *observation biases*, i.e. the offset between the centres of brightness and mass. Further information on the position of the nucleus within the coma can be gained from more detailed analysis of the cometary images in which visible phenomena such as jets or other dust inhomogeneities point to their invisible common origin, the outgassing nucleus.

Conclusion

A major difficulty in navigating the Giotto spacecraft to comet Halley is due to the gas and dust emerging from the nucleus. The resulting huge coma hides the nucleus, so that observation errors as well as nongravitational forces degrade our target position accuracy. The dust may also destabilise and damage the spacecraft itself.

Quantitative modelling of these influences is mandatory in order to reduce the risks in the targeting process. The models must be based on reliable, 'up to date' information on both the nucleus and coma, derived from both ground-based and spaceborne observations of comet Halley.

Acquisition of these data necessitates extensive international collaboration. The International Halley Watch is providing, through the Astrometry and Near Nucleus Study Net, precise astrometric positions and information on coma structures, the evolution and location of jets. The collaboration with the Academy of Sciences of the USSR will contribute valuable observations of target position and environment collected during the cometary flyby of the Vega-1 and 2 spacecraft.

Terminal Navigation for Giotto – The Benefits of International Cooperation

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ESA's Giotto spacecraft is planned to fly by comet Halley in March 1986, at a distance of less than 1000 km. To achieve this goal, a variety of measures are being considered for the improvement of the terminal-navigation process. The most important factors are the accuracies with which the spacecraft and comet orbits can be determined. International cooperation is playing a considerable role in the achievement of an optimal flyby trajectory with the following elements: ground-based observations of the comet by the International Halley Watch (IHW); consultancy by NASA/JPL for the Giotto orbit determination; optical observations by the Soviet Vega project with two spacecraft flybys before the Giotto encounter; and improvement of Vega orbit accuracies by employing Deep Space Network VLBI* data.

* Very Long Baseline Interferometry

This article describes the benefits of international cooperation for the scientific return of the Giotto mission by elaborating upon the terminal-navigation process. In the last few days before the cometary encounter in particular, the navigation requirements will be highly demanding and it will be explained here how the sequence of events for achieving an optimal flyby trajectory is constructed from a combination of mathematical, organisational and data-exchange tasks.

Giotto is a spin-stabilised spacecraft with a despun high-gain antenna, pointed continuously towards the Earth during the cruise and encounter phases. The spacecraft, which will weigh 950 kg at launch, is equipped with the following instruments for navigational purposes:

Sensors:
- V-slit Sun sensors
- Infrared pencil-beam Earth sensors (for the geostationary transfer orbit only)
- Star mapper (for the cruise phase only)

Actuators:
- Hydrazine thrusters for attitude and orbit manoeuvres
- Solid-propellant motor for the perigee kick.

In addition to ground-based operations, a variety of autonomous onboard functions will be used for spacecraft control.

Giotto will be launched in July 1985 by Ariane, and injected into a geostationary transfer orbit. The spacecraft's solid-propellant motor will be fired at an appropriate perigee passage to achieve a transfer to a heliocentric orbit. The spacecraft will then travel in the ecliptic plane until its encounter with the comet.

The encounter is planned for a fixed arrival time on 13/14 March 1986, based on ground-station availability, and with a nominal target point several hundred kilometres sunward of the comet nucleus. For navigational purposes, this aiming point will be defined in the Giotto target plane, which contains the spacecraft position at comet encounter, the plane normal being parallel to the spacecraft's velocity relative to the comet.

For navigational purposes, the scientific instruments onboard can be classified into three groups. The first group consists of those experiments that could expect their optimal return by impacting the comet nucleus. They are a plasma analyser (electron), a neutral mass-spectrometer, a magnetometer, and an optical probe.

The second group requires an optimal flyby at a distance of no more than 500 km on either side of the nucleus with respect to the Sun (impact would be suitable, though less desirable). This group comprises an ion mass-spectrometer, a dust impact detector, a dust mass-spectrometer, an instrument for measuring energetic particles, and a plasma analyser (fast ion).

The last group actually contains only one experiment, a multicolour camera. Its optimal flyby distance is 1000 km on the

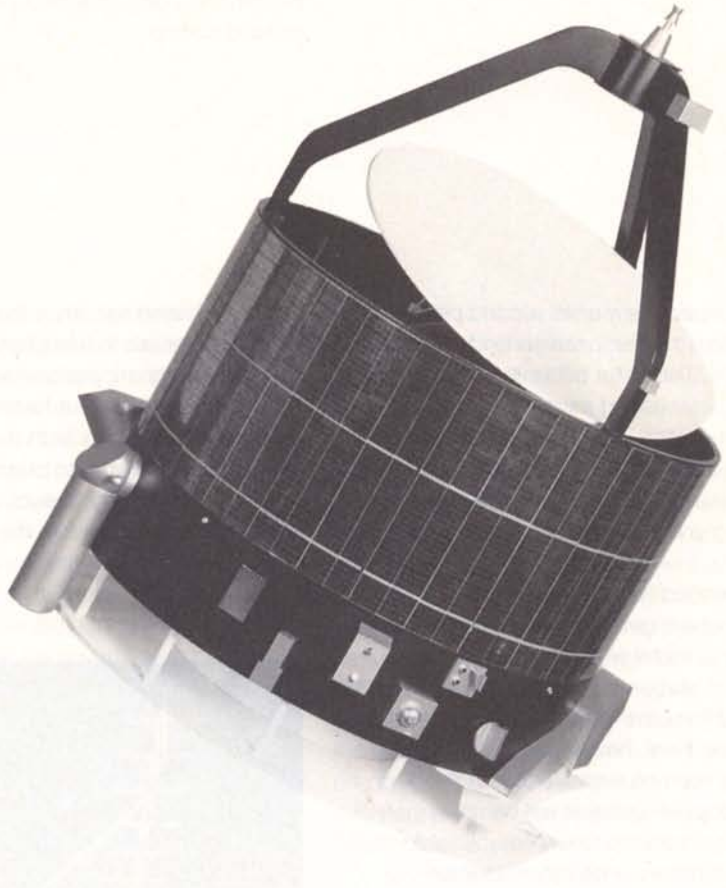


Figure 1 – The Giotto spacecraft

sunward side of the comet, determined by the flyby velocity (movement of camera mirror) and the size of the comet's inner coma.

Apart from checkout and several rehearsals, the instruments will only be switched on during the last four hours before encounter. At encounter, with a relative velocity between comet and spacecraft of 68 km/s, the disturbances caused by the cometary, dust may influence the spacecraft's stability, so that the communications downlink could be lost.

Navigational requirements
The navigational requirements for the Giotto mission are derived directly from the scientific aims of the various instruments. The overall navigation process must be performed such that the required flyby conditions are met at comet encounter and that the scientific data measured during the encounter interval can be transmitted to the appropriate ground station. The latter fixes the flyby time, whilst the former determines the flyby direction and distance.

Based on the differing natures of the instruments, requirements varying from comet impact to remote flyby have to be combined and optimised, and spacecraft constraints and accuracy limitations have also to be taken into account.

Injection and cruise phase
The baseline mission foresees an Ariane launch and injection into geostationary transfer orbit in a launch window to be determined on the basis of the latest information on the comet's orbit. The requirements in this transfer orbit centre around orbit determination, attitude determination, optimisation of the perigee-motor firing direction and time, attitude-reorientation manoeuvres, and the firing of the large, solid-propellant motor during a perigee passage.

For the optimisation in transfer orbit and the dispersion-correction manoeuvres immediately following, the selected 'target' is comet impact, based on the estimated comet orbit accuracy at that time.

During the cruise phase, the navigational requirements are essentially concerned with spacecraft orbit determination, attitude determination and control to keep the high-gain antenna Earth-pointing and the performance of a few orbit-correction manoeuvres. The latter are to be implemented taking into account improvements in knowledge of the comet's orbit through intense ground-based observations.

Pre-encounter phase
For the terminal navigation, the actual flyby requirements have to be considered in combination with the spacecraft constraints and accuracy limitations. Thus, it will be a question of proceeding according to a predetermined decision algorithm. The parameters in this algorithm, which will essentially only be known a few days before encounter, are:
- the estimated accuracy with which the comet orbit will be known
- the estimated accuracy with which the spacecraft orbit will be known
- the estimated accuracy with which a spacecraft orbit manoeuvre can be performed without verification
- the estimated influence of the cometary dust environment on the spacecraft spin-axis direction, and thus the antenna's Earth-pointing.

The decision algorithms will include probability levels, in order to make an optimum trade-off between mission requirements and spacecraft safety.

Navigational accuracy
The navigational accuracy largely depends on the stochastic nature of measurements being processed. It can be assumed that the computer software involved will be of such a standard that its error contributions can be neglected. The various components affecting overall navigational accuracy can be analysed by subdividing the navigational task into specific functions.

Spacecraft orbit
Spacecraft orbit accuracy can be addressed by considering the three types of orbits that form part of the Giotto mission. The first is the standard Ariane geostationary transfer orbit, with well-known accuracy figures for VHF ranging utilising the ESA network of ground stations (in Kourou, Malindi, Carnarvon and Redu). Extrapolation to S-band ranging (without Redu) is easy and results

Figure 2 — The Carnarvon (Australia) ground station

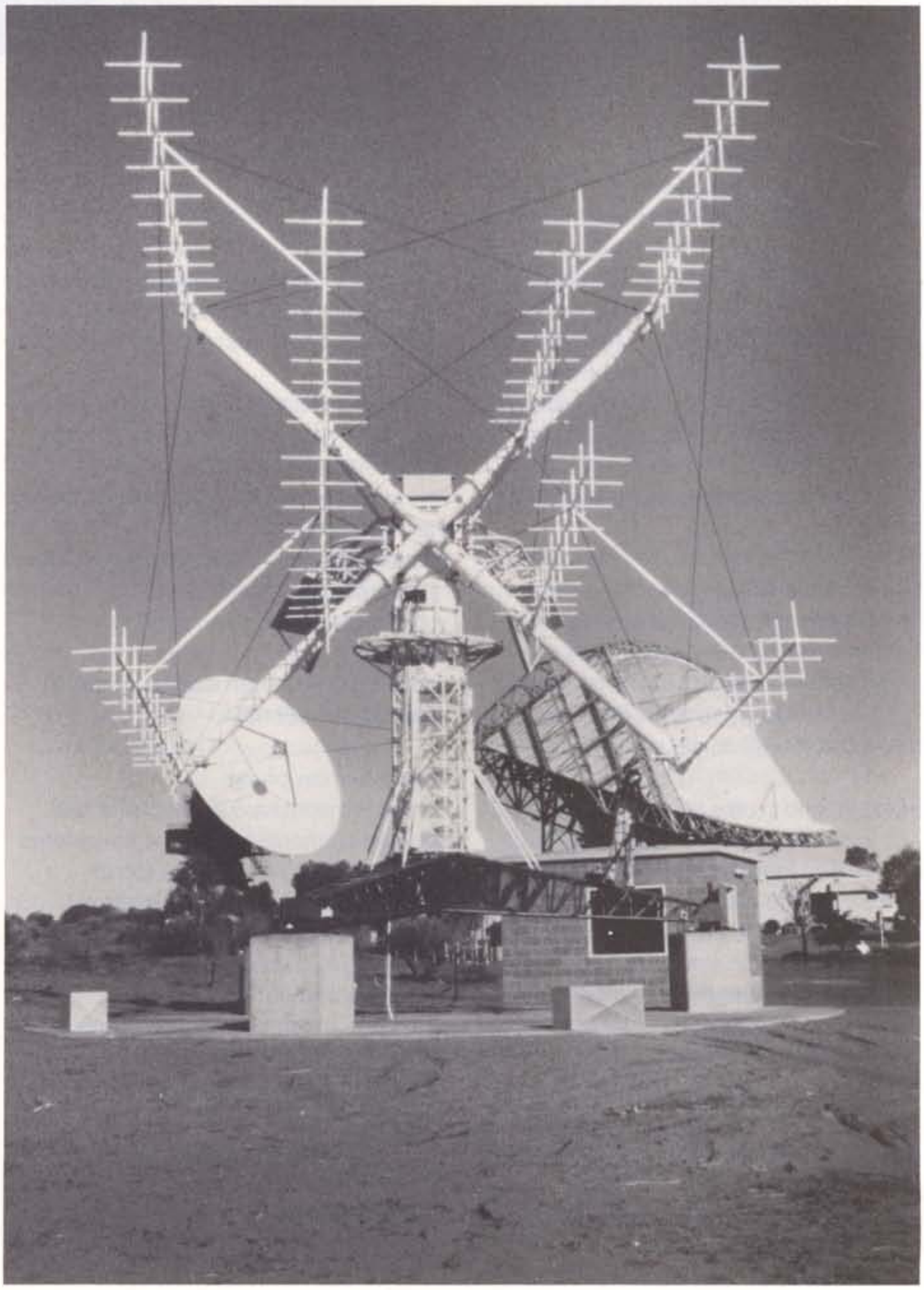
in an inaccuracy after second perigee of less than 1 km in position and 20 cm/s in velocity. This is far better than the accuracy needed for attitude determination with Earth sensors (no better than 50 km in position) and for the optimisation of the perigee-kick-motor firing (no better than 10 m/s in velocity).

The second type of orbit is the near-Earth orbit, where geopotential forces are still dominant and where the ESA S-band ground-station network can still be used, i.e. out to some 40 000 km from the Earth's surface. Here, newly established deep-space stations with advanced ranging and doppler facilities will be used, together with the newly established interplanetary orbit-determination software.

Both systems will have undergone extensive testing, the deep-space stations (Carnarvon and Weilheim) by tracking Exosat, ESA's highly eccentric orbiting X-ray observatory with an apogee of 200 000 km; the software by processing tracking data from the NASA's Voyager mission. It is expected that a first-level validation of the new systems can be performed in this phase and that the planning of the first dispersion-correction manoeuvre will be based on the results of the 'standard' system (advanced geostationary stations and software). The accuracy expected in this phase will be comparable with that in transfer orbit and is expected to be better than 25 km in position and 10 cm/s in velocity two days after perigee-kick-motor firing. These figures assume that ranging from the deep-space stations is also available.

The third, interplanetary type of orbit is characterised by the sole use of the new stations and the new software. Independent studies, including one by NASA/JPL, have shown that the final accuracy attainable for the encounter phase is of the order of 100 km, assuming availability of one southern-hemisphere ground station as a minimum, with additional tracking passes from a second station. It is also assumed that, during selected intervals in this phase, tracking measurements are performed by the NASA/JPL Deep Space Network (DSN) and the data fed into both the JPL and the ESA navigational software. Comparison of these results is expected to increase confidence in the newly established ESA facilities.

Spacecraft attitude
Spacecraft-attitude accuracy can also be addressed by considering two phases of the mission. In the geostationary transfer orbit Sun sensors and infrared Earth sensors are used to determine the spin-axis direction. This is a well-established procedure, and accuracy is expected to be in the order of 0.2°. For the remainder



of the mission, an ESA star mapper is to be used in place of the Earth sensors, with an expected accuracy of better than 0.1°.

We can assume that the figures quoted for both phases are realistic and do not give rise to any disturbances in the navigational process. This means that the spacecraft's spin-axis orientation can be established for the perigee-kick-motor firing, that the cruise-phase orbit manoeuvres can be performed satisfactorily, that the attitude control for antenna Earth-pointing is feasible, and that the disturbances generated by the frequent attitude manoeuvres during the cruise phase can be well-modelled for orbit-determination purposes.

Comet orbit

The accuracy of this factor may also be addressed by looking at two mission phases. The first phase, which actually started when Halley's return was first observed in October 1982 by Mount Palomar, involves establishing the long-term behaviour of the comet's orbit. Together with observations of the previous apparitions, new measurements taken by ground-based observatories will lead to improved accuracy by also considering modelling of the nongravitational forces and the observation biases.

It is expected that, with conservative assumptions about observations near solar conjunction, the comet's orbit will be predictable for the period of spacecraft encounter with an accuracy of 500 km in the directions most critical for the targeting, i.e. in the Giotto target plane. Any unexpected outgassing effects near perihelion, such as transitory jets, will jeopardise this predicted accuracy, especially as there will be only a few measurements available after solar conjunction and before the Giotto encounter.

The only improvements presently feasible to counteract firstly the nonavailability of measurements, and secondly the rather unfavourable accuracy provided by ground-based observations only, are related to improvements in observation techniques and to the utilisation of other data. Studies are being made to find out how close the Sun can be to the local horizon and still allow good comet observations. The presently assumed figure of 40° limits the observation period drastically, especially after conjunction. Any reduction in this figure will contribute to a worthwhile improvement in orbit estimation for the comet.

A more obvious improvement can be expected via other types of observations, such as those from other spacecraft. The Soviet Vega project will launch two spacecraft which will fly by the comet a few days before Giotto. These spacecraft will carry Hungarian-built cameras which will observe the comet during flyby at a distance of approximately 10 000 km. Depending on the measurement intervals around encounter and on which of the two spacecraft will deliver data in the time periods relevant to the Giotto encounter, accuracies in comet-orbit determination comparable with those for the spacecraft themselves can be expected. These will be in the order of 400 km if the standard Vega orbit-determination results are used, but improve to less than 100 km if VLBI tracking is also established.

Spacecraft manoeuvring

The factors that play a role here are hydrazine-thruster performance and predictability, and perigee-kick-motor performance. Looking at the different phases of the Giotto mission, it is apparent that only the terminal navigation might really suffer from manoeuvring problems. In geostationary transfer orbit, attitude manoeuvres for spin-axis alignment (perigee-kick-motor firing) are part of an iterative process that eventually compensates for any non-nominal behaviour. Non-nominal performance of the kick motor is catered for by loading enough hydrazine onboard for correction manoeuvres. These manoeuvres themselves are again part of an iterative process to compensate for non-nominal behaviour. The frequent attitude manoeuvres for antenna Earth-pointing follow the same principle.

What remains are orbital manoeuvres during the terminal navigation process. For a manoeuvre implemented one or more days before encounter, there is little chance to evaluate its performance via orbit determination. For a predicted encounter geometry, it is therefore necessary to include a manoeuvre performance error of some 5%, or 10% in the worst case. These figures are based on operational experience with hydrazine thrusters and represent a maximum error of 80 km for a typical 10 m/s manoeuvre one day before encounter.

International cooperation

The Giotto mission is notable for its planned high level of international cooperation, which will reach a climax during the terminal-navigation process. The key elements are the International Halley Watch (IHW), responsible for the gathering of ground-based comet observations, a NASA/JPL consultancy arrangement for the setting-up of the ESA deep-space facilities, and the inclusion of comet observations by the Vega spacecraft, via the so-called 'Pathfinder Concept'.

The International Halley Watch

The International Halley Watch was officially created during an International Astronomical Union conference at Patras, Greece, in August 1982. Various disciplines for the cometary exploration were singled out, the one of interest for Giotto navigational purposes being the astrometric discipline. The main tasks here are the standardisation of observations and observation techniques, and the gathering of observations for comet orbit-determination purposes. The data from ground-based observatories are principally routed to two centres, one at JPL in California, the other in Bamberg in Germany for evaluation and inclusion into a centralised database. The comet-orbit determination will be performed at three centres: at JPL; by the Vega project in Moscow; and at ESOC, the Giotto navigation centre.

For the terminal navigation, i.e. the measurements taken after the solar conjunction, only a few observatories in the southern hemisphere will deliver the data essential for the assessment of the comet's perihelion behaviour.
For operational reasons, it has been decided to route these data directly to ESOC.

Consultancy by NASA/JPL

For the Giotto mission and also to a certain extent for its International Solar-Polar Mission (ISPM), ESA is setting up deep-space ground-station equipment and navigational-software facilities. For the validation of these systems, various measures are being taken, including a consultancy arrangement with NASA/JPL, which is playing an important role. The following topics will form part of this consultancy:

- transfer of operational experience via intensive workshops
- comparison of mathematical formulations for deep-space orbit determination via specific software tests
- pre-launch validation of the ESA orbit-determination system via processing of/comparison with Voyager data
- post-launch calibration of the ESA deep-space stations by comparison with results from NASA's DSN stations
- post-launch validation of the ESA orbit-determination system by comparison with results obtained at JPL with DSN data.

Arrangements will also be made for DSN station data to be routed to ESOC operationally, so that during special campaigns these data can be processed together with ESA station data, and moreover might be used as a backup. An additional agreement concerns the collaboration between JPL and ESA relating to the comet orbit determination. Software being established at JPL is being transferred to ESOC for comparison with the ESA comet-orbit-determination software.

The 'Pathfinder Concept'

Under the patronage of the Inter-Agency Consultative Group (IACG), international cooperation in all areas concerned with comet Halley is being explored and developed. Here the Japanese Planet-A and MS-T5 missions, the Soviet Vega mission, the Giotto mission and NASA's ICE (formerly ISEE-3) mission to comet Giacobini-Zinner will try to optimise the overall scientific return by attempting a collaboration that should both improve the returns of the individual missions and maximise the overall scientific return from the missions as a whole. Of particular interest for Giotto navigation, specifically for its terminal navigation, is the earlier flyby of the two Vega spacecraft.

At the Third Meeting of the IACG, in Japan on 18/19 December 1983, agreement was reached on the implementation of the so-called 'Pathfinder Concept' (see page 90 of this issue). Its prime objective is the improvement of Giotto targeting, by processing Vega data together with ground-based comet observations to improve the comet-Halley ephemeris. The Vega data itself consists of improved VLBI-based spacecraft orbit and inertial pointing angles to the comet derived from spacecraft attitude and camera data.

The cooperation here is truly international in that the Vega spacecraft data (attitude orientation angles) are to be provided by the Soviets, the camera for the pointing angles will be provided by Hungarian scientists, the Vega orbit accuracy will be improved by employing DSN stations for VLBI orbit determination, and ESA/ESOC will utilise all of this information for Giotto's terminal navigation. Information on the cometary dust environment experienced by Vega may serve as an additional input for Giotto navigation, given the expected dust hazard (see page 36 of this Bulletin).

The terminal-navigation process

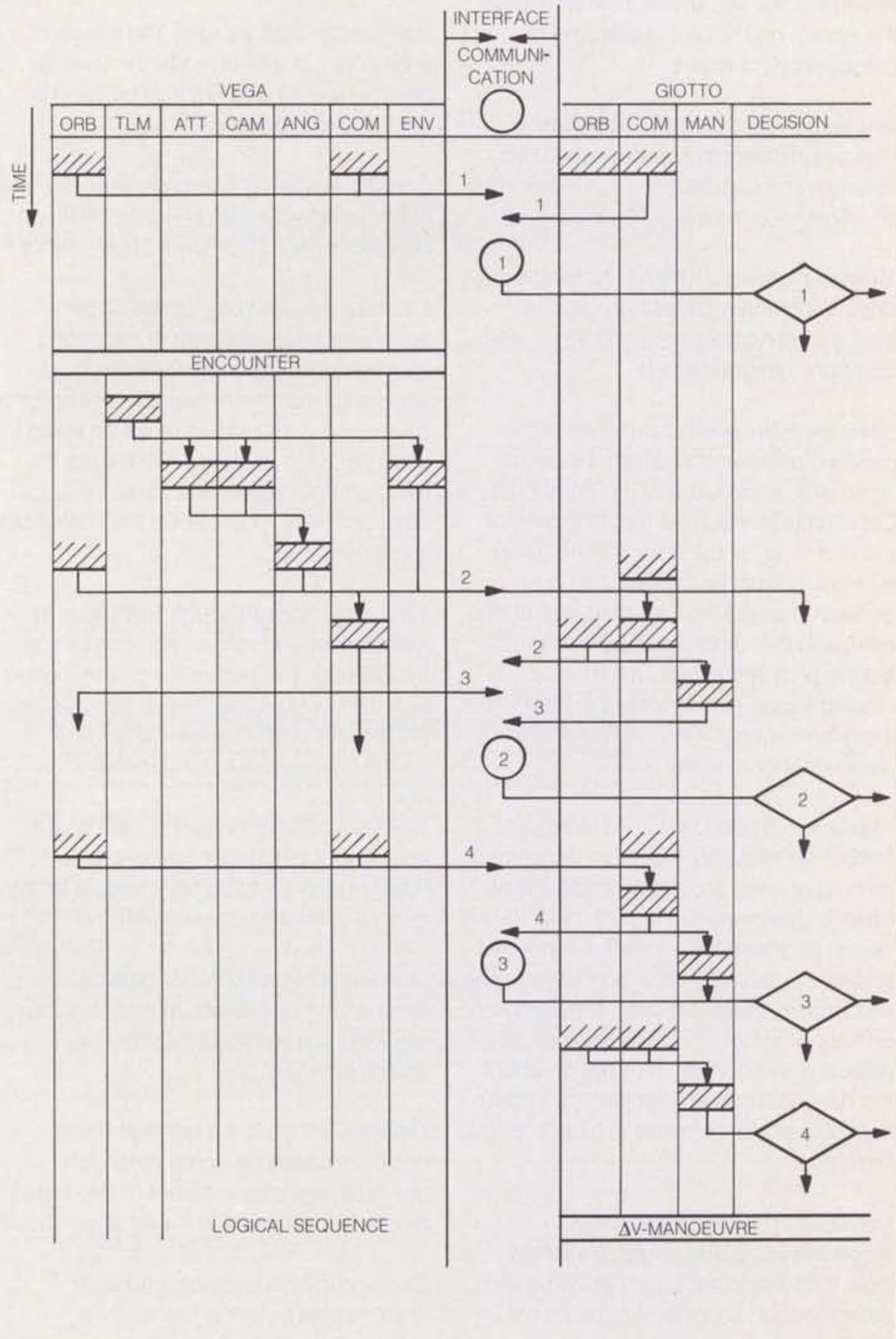
The terminal-navigation process for Giotto will lead to an optimal flyby trajectory which takes into account all the scientific requirements, spacecraft constraints and operational principles. The solution is therefore not so much related to a mathematical method, but more to a carefully planned operational scenario.

The mathematical tasks during the terminal-navigation process are mainly those of estimation and optimisation. Both batch and sequential methods will be used for the determination of the orbits of the comet and the spacecraft. For the optimisation of one, or maybe two, terminal ΔV-manoeuvres for Giotto, a numerical iteration will be applied. All solutions will be accompanied by error estimates for the assessment of confidence levels.

Several auxiliary tasks are involved for measurement-data routing and extraction. They are concerned with tracking data (doppler, range, and VLBI), Vega telemetry data (inertial attitude, camera pointing direction, comet image identification), Giotto telemetry data (attitude determination), IHW observations (astrometric and special events), and dust-hazard assessment.

At present, it is assumed that the Giotto encounter will take place around midnight (GMT) on 13/14 March 1986. The Vega encounters are expected to be five to eight days earlier. For operational reasons, utilisation of data from both Vega spacecraft should be attempted, which requires that the Giotto terminal-navigation process be completed in the interval between the Vega-2 and Giotto encounters.

Figure 3 — The time-line for the terminal-navigation process



The sequence of events that must take place in this interval includes:

- Vega spacecraft orbit determination (ORB), (which may include the improved processing by utilising NASA VLBI data)
- Vega telemetry processing (TLM)
- Vega attitude determination (ATT)
- Vega camera relative-attitude and comet position determination (CAM)
- Vega inertial-pointing-angle determination (ANG)
- Vega comet-ephemeris determination (COM)
- Vega environment (dust) assessment (ENV)
- Giotto spacecraft orbit determination (ORB)
- Giotto comet-ephemeris determination (COM)
- Giotto ΔV-manoeuvre preparation (MAN)

These activities can be linked logically as shown in Figure 3. It should be noted that

- only the activities directly connected with terminal navigation are shown (e.g. the daily attitude manoeuvres for Giotto are omitted)
- no absolute times for activities are indicated
- only the option of using data from one Vega spacecraft is presented
- the decision points indicated concern only Giotto activities
- 'communication' includes comparison and assessment of results.

The explanations in Table 1, ordered chronologically, illustrate the data interfaces, the communication needs and the decision points.

Table 1 – Data interfaces, communication needs and decision points

Interface 1 (Vega/Giotto): At some time before the Vega encounter, information about the Vega orbit and the comet's ephemeris will be provided for setting-up the system on the Giotto side and for comparison purposes.

Interface 1 (Giotto/Vega): At the same time, results from the comet-ephemeris determination will be provided in the other direction for comparison purposes.

Communication 1: The results for the comet ephemeris (based on ground-based observations only) will be compared and assessed.

Decision 1: Based on the results of the previous assessment, Giotto will decide whether to continue with the Pathfinder Concept (it is assumed that this decision is the default, as the assessment at this time will have to be the last step in an iteration process for the achievement of compatibility), or to continue with the assessment in the case of minor discrepancies, or to cancel the Pathfinder implementation (Decision 3 is heavily dependent on compatibility).

Interface 2 (Vega/Giotto): After Vega-encounter telemetry has been processed, data have been provided for spacecraft attitude determination and camera-data-processing purposes, and the combined task of producing inertial pointing angles is complete, these last data, together with a final update of the Vega orbit, will be delivered. In addition, information about the dust environment derived from dust experiments will be made available at this time.

Interface 2 (Giotto/Vega): After incorporation of the angles and Vega orbital data into the comet-ephemeris determination process, the results will be sent to Vega.

Interface 3 (Vega/Giotto): The results achieved by the parallel comet-ephemeris determination will be passed back.

Interface 3 (Giotto/Vega): The results of preliminary manoeuvre planning will be communicated and will also be used in the following assessment activity.

Communication 2: The preliminary results of the parallel comet-orbit determination processes will be compared and assessed.

Decision 2: Based on the assessment concerning improvement of the comet ephemeris, the dust environment hazard, and consequently the identified need for a ΔV-manoeuvre, a decision will be taken to go ahead with refinement of the results (no major discrepancies), or to initiate other activities, or to cancel the Pathfinder implementation.

Interface 4 (Vega/Giotto): Further assessment and refinement (combining, for example, the Vega orbit determination with the comet-ephemeris determination) will result in refined angles and Vega orbital parameters to be transferred.

Interface 4 (Giotto/Vega): Based on the refined input, a further comet-orbit determination is to be performed with the goal of achieving compatibility.

Communication 3: This is the final comparison and assessment of results, resulting in a recommendation for implementation.

Decision 3: This is the last Pathfinder decision, based on compatibility of previous steps; assessment of the overall results will bring about the final go-ahead.

Decision 4: This decision will be for implementation of the manoeuvre considering all other input (spacecraft status, other activities, station performance, etc.).

The benefits of the navigational approach

The optimal flyby trajectory that can be achieved by the terminal-navigation process, including the 'Pathfinder Concept', will be established such that a true compromise between all scientific requirements can be reached. This is made possible by the fact that the accuracies achievable are of such an order that the targeting to a flyby point can be achieved with an accuracy of better than 150 km in the best case. The breakdown in Table 2 illustrates for various cases how beneficial the terminal navigation can be (the figures quoted represent orders of magnitude in the target plane and do not distinguish directional accuracy variations, etc.).

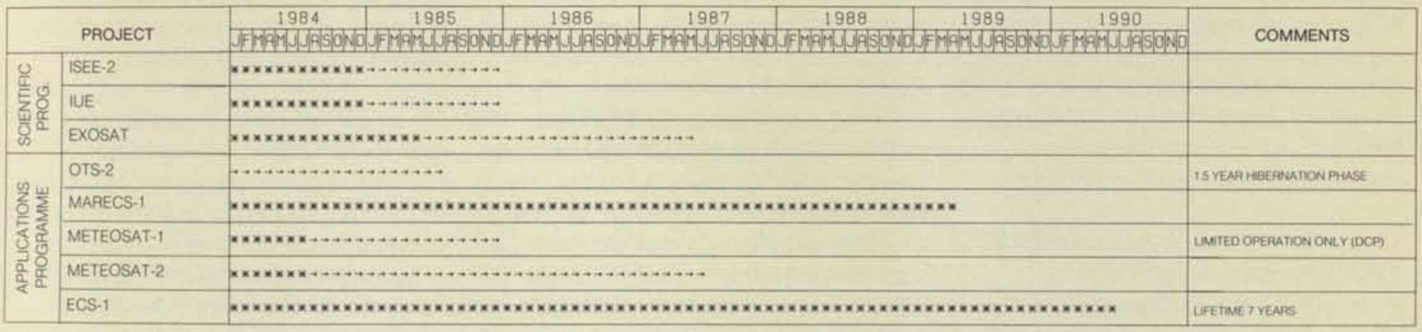
*Table 2 – Achievable terminal-navigation accuracies**

Giotto spacecraft orbit	100 km
Comet orbit (no Pathfinder)	500 km
Giotto spacecraft orbit	100 km
Comet orbit (Pathfinder, no VLBI)	
Vega-1 only	350 km
Vega-2	200 km
Giotto spacecraft orbit	100 km
Comet orbit (Pathfinder, VLBI)	
Vega-1 only	150 km
Vega-2	80 km

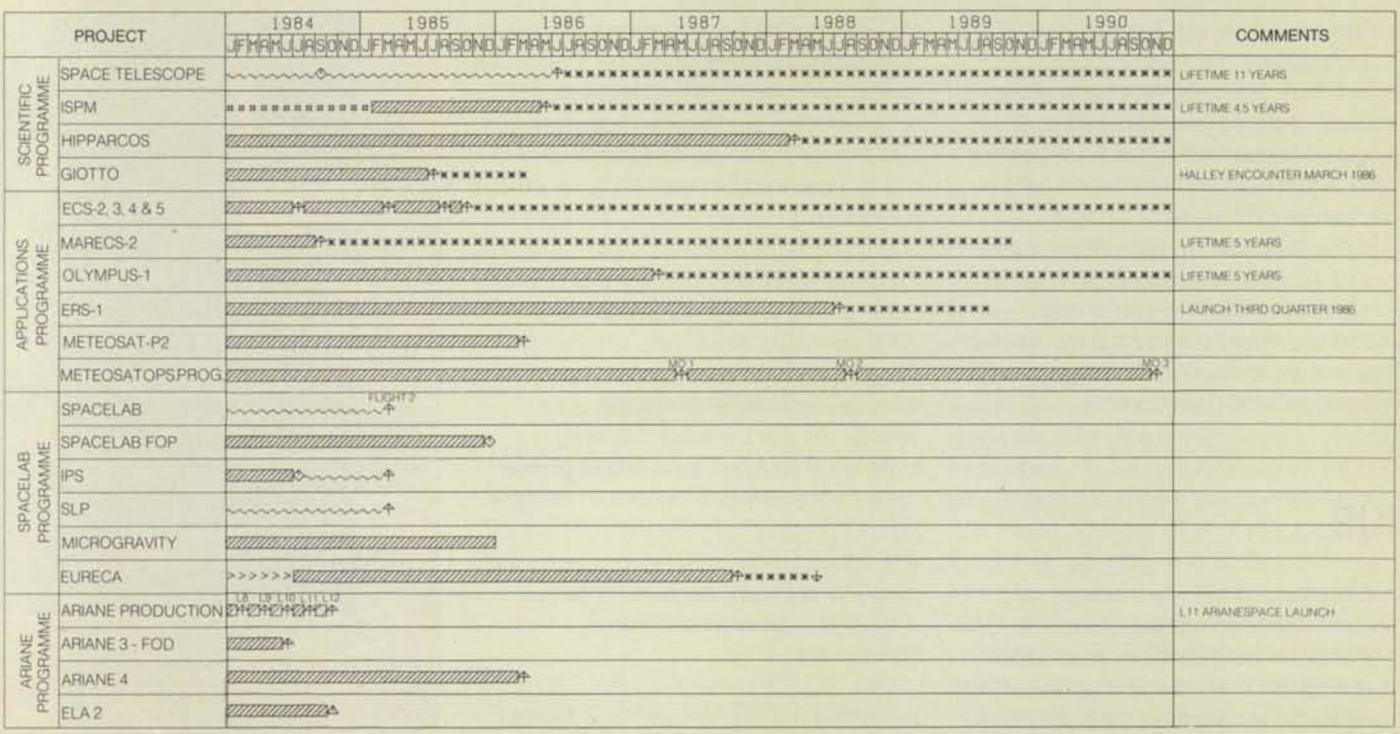
* These figures, like those in the text, are based on a 1 σ probability (ca. 65%)

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

In Orbit / En orbite



Under Development / En cours de réalisation



= DEFINITION PHASE
~ INTEGRATION
> PREPARATORY PHASE
LAUNCH/READY FOR LAUNCH
MAIN DEVELOPMENT PHASE
* OPERATIONS
STORAGE
→ ADDITIONAL LIFE POSSIBLE
HARDWARE DELIVERIES
RETRIEVAL

ISEE

Le satellite ISEE-3, qui avait exécuté en 1983 un certain nombre de manoeuvres dans la queue géomagnétique lointaine en mettant à profit l'effet de gravitation de la lune, a effectué le 23 décembre 1983 un dernier crochet autour de cette dernière et s'est placé sur une nouvelle orbite qui le conduira à sa rencontre avec la comète de Giacobini-Zinner en septembre 1985. Après confirmation de la nouvelle orbite, le véhicule spatial a été rebaptisé ICE (International Cometary Explorer) (voir l'article page 46 – 50 dans le bulletin ESA no 37).

Si les opérations effectuées dans la magnétoqueue ont été spectaculaires par l'utilisation d'orbites nouvelles, les données scientifiques l'ont été plus encore; elles ont montré que les champs et les plasmas magnétiques présentent dans la queue des structure nettes jusqu'à une distance de 24 rayons terrestes. Au-delà d'environ 100 rayons terrestres, la section de choc de la magnétoqueue est presque constante.

Le couple ISEE-1/ISEE-2 a continué de fonctionner sans aucun incident technique. ISEE-2 ne dispose, pour effectuer ses corrections d'orbite par rapport à ISEE-1, que d'une faible quantité de gaz qui sera toutefois suffisante, moyennant une planification minutieuse, pour deux années encore.

La communauté des chercheurs d'ISEE a poursuivi son importante activité scientifique. Une réunion consacrée aux résultats obtenus par ISEE-3 dans la magnétoqueue s'est tenue en décembre 1983 à San Francisco en liaison avec la réunion de l'Union américaine de Géophysique. Un symposium sur les ondes de choc interplanétaires a eu lieu en février en Californie et d'autres réunions sont actuellement organisées en liaison avec la réunion du Cospar pour le mois de juin 1984 en Autriche.

IUE

L'Observatoire IUE, qui a bouclé sa sixième année en orbite le 26 janvier 1984, continue de jouer pleinement son rôle scientifique. La demande d'utilisation du satellite par la communauté scientifique reste très forte, comme on a pu le constater lors de la soumission des propositions pour la septième année. On a reçu 263 demandes de temps d'observation (contre 262 l'an dernier), correspondant au total à 3,3 fois le temps disponible. Divers temps d'utilisation ont été accordés à 164 propositions.

Une étude détaillée des résultats observés lors des précédents passages en éclipse du véhicule spatial, effectuée par la NASA, montre que les panneaux solaires peuvent assurer l'alimentation en énergie pour encore au moins quatre années de fonctionnement. A la réunion tripartite semestrielle, il a été convenu d'étudier les incidences d'un arrêt progressif des opérations scientifiques d'IUE. Les conclusions de cette étude seront présentées en mai 1984.

Entre autres modifications concernant l'exploitation du véhicule spatial, il faut noter la décision tripartite de remplacer la chambre de prise de vues standard pour les grandes longueurs d'onde actuellement utilisée par la Chambre principale 'grandes longueurs d'onde' en raison d'une défaillance qui s'était traduite par un 'éclat lumineux' dans la chambre standard. Ce remplacement s'est effectué sans incident et n'a pas affecté le cours normal des opérations scientifiques. Le gyroscope no 1, qui avait déjà été déconnecté de l'ensemble opérationnel en raison d'une défaillance électronique, a été mis définitivement hors service le 12 décembre 1983.

Un nouveau système opérationnel permettant de faire fonctionner le véhicule spatial avec deux gyroscopes seulement sera bientôt disponible dans les deux stations sol, mais il ne sera utilisé qu'en cas de nouvelles défaillances d'un gyroscope.

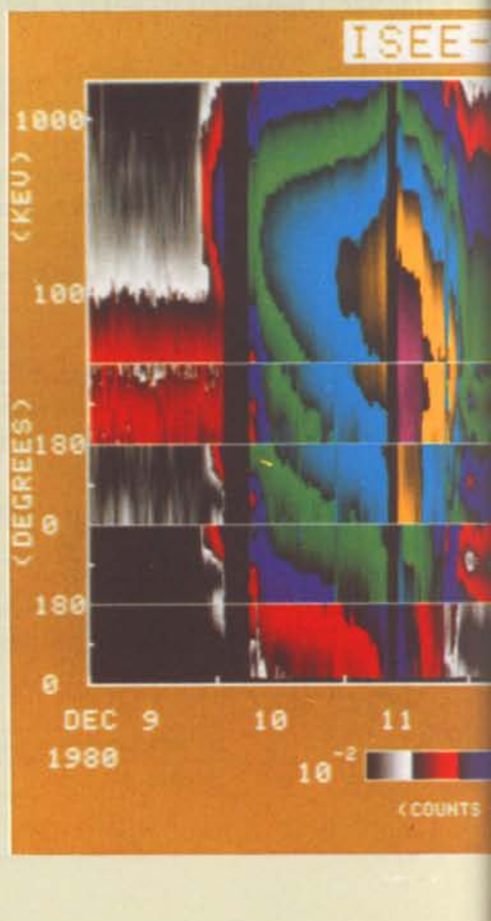
La disponibilité d'Exosat a grandement influé sur les opérations scientifiques d'IUE au cours de l'année. Un grand nombre d'observations simultanées ont été programmées et effectuées avec succès. Pour la première fois, une supernova de type I a pu être observée dans l'ultraviolet avant qu'elle n'atteigne son maximum et ces observations ont pu être coordonnées avec les mesures prises par IRAS et Exosat dans les longueurs d'onde du rayonnement X et de l'infrarouge.

Le rendement scientifique d'IUE reste très satisfaisant, et l'utilisation des données archivées du satellite augmente dans des proportions considérables, ce qui montre que les observations recueillies servent à une vaste communauté. Le nombre des articles parus dans les revues spécialisées atteint maintenant 623 si l'on additionne les contributions des trois agences.

Exosat

Exosat, lancé en mai 1983, fonctionne de façon satisfaisante depuis un an et a effectué plus de 700 observations, en dépit de quelques problèmes non négligeables qui ont affecté tant la charge utile que le véhicule spatial. Ces problèmes, compte tenu du grand nombre d'observations coordonnées (plus de 60% de toutes les propositions approuvées au titre de la première offre de participation: AO-1) ont entraîné de sérieuses difficultés de reprogrammation dans le planning de la mission.

Les problèmes posés durant les premiers mois de la mission par le système de commande d'orientation et le calculateur de bord ont été résolus grâce à la mise en oeuvre de procédures de contrôle et de commandes appropriées. En ce qui concerne les détecteurs associés aux deux télescopes imageurs, le deuxième



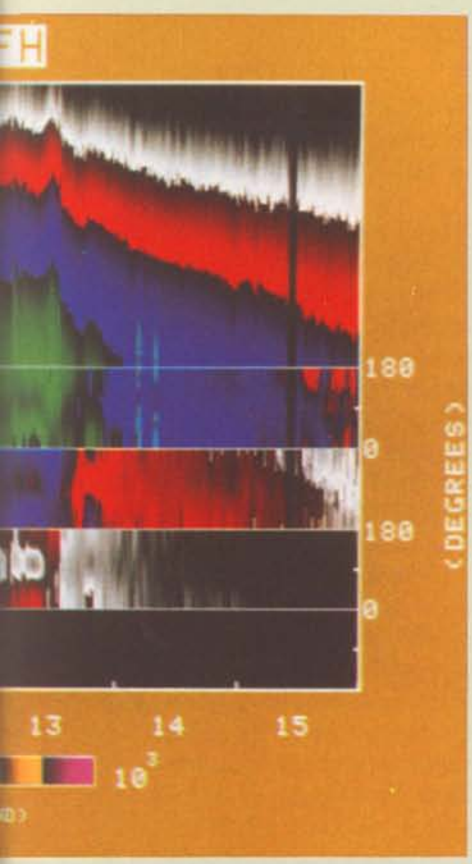
ISEE

The ISEE-3 spacecraft which, assisted by lunar gravity, executed a number of manoeuvres in the distant geomagnetic tail in 1983, made a final lunar swingby in December 1983, and started on a new orbit taking it to a rendezvous with Comet Giacobini-Zinner in September 1985. After confirmation of the new orbit, the spacecraft was renamed ICE – the International Cometary Explorer (see article in ESA Bulletin No. 37, pp. 46–50).

ISEE-3's magnetotail operations were spectacular in terms of the use of new orbits, and the scientific data was even more spectacular, demonstrating that magnetic field and plasma have clear tail structures all the way out to 24 Earth radii. The cross section of the magnetotail is nearly constant beyond ~100 Earth radii.

The ISEE-1/ISEE-2 pair of spacecraft have continued to operate without any technical problems. The ISEE-2 gas supply for orbit control relative to ISEE-1 is low, but can last another two years with careful planning.

The ISEE community has continued its strong scientific activity. A meeting on ISEE-3 magnetotail results was arranged in December in San Francisco, in connection with the American Geophysical Union meeting. A symposium on interplanetary shocks took place in February in California, and other meetings are being arranged in connection with the COSPAR meeting in Austria in June 1984.



Spectrogramme des protons de 35–1000 keV observés au cours d'une traversée d'un choc interplanétaire de grande envergure par l'expérience conjointe (ESA/SSD, SRL/Utrecht et IC/Londres) embarquée sur ISEE-3. Le procédé pseudo-couleur utilisé est destiné à mettre en valeur les variations d'intensité et les variations angulaires

Spectrogram of 35–1000 keV protons observed during passage of a large interplanetary shock by the joint ESA/SSD, SRL/Utrecht and IC/London experiment on ISEE-3. False colours are used to enhance intensity and angular variations

IUE

On 26 January 1984, the IUE Observatory completed six years in orbit and the satellite still fully supports scientific operations. As was shown during the seventh-year proposal cycle, the demand from the scientific community remains very high; observing time was requested in 263 proposals (compared with 262 last year) for 3.3 times the available time. Time has been granted to 164 proposals.

A detailed study by NASA of the results for previous eclipse passages of the spacecraft shows that the solar-panel power supply can be expected to support at least four further years of operation. At the bi-annual three-Agency meeting, it was agreed to study the implications of a scientific rundown of IUE. The conclusions are to be reported in May 1984.

Changes in the spacecraft operations include the three-Agency decision to replace the standard operational long-wavelength camera by the long-wavelength prime camera, because of a 'flare' fault in the standard camera. This change was accomplished smoothly without impact on normal scientific operations. Gyro 1, which had been taken out of the operational set earlier due to electronic failure, was finally turned off on 12 December 1983.

A new operational system, capable of operating the spacecraft on two gyros only, will soon be available at both ground stations, but will be used only in the case of further gyro failure.

The scientific operations of IUE have been strongly influenced this year by the availability of Exosat. A large number of simultaneous observations had to be scheduled and were successfully carried out. For the first time ever, it was possible to observe a type-I supernova in the ultraviolet before its maximum and to coordinate the observations with Exosat and IRAS measurements in the X-ray and infrared wavelengths.

The scientific output of IUE remains high and at the same time the use of the IUE archive is increasing considerably, showing that the observations made by IUE support a wide community. The number of journal publications now stands at 623 (all three Agencies combined).

Exosat

Exosat, launched in May 1983, has now been operating successfully for eight months and has performed over 700 observations, even though some significant problems have been encountered with both the payload and spacecraft. These problems, when considered in association with the large number of coordinated observations (over 60% of all AO-1 approved proposals), have led to significant rescheduling difficulties in mission planning.

Problems with the attitude-control system and on-board computer experienced in the early months of the mission have been overcome by the implementation of appropriate monitoring and control procedures. Of the detectors associated with the two imaging telescopes, PSD-2, which broke down shortly after switch-on, has not recovered and shows no signs of doing so. CMA-2 functioned perfectly until 28 October 1983 when, for no apparent reason, it stopped working. Routine reactivations were unsuccessful until 9 February, when the detector began working perfectly again, only to stop once more on 11 February. PSD-1, which showed anomalous behaviour in June 1983, has been again

The Exosat Observatory Control Room, at ESOC (Darmstadt)

Salle de contrôle Exosat à l'ESOC (Darmstadt)

détecteur de position (PSD-2), tombé en panne peu après sa mise en service, ne fonctionne toujours pas et ne montre aucun signe de reprise. Le CMA-2 (réseau multiplicateur à microcanaux) a parfaitement fonctionné jusqu'au 28 octobre 1983 où son fonctionnement a cessé sans raison apparente. Les tentatives de remise en service normal n'ont donné aucun résultat jusqu'au 9 février, puis le détecteur s'est remis à fonctionner parfaitement pour retomber en panne le 11 février. Le premier détecteur de position (PSD-1), qui avait montré des signes de comportement anormal en juin 1983, a été à nouveau utilisé à niveau réduit pour des observations depuis le mois de décembre 1983. Les analyses de données auxquelles l'équipe de l'observatoire et les expérimentateurs ont procédé n'ont fourni aucune explication réelle quant aux causes de ces défaillances du détecteur. Le fonctionnement des instruments de l'équipement 'moyenne énergie' et celui du spectromètre à scintillateur à gaz sont restés nominaux depuis le début de la mission.

Exosat a réalisé avec succès des observations simultanées en coordination avec d'importants moyens au sol et avec les véhicules spatiaux IRAS, Tenma et IUE. La coordination avec le satellite japonais d'étude du rayonnement X – Tenma – a été particulièrement fructueuse, un certain nombre de 'cibles de circonstance' constituées de transitoires de rayonnement X, ayant permis d'aboutir à d'importants résultats scientifiques.

Plus de 2000 bandes d'observation sous forme définitive (FOT) ont été produites à ce jour et les retards de production de ces bandes ont été ramenés à environ 25 jours en ce qui concerne les expériences du spectromètre à scintillateur à gaz et 'moyenne énergie' et à 60 jours environ pour les expériences du télescope pour les faibles énergies. L'analyse scientifique automatique des FOT est maintenant diffusée régulièrement aux observateurs. Les retards de production restent toutefois longs (100 jours) en raison des problèmes qu'avaient posé l'étalonnage des expériences et qui sont maintenant résolus.

Le 26 janvier 1984 a été diffusée la deuxième offre de participation (AO-2) à un programme d'observation qui doit se dérouler pendant une période 6 mois à partir d'avril 1984. Cette deuxième offre de participation, comme toutes les suivantes, s'adresse à la communauté des astronomes dans le monde entier. Il semble que le temps d'observation disponible au cours de ce deuxième programme doive donner lieu à au moins autant, si ce n'est plus, de demandes que le premier, pour lequel la demande était six fois supérieure au temps disponible.

A la suite d'un certain nombre de discussions avec les observateurs d'Exosat, il a été décidé d'agrandir les installations de traitement des données offertes aux chercheurs à l'observatoire de l'ESOC. Un système d'analyse interactif fournira à ceux-ci des moyens qui viendront s'ajouter à la capacité d'analyse en temps réel et quasi réel déjà disponible, et complètera l'analyse automatique des FOT.

C'est dans l'étude des sources galactiques qu'ont été, en général, enregistrés les principaux résultats scientifiques obtenus jusqu'à présent. L'orbite lointaine d'Exosat notamment a permis de procéder aux premières observations prolongées et continues de sources de rayonnement X binaire d'origine galactique. Quelques-unes des used, at lower gas gain, for observations from December 1983. No real clue to the reasons for these detector problems has emerged from analysis of the data undertaken by the observatory team or the experimenters. The medium-energy (ME) and gas-scintillation-spectrometer (GS) instruments have continued to be operated nominally since the start of the mission.

Exosat has successfully achieved simultaneous coordinated observations with major ground-based facilities and has also been coordinated with the IRAS, Tenma and IUE spacecraft. The coordination with the Japanese X-ray satellite Tenma has been particularly fruitful, with a number of 'targets of opportunity' of transient X-ray sources leading to major scientific results.

To date, over 2000 final observation tapes (FOTs) have been issued and FOT production delays have fallen to ~25 days for the GS/ME experiments and ~60 days for the low-energy telescope experiments. The automatic scientific analysis of the FOTs is now being issued to observers on a regular basis. Current output delays remain long (100 days), however, as a result of problems arising earlier with the calibration of the experiments. These problems have now been overcome.

The second Announcement of Opportunity (AO-2) was issued on 26 January 1984 for a programme scheduled to run for six months from April 1984. This second AO and all subsequent AOs are open to the worldwide astronomical community. Indications are that the time available during the second observational programme will be as, if not more, oversubscribed than the first. Then, demand exceeded available time by a factor of six.

As a result of a number of discussions with Exosat observers, the data-processing facilities offered to observers at the observatory (ESOC) will be expanded. An interactive analysis system will provide observers with a capability additional to the real-time and quasi-real-time analysis support already provided, as well as complementing the automatic analysis of the FOTs.

The principal scientific results that have appeared so far have in general involved the study of galactic sources. In particular, the deep Exosat orbit has provided the first long, continuous observations of galactic binary X-ray sources. Some of the finest light curves obtained to date have come from these studies using the medium-energy and gas-scintillation-spectrometer experiments. The GS has, in addition, provided detailed results on iron-emission-line features in galactic bulge sources.

The complementary nature of the payload elements has been highlighted by the detailed morphological studies of supernova remnants carried out by the low-energy telescopes in a number of different wavebands accompanied by detailed ME and GS spectra.

The low-energy spectral mapping has been further enhanced by the successful reactivation of the PSD-1. The observations with this detector of the supernova remnant Pup-A have provided the first multicolour images of this remnant and should provide data on the variation of plasma temperature and electron densities throughout the remnant and on its interaction with the interstellar medium.

Geos

In line with an international convention to avoid overcrowding and the danger of interference and even collision in the geostationary orbit, the Geos-2 spacecraft was removed from geosynchronous orbit on 24 and 25 January 1984 (see article on page 86 of this issue).

The Geos missions have made valuable contributions in several areas:
- individual Geos instruments have established the particle wave and field environment at the geostationary orbit and its variation over a significant part of a solar cycle
- intercomparison of data from the various Geos instruments has advanced our knowledge of wave – particle reactions and basic plasma physics
- correlation of Geos data with that from other IMS spacecraft has made it possible to study dynamic magnetospheric phenomena, some of which were observed on a global scale.

Geos observations have also permitted extensive studies of geomagnetic conjugate phenomena by comparing Geos data with data from ground-based observatories. The Geos missions have also furthered our understanding of the interaction of a spacecraft with its plasma environment and the ensuing charging of the spacecraft. This, of course, has

La salle de contrôle des expériences Geos à l'ESOC en 1977

The Dedicated Control Room for Geos experiment operations at ESOC (photographed in 1977) *meilleures courbes de lumière observées à ce jour résultent d'études effectuées à l'aide des expériences de l'équipement 'moyenne énergie' et du spectromètre à scintillateur à gaz. Ce dernier a, en outre, fourni des résultats détaillés sur les caractéristiques générales des raies d'émission du fer dans les sources situées dans le renflement galactique.*

La complémentarité des équipements de la charge utile a été mise en évidence par les études morphologiques détaillées des restes de Supernova réalisées au moyen des télescopes pour les faibles énergies dans plusieurs bandes d'onde, auxquelles il convient d'ajouter les spectres détaillés obtenus par l'équipement 'moyenne énergie' et le spectromètre à scintillateur à gaz.

La spectrographie des faibles énergies a été améliorée du fait de la remise en marche du détecteur PSD-1. Les observations du reste de Supernova Pup-A effectuées à l'aide de ce détecteur ont permis d'en obtenir les premières images en plusieurs couleurs et elles devraient fournir des informations sur les variations de température du plasma et les densités d'électrons dans tout ce reste de Supernova et sur son interaction avec le milieu interstellaire.

Geos

En application d'une convention internationale visant à éviter l'encombrement et les risques d'interférences et de collisions sur l'orbite de géosynchronisme, le satellite Geos-2 a été retiré de cette orbite les 24 et 25 janvier 1984 (voir l'article page 86 dans ce bulletin).

Les missions Geos ont permis d'obtenir un certain nombre de résultats précieux dans plusieurs domaines:

- *grâce aux instruments embarqués, on a pu déterminer l'environnement du champ et des ondes de particules sur l'orbite des satellites géostationnaires et l'évolution de cet environnement pendant une partie importante d'un cycle solaire;*
- *la comparaison des données des divers instruments nous a permis d'en connaître davantage sur les réactions des particules constituant les ondes et sur la physique fondamentale des plasmas;*
- *la corrélation des données des satellites Geos avec celle d'autres satellites IMS a permis d'étudier les phénomènes de dynamique de la magnétosphère, dont certains ont été observés à l'échelle globale.*

Les observations des satellites Geos ont, en outre, rendu possibles des études poussées des phénomènes de conjuguaison géomagnétique en procédant à des comparaisons entre les données fournies par eux et celles d'observatoires basés au sol. Les missions Geos ont également contribué à faire progresser notre connaissance des interactions entre un véhicule spatial et le plasma qui l'environne et des charges électrostatiques qui en résultent pour le véhicule spatial. Ce dernier revêt manifestement une importance considérable sur le plan commercial puisque la plupart des satellites de télécommunications gravitent sur des orbites géostationnaires où les charges électrostatiques peuvent poser des problèmes de fonctionnement, voire occasionner des dégâts. Un grand nombre d'articles scientifiques traitant de ces aspects de la recherche ont été publiés et d'autres continuent de l'être. On en compte actuellement 240 au total.

Le programme Geos a également à son actif de très nombreuses 'premières' technologiques qui ont été utilises à d'autres programmes, ainsi:

- *Geos-1 a été la premier véhicule spatial de l'ESA équipé d'un moteur d'apogée et utilisant un système à hydrazine pour la correction d'orbite et la commande d'orientation;*
- *l'opération de sauvetage de la mission, effectuée à l'aide du moteur d'apogée récemment mis au point, a constitué la première manoeuvre orbitale d'envergure d'un satellite commandée de l'ESOC;*
- *le satellite a assuré un débit de données (100 000 bps) beaucoup plus important que celui de tous les véhicules spatiaux précédents de l'ESA ou de l'ESRO;*
- *sa charge utile était commandée par un système informatique en direct basé au sol;*
- *pour l'installation de sa charge utile, huit bras au total — dont deux de 20 m de longueur — avaient été utilisés;*
- *une attention particulière avait été accordée à sa propreté, Geos-1 étant notamment le premier au monde des satellites géostationnaires à être électrostatiquement propre.*

Ainsi, en dépit de l'échec du lanceur en 1977, le programme Geos a été marqué par un réel succès. L'exploitation de Geos-1 sur son orbite anormale pendant une année environ, puis celle de Geos-2 sur l'orbite des satellites géostationnaires prévue, ont permis aux chercheurs d'obtenir plus de données scientifiques qu'on ne le prévoyait au départ. A la fin de 1983, Geos-1 puis Geos-2 avaient assuré en succession une exploitation de sept ans au total. La couverture de plus de la moitié d'un cycle solaire a donné une dimension nouvelle à l'analyse des données. Depuis la mi-1982, Geos-2 fonctionne en mode réduit, c'est-à-dire qu'il ne transmet plus les données d'ondes à haute résolution. Depuis février 1983, le satellite était exploité dans le cadre d'un projet spécial financé par l'Allemagne et la Suisse. Même depuis qu'il a été retiré de son orbite, il reste possible d'en recevoir des données. Geos-2 dérivera vers l'ouest à raison de 4° par jour environ et sera donc visible de sa station sol de l'Odenwald quelques jours par trimestre. Le programme scientifique obligatoire ne prévoit pas le financement de la poursuite de l'acquisition des données. Quoi qu'il en soit, la base de données accumulées par Geos occupera la communauté scientifique pendant encore plusieurs années.

OTS

L'utilisation d'OTS par Eutelsat a cessé à la fin de 1983 après cinq années et demie d'excellents services. Au cours du premier trimestre de 1984, on procède à une série d'essais 'de fin de service' destinés à vérifier des modes d'exploitation particuliers dont certains ont été jugés plutôt dangereux au cours de la période pendant laquelle Eutelsat utilisait le satellite. La récupération du satellite d'une sortie de 'spin à plat' est l'une de ces manoeuvres qui ont été exécutées avec succès. C'est la première fois que l'on récupérait ainsi un satellite géostationnaire stabilisé sur trois axes. Cet essai était particulièrement important car il risque d'avoir des incidences directes sur les futures opérations de satellites.

considerable commercial significance since the majority of communications spacecraft are in geostationary orbits where electrostatic charging can cause operational problems and even damage. A large number of scientific papers covering these areas of research have been, and are still being, published. The total currently stands at 240.

The Geos programme also accomplished a large number of technological firsts, from which other programmes were able to benefit:
- Geos-1 was the first ESA spacecraft incorporating an apogee boost motor and using a hydrazine system for orbit and attitude control.
- The mission salvage action employing the newly developed apogee boost motor was one of the first major satellite orbital manoeuvres ever conducted by ESOC.
- The data rate of 100 000 bit/s was considerably greater than that from any previous ESA (ESRO) spacecraft.
- The payload was controlled by an on-line ground-based computer system.
- For payload accommodation, a total of eight booms – two of them 20 m long – were employed.
- Special attention was given to cleanliness; in particular Geos-1 was the world's first electrostatically clean geostationary spacecraft.

Thus, in spite of the initial launcher failure in 1977, the Geos programme has been highly successful. The exploitation of Geos-1 in its anomalous orbit for about one year, and later the operation of Geos-2 in the planned geostationary orbit, have given more scientific data to the investigators than originally expected. By the end of 1983, Geos-1 and 2 had operated sequentially for a total of seven years. The coverage of more than half of a solar cycle has given a new dimension to data analysis. From mid-1982, Geos-2 was operated in a reduced mode, e.g. without the transmission of high-resolution wave data. From February 1983, it was run as a special project funded only by Germany and Switzerland. Even after the recent removal of Geos-2 from geostationary orbit, the possibility of further data-acquisition remains. The satellite will drift westward at a rate of approximately 4° per day and will thus be visible for a few days every three months to ESA's Odenwald ground station.

Funding of further data acquisition from within the Agency's mandatory Science Programme is not foreseen. In any case, the accumulated Geos database will keep the science community busy for several years to come.

OTS

EUTELSAT usage of OTS ceased at the end of 1983, after five and a half years of excellent service from the spacecraft (see ESA Bulletin No. 37, page 72). During the first quarter of 1984, a series of end-of-service tests are being performed to check out particular operating modes, some of which were regarded as being rather risky during the period when EUTELSAT was using the satellite. One such manoeuvre which has been successfully completed is the recovery from a flat-spin, the first time a three-axis geostationary satellite has been successfully recovered. This test was considered particularly important since it could have direct relevance to future satellite operations.

The final phase of OTS's life will be the so-called 'hibernation' period, during which the payload transponder function will be inhibited and long-term data on the degradation of spacecraft subsystems will be compiled.

Marecs

Marecs-A has continued to give Inmarsat excellent service over the Atlantic Ocean region. Marecs-B2 is in the final stages of preparation prior to storage in Europe awaiting its launch campaign (launch date September 1984).

Finally, the Prosat Phase-1 trials with small terminals using spare Marecs-A capacity have been progressing with good results. Phase-2 of the project will be discussed at the March meeting of the Agency's Joint Communications Satellite Programme Board (JCB).

Meteosat

Pre-operational programme

On 23 November 1983, the arrangement for the exploitation of Meteosat-1 and 2 expired, and operation of these two satellites was transferred to the Meteosat Operational Programme.

At the Meteosat Programme Board held in November, the proposal to launch the Meteosat-P2 model as passenger on the Ariane-4 test flight was approved. The launch is scheduled for March 1986. The P2 model is at present in storage and preparations for launch will start in April 1984.

Space segment

The development/manufacture of the satellites for the Operational Programme is well under way. The first production releases for items that are unchanged from the Pre-Operational Programme have been given by the Prime Contractor, SNIAS, while a Critical Design Review has been held for the electrical ground-support equipment. Similar reviews will be held for items that are changed from the Pre-Operational Programme. No major problems have been identified and launch of the first operational unit is scheduled for June 1987.

Ground segment

Following repair of the data-transmission system (November 1983), ground-segment performance was well within specifications and continued to be so. The procedures for replacement of some of the ground-segment elements have been initiated and some modifications will already be implemented during 1984, mainly in the Meteosat Ground Computer System (MGCS) and the Meteorological Information Extraction Centre (MIEC).

The extension of the MIEC processing area to 55° great circle arc is well advanced and will be implemented operationally at the beginning of the second quarter of 1984.

The processing software for DCP data has been modified to enable speedier re-transmission of coded DCP data to the Meteorological Centres through the Global Telecommunications System (GTS).

ECS

ECS-1 has been operating satisfactorily since its acceptance by EUTELSAT in October 1983. All of the available channels on board have been allocated to European PTTs, three of which

La dernière phase de la vie d'OTS sera sa mise en 'hibernation', la fonction répéteur de la charge utile étant inhibée. Pendant cette période, on rassemblera des données à long terme sur la dégradation des sous-systèmes du véhicule spatial.

Marecs

Le service opérationnel de Marecs-A pour le compte d'Inmarsat a continué de donner d'excellents résultats au-dessus de l'Atlantique. Marecs-B2 est parvenu au stade final de la préparation avant d'être entreposé en Europe en attendant la campagne de lancement et le lancement prévu pour septembre 1984.

Enfin, les essais de Phase 1 de Prosat avec des petits terminaux utilisant la capacité de réserve de Marecs-A se sont poursuivis et ont donné de bons résultats. La Phase 2 du projet devait faire l'objet d'un examen lors de la réunion du Conseil directeur commun des satellites de communications (JCB) en mars 1984.

Météosat

Programme préopérationnel
Le 23 novembre 1983, les dispositions relatives à l'exploitation des deux satellites Météosat 1 et 2 ont pris fin et ont été transférées au programme opérationnel Météosat comme il est indiqué ci-après.

Lors de sa réunion de novembre 1983, le Conseil directeur du Programme a approuvé la proposition de lancement du modèle Météosat P2 à l'occasion du vol d'essai Ariane 4, prévu pour le mois de mars 1986. Le modèle P2 est actuellement entreposé et les opérations de préparation du lancement commenceront en avril 1984.

Secteur spatial
Le développement et la fabrication des satellites du programme opérationnel progressent normalement. La SNIAS, contractant principal, a autorisé la sortie des premiers équipements de production qui ne sont pas modifiés par rapport au programme préopérationnel tandis que le matériel de soutien électrique au sol (EGSE) a fait l'objet d'un examen critique de la conception. Des examens semblables seront organisés pour les articles qui ont été modifiés par rapport au programme préopérationnel. Aucun problème majeur n'a été identifié et le lancement de la première unité opérationnelle est prévu pour juin 1987.

Secteur sol
Après réparation du système de transmission de données (novembre 1983), les performances de fonctionnement du secteur sol se sont avérées parfaitement conformes aux spécifications et le sont toujours. On a lancé la procédure de déclenchement de certains des éléments du secteur sol et une partie des modifications sera exécutée en 1984; elles porteront, pour l'essentiel, sur le système informatique sol de Météosat et sur le centre d'extraction d'informations météorologiques (MIEC).

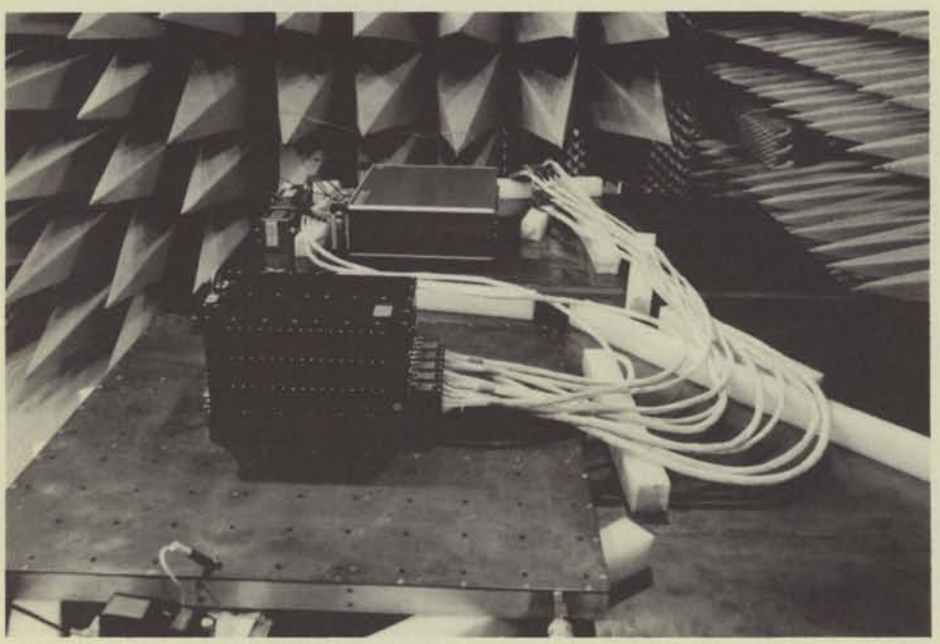
L'extension de la zone de traitement MIEC à 55° (angle de grand cercle) est bien avancée et deviendra opérationnel au début du deuxième trimestre de 1984.

Le logiciel de traitement de données de DCP a été modifié pour accélérer la retransmission des données de DCP codées vers les centres météorologiques par l'intermédiaire du système de télécommunications global.

ECS

Le satellite ECS-1 a fonctionné de manière satisfaisante depuis sa recette par Eutelsat en octobre 1983. Tous les canaux disponibles à bord ont été alloués à des administrations européennes des postes et télécommunications dont trois (France, Allemagne, Royaume-Uni) les utilisent régulièrement pour la distribution de la télévision. Les autres canaux seront progressivement mis en service opérationnel au cours de l'année.

Le modèle de vol d'ECS-2 est en préparation finale avant son lancement en juillet 1984 par Ariane 3 (Vol 10) en double configuration avec le satellite français de télécommunications Télécom 1-A.



Space Telescope flight-model Deployment Control Electronics (DCE) undergoing EMC testing at ESTEC (Noordwijk)

Essai de compatibilité électromagnétique de l'électronique de commande du mécanisme de déploiement du modèle de vol du Télescope spatial à l'ESTEC (Noordwijk)

(France, Germany and UK) are utilising them for TV distribution on a regular basis. The other channels are expected to become operational progressively during the remainder of the year.

The ECS-2 flight unit is in the final preparation stage, prior to the launch by Ariane-3 (L10) in July 1984 in a dual-launch configuration with a French telecommunications satellite, Telecom-1A.

ECS-3 is presently at the subsystem integration stage in Matra's Toulouse facility. Current planning foresees launch of this unit in August 1985, thus completing the three-satellite European system for EUTELSAT.

After completion, ECS-4 and 5 will go into storage until they are needed as replacements for their predecessors.

Space Telescope

NASA
All NASA activities are proceeding on schedule for a launch of the Space Telescope by mid-1986. An important milestone has been achieved by NASA, with finalisation of the integration of the first fine guidance sensor system and the demonstration by test that tracking of stars of visible magnitude 15 is possible.

Solar array
The development/qualification wing has been delivered to LMSC, the Space Telescope integration contractor. This wing will be used later in the year for fit checks with the Space-Telescope structure.

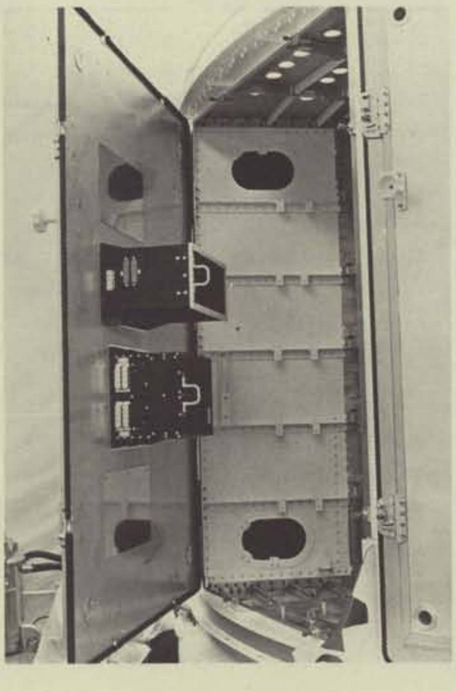
Faint Object Camera
The flight model of the FOC has been shipped to GSFC, where it has started the verification and acceptance programme. This programme is intended to confirm the correct electrical and software interfaces with the other scientific instruments. Mission simulation tests are also foreseen, prior to the end of March 1984.

It is planned to utilise the time between then and delivery of the FOC to LMSC to achieve improved calibration of the instrument.

Hipparcos

Following evaluation of the MESH Phase-C/D proposal (main development phase) for the Hipparcos satellite, the last weeks of 1983 were primarily devoted to Preliminary Design Reviews (PDRs) for payload and spacecraft systems. The outcome of these PDRs was generally satisfactory and provided a sound understanding of the technical baseline upon which the project could proceed.

Following approval by the Industrial Policy Committee (IPC) at its 67th meeting, held during December 1983, the satellite development phase was formally initiated with a kick-off meeting, held in Toulouse, on 23-24 January. Representatives of all contractors participated in the meeting and were informed of the project baseline resulting from the evaluation and PDR, and the plans for the future conduct of the project.



Electronique de manoeuvre (SADE) et de commande (DCE) des panneaux solaires du Télescope spatial en cours de vérification sur le module du système de soutien au LMSC

Space Telescope Solar Array Drive Electronics (SADE) and Control Electronics (DCE) during a fit check with the Support System Module (SSM) at LMSC

A near-term schedule for contractual negotiations at subsystem level has been prepared. It is planned to aim for initial negotiation meetings with each subcontractor within six months. It is possible that, for a number of contractors, these negotiations may be concluded with just one meeting.

Olympus

The programme of platform and payload subsystem Development Baseline Review has continued in industry and is nearing completion. The System Level Development Baseline Review to be conducted by the Agency is now expected to be held in June.

Manufacture and test of the engineering-model equipment items is continuing for all subsystems. The development model of the solar array has been partially integrated and tests completed satisfactorily on the primary release system before further integration of the solar-array blanket.

The spacecraft structural model has been completed and mounted in the special test rig ready for the static test, which forms part of the structure qualification. Final preparations are in hand for this test in March. Work has continued on both the structure and propulsion modules of the spacecraft thermal model, which have been delivered for integration of the thermal-model equipment and surfaces.

Nearly all the system-level Mechanical Ground Support Equipment (MGSE) for the programme has been delivered. Road-test and aircraft-fit checks have been made with the spacecraft transport container. The quotation for the in-orbit ground segment operations has been evaluated and is being negotiated prior to the placing of a contract.

Remote-Sensing

Since the last report (Bulletin 35) all remote-sensing activities have been moved from Toulouse to ESTEC, without a significant break in working activities.

FSLP
The two remote-sensing experiments on FSLP were finally launched on

On procède actuellement chez Matra (Toulouse) à l'intégration des sous-systèmes du satellite ECS-3. Le calendrier actuel prévoit le lancement de ce satellite en août 1985 pour compléter le système européen à trois satellites d'Eutelsat.

Les satellites ECS-4 et ECS-5 terminés seront entreposés jusqu'à ce qu'il devienne nécessaire de les utiliser pour remplacer les autres satellites.

Télescope spatial

Activités NASA
Toutes les activités de la NASA se poursuivent conformément au calendrier qui prévoit que le Télescope spatial sera lancé à la mi-1986. La NASA a franchi une étape importante avec l'intégration complète du premier système de guidage fin et en démontrant par des essais qu'il était possible de poursuivre des étoiles dont la grandeur visible est de 15.

Réseau solaire
L'aile de développement/qualification a été livrée à la LMSC (Lockheed Missile and Space Corporation), contractant chargé de l'intégration du Télescope spatial. Dans le courant de l'année, cette aile servira à des contrôles d'adaptation sur la structure du Télescope spatial.

Chambre pour astres faibles (FOC)
Le modèle de vol de la FOC a été expédié au Centre des vols spatiaux Goddard pour y être soumis au Programme de vérification et de recette. Ce programme vise à contrôler les interfaces électriques et de logiciel avec les autres instruments scientifiques. Tous les essais de simulation de mission devaient se terminer avant la fin mars 1984.

Par la suite et avant la livraison de la FOC à la LMSC, on envisage de mettre à profit cette période pour obtenir un meilleur étalonnage de l'instrument.

Hipparcos

A la suite de l'évaluation de la proposition de phase C/D du satellite Hipparcos soumise par le consortium MESH, les dernières semaines de 1983 ont été consacrées, pour l'essentiel, aux examens de conception préliminaire (PDR) des sous-systèmes de la charge utile et du véhicule spatial. Dans l'ensemble les résultats des PDR sont satisfaisants et dénotent une bonne compréhension de la référence technique à partir de laquelle le projet pourra se poursuivre. Après l'approbation donnée par le Comité de la Politique industrielle (IPC) lors de sa 67ème réunion tenue en décembre 1983, la phase de développement du satellite a été officiellement lancée lors d'une réunion initiale tenue à Toulouse les 23 et 24 janvier 1984. Des représentants de tous les contractants ont participé à cette réunion au cours de laquelle on les a informés de la référence du projet résultant de l'évaluation et des PDR; on leur a également fait par des plans relatifs au futur déroulement du projet.

On a préparé un calendrier à court terme des négociations contractuelles au niveau des sous-systèmes. Les premières réunions de négociation avec chaque sous-traitant devraient avoir lieu dans les six prochains mois. Il est possible que pour un certain nombre de contractants une seule réunion suffise pour conclure les négociations.

Olympus

Le programme d'examens des bases de référence de développement des sous-systèmes de la plate-forme et de la charge utile s'est poursuivi chez les industriels et est presque terminé. L'examen de la base

Image de la région sud-ouest de l'Iran et du Détroit d'Ormuz prise par la Chambre photogrammétrique embarquée sur Spacelab

Image of the southwest region of Iran and the Straits of Hormuz, taken by the Metric Camera on board Spacelab-1

28 November. The Metric Camera returned over 1000 images, which are now being distributed to experimenters for evaluation. A re-flight is planned for mid-1985. The MRSE experienced some operational problems and was only able to work in the passive sensing mode. Initial hardware failure analysis is currently being performed, but first indications are that the equipment works nominally in the laboratory. Vacuum tests are the next step in the analysis.

ERS-1

The project is currently nearing the end of a limited extension to the Phase-B, aimed at rectifying some critical problems identified during the Phase-B evaluation and in the industrial Phase-C/D offer.

The Phase-C/D proposal to the Remote Sensing Programme Board is the subject of a sequence of ongoing 'participants' meetings to finalise the detailed programme content and to decide on certain options. Phase-C/D is expected to be initiated in the second half of the year.

Meanwhile, technical progress continues in critical technological areas and in increasing the understanding of the relationship between the engineering measurements to be made by the satellite radar equipment and geophysical parameters. Currently the Agency, together with several National Institutes, is involved in a campaign to consolidate the understanding of the relationship between C-band scatterometer measurements and the sea surface as a function of surface wind speed.

Spacelab

Spacelab-1, which completed a satisfactory 10-day flight on 7 December, is now being de-integrated and all subsystems are being inspected in the process. De-integration will be complete by mid-February and the components of the Spacelab will be made available for the D1 mission scheduled for a November 1984 launch. There are minor problems appearing, such as discolouration of HP1 blankets, high particulate count in the freon fluid, and sill keel trunnion surface dulling, but nothing that could have prejudiced the flight has been revealed. The two items that caused concern during the flight have been extensively tested. The High-Data-Rate Recorder (HDRR) belts, one of which broke in flight, were examined and the problem discussed with their manufacturer. It emerged that the belts were wider than those that had previously given completely satisfactory service and the corrective action will be to return to narrower belts.

The Remote Acquisition Unit (RAU) problem has been investigated in vacuum at Marshall Space Flight Center (MSFC) with the following results to date:

- Expt. RAU 21 (flown on SL-1): on-orbit problem has been reproduced at 25°C.
- Expt. RAU 23 (flown on SL-1): failure demonstrated at 40°C.
- Engineering unit: no problems up to 40°C.

No definite conclusion can be drawn from the above results and a test programme will be initiated with the RAU manufacturer to seek further data and insight into the problem.

The subsystem integration of Spacelab-2 (SL-2) at Kennedy Space Flight Center is virtually complete, and SABCA personnel have been involved in work on the Igloo cover. Subsystem checkout is planned to begin in February and to proceed with IPS integration as soon as the IPS is delivered from Europe (now July 1984). This late delivery is giving cause for concern, since the interface between IPS and the Control & Data Management System (CDMS) in the Igloo is extensive, and the time remaining in which to solve potential problems is decreasing.

Follow-On Production

Assembly and integration of the Short Core Module (SCM) is proceeding. New GORE cables are being installed. Due to the difficulties experienced in finding a suitable replacement cable, exchange activities have been slightly delayed, with the result that SCM delivery is projected to be two weeks late. It is now scheduled for 17 August 1984. NASA has advised ESA that this delay is not acceptable and the schedule is being reviewed accordingly.

The Acceptance Review for the Experiment Segment + Aft End Cone was held successfully after assembly and testing had been completed. The Acceptance Certificates have been signed and the hardware is in storage to await the C5A delivery flight in August 1984.

The system test for the Igloo/Pallet configuration is in progress. Hardware/software problems have been experienced during this test phase, which will delay completion of the testing by approximately one week. The delivery date is presently unaffected.

de référence de développement au niveau 'système' que doit effectuer l'Agence aura lieu en juin 1984.

La fabrication et les essais des équipements du modèle d'identification progressent et concernent tous les sous-systèmes. Le modèle de développement du réseau solaire a été partiellement intégré et les essais du système de libération primaire se sont achevés avec succès avant intégration de la nappe du réseau solaire.

Le modèle de structure du satellite est terminé et monté sur le banc de test spécial sur lequel il sera soumis à des essais statiques en vue de la qualification de la structure. Les derniers préparatifs des essais qui doivent être exécutés en mars 1984 sont en cours. Les travaux se sont poursuivis sur la structure et sur les modules de propulsion du modèle thermique du véhicule spatial qui ont été livrés pour intégration des équipements et des surfaces du modèle thermique.

La plupart des équipements de soutien mécanique sol au niveau système du programme ont été livrés. Des essais sur route et des contrôles d'ajustement sur l'avion ont été effectués sur le conteneur de transport du satellite. Le coût des opérations en orbite du secteur sol a été évalué et fait l'objet de négociations avant la passation d'un contrat.

Télédétection

Depuis le dernier Bulletin (Bulletin no. 35), toutes les activités liées à la télédétection ont quitté Toulouse pour l'ESTEC sans qu'il y ait eu interruption significative des travaux.

FSLP

Les deux expériences de télédétection de la FSLP ont finalement été lancées le 28 novembre 1983. La chambre photogrammétrique a rapporté plus de 1000 images qui sont actuellement distribuées aux expérimentateurs pour évaluation. On envisage un nouveau vol pour la mi-1985. L'expérience de télédétection à hyperfréquences (MRSE) a souffert de quelques problèmes opérationnels et n'a pu fonctionner qu'en mode de télédétection passive. On procède actuellement aux premières analyses de la défaillance du matériel; d'après les résultats obtenus, il semble que les équipements fonctionnent de manière nominale dans le laboratoire. L'analyse va se poursuivre avec des essais sous vide.

ERS-1

Le projet approche actuellement la fin d'une période d'extension limitée de la phase B destinée à remédier à certains problèmes critiques identifiés lors de l'évaluation de la phase B et pendant l'offre de la phase C/D industrielle.

La proposition de phase C/D présentée au Conseil directeur du Programme de télédétection est examinée par les participants au cours d'une série de réunions actuellement organisées pour mettre au point le contenu du programme détaillé et pour décider de certaines options. La phase C/D devrait démarrer au cours du second semestre de 1984.

Entretemps, des domaines technologiques critiques continuent à bénéficier de progrès techniques et on comprend mieux les rapports établis entre les mesures techniques qui doivent être effectuées par l'équipement radar du satellite et les paramètres géophysiques. Actuellement. l'Agence, avec plusieurs établissements nationaux, participe à une campagne destinée à approfondir la connaissance des rapports entre les mesures du diffusiomètre en bande C et la surface de la mer en fonction de la vitesse du vent à la surface.

Spacelab

Après dix jours d'une mission satisfaisante qui s'est terminée le 7 décembre, Spacelab-1 a commencé à être démonté et tous ses sous-systèmes sont à cette occasion soumis à inspection. Le démontage sera terminé vers la mi-février et les composants du Spacelab seront mis à la disposition de la mission D1 prévue pour novembre 1984. Des problèmes mineurs sont apparus, entre autres une décoloration des revêtements superisolants, la présence d'une grande quantité de particules dans le fréon et un dépolissage de la surface des tourillons au niveau de la quille, mais rien n'a été décelé qui aurait pu affecter le vol. Les deux types d'instruments qui ont suscité des préoccupations pendant le vol ont été longuement testés. Les courroies de l'enregistreur de données à haut débit (HDRR), dont l'une s'est cassée pendant le vol, ont été examinées et la question a été débattue avec le fabricant. Il est apparu que ces courroies étaient plus larges que celles qui avaient auparavant parfaitement fonctionné et on résoudra le problème en réutilisant des courroies plus étroites.

Le problème du fonctionnement des unités de télé-acquisition (RAU) a fait l'objet d'une étude sous vide au Centre des Vols spatiaux Marshall (MSFC) qui, jusqu'à présent, a donné les résultats suivants:

- *RAU 21 (sur SL-1): l'incident survenu pendant le vol s'est reproduit à 25°C.*
- *RAU 23 (sur SL-1): défaillances mises en évidence à 40°C.*
- *Pas d'incident jusqu'à 40°C sur le modèle d'identification de l'enregistreur.*

Aucune conclusion définitive ne peut être tirée de ces résultats et il a été décidé avec le fabricant des RAU de mettre en route un programme d'essais pour recueillir davantage de données et approfondir le problème.

L'intégration des sous-systèmes du SL-2 au Centre spatial Kennedy est presque terminée et le personnel de SABCA a participé aux travaux sur le couvercle de l'igloo. La vérification des sous-systèmes doit commencer en février et se poursuivre avec l'intégration de l'IPS dès que celui-ci sera livré par les Européens (juillet 1984 d'après le calendrier actuel). Ce retard de livraison constitue un sujet de préoccupation en raison de l'importance des interfaces entre l'IPS et le système de commande et de traitement des données (CDMS) pour la partie Igloo et du peu de temps restant disponible pour résoudre les éventuels problèmes.

Production ultérieure (FOP)

L'assemblage et l'intégration du module principal court (SCM) se poursuivent normalement. On procède actuellement à la pose de nouveaux câbles Gore. Les difficultés éprouvées pour trouver un câble de remplacement approprié ont légèrement retardé les activités d'échange par rapport au calendrier; il en résulte que le SCM sera livré avec deux semaines de retard, soit le 17 août 1984. La NASA a informé l'ESA que ce retard était inacceptable. Le calendrier est donc revu en conséquence.

In IPS-FOP, the Phase-C/D (main development) programme continues to drive the production schedule. An attempt by ESA to investigate the reasons for projected delays failed initially due to the contractor's reluctance to support the corresponding reviews. ESA subsequently requested a schedule inspection, as foreseen in the FOP contract. This inspection showed that there is sufficient planning data available at the contractor with a sufficient level of detail to measure the progress made and to assess the impact of delays when they occur. Delivery of the FOP-IPS is projected to be on schedule for 31 December 1984.

Payload Clamp Assembly (PCA) fittings passed final FOP acceptance and have been shipped to the USA. The main parts of the FOP PCA cannot, however, be delivered as planned, because of incomplete qualification. As a work-around solution, a loan arrangement has been agreed between Dornier, ESA and NASA under which the FOP PCA items are given to NASA in 'as is' condition for temporary use for a period of up to eight months. At the end of the loan period, the hardware will be returned to Dornier for refurbishment, completion of testing and final acceptance review.

The use of the FOP-IPS and some other FOP hardware to support qualification tests of the Phase-C/D programme is presently being considered.

IPS

The flight model of the Instrument Pointing Subsystem has been assembled. It has successfully passed the acoustic-noise/random-vibration, modal-survey and mass-property tests, and is now ready for electrical integration and system tests. The electrical boxes are ready for integration, except for the gyro and accelerometer packages, which failed in hot thermal vacuum.

The optical sensor package is not yet complete and will have to enter electrical integration later than foreseen in the schedule.

IPS software is in qualification testing (activation and de-activation, acquisition and pointing software), with approximately two weeks delay compared with the nominal schedule.

FSLP

The Spacelab-1 mission took place from 28 November to 8 December, lasting one day longer than originally planned. An initial assessment of the scientific accomplishments and the performance of the Spacelab system appeared in Bulletin No. 37 (pp. 6–31).

An Investigators' Meeting will be held in June, when the scientific results will be systematically reviewed.

From the point of view of the flight operations of the European payload it can be said that:

- all instruments operated and produced data
- nearly all of the 57 experiments were carried out as planned, the total functioning times being close to or greater than those planned in the basic timeline
- several experiments were able to exploit the additional mission day, so that extra scientific opportunities or improved performances were attained.

Faults were few for such a complex multidisciplinary payload and the availability of inflight data enabled several experimenters to upgrade their operating procedures in an interactive manner. This was particularly the case when Spacelab's television system could be used as an aid.

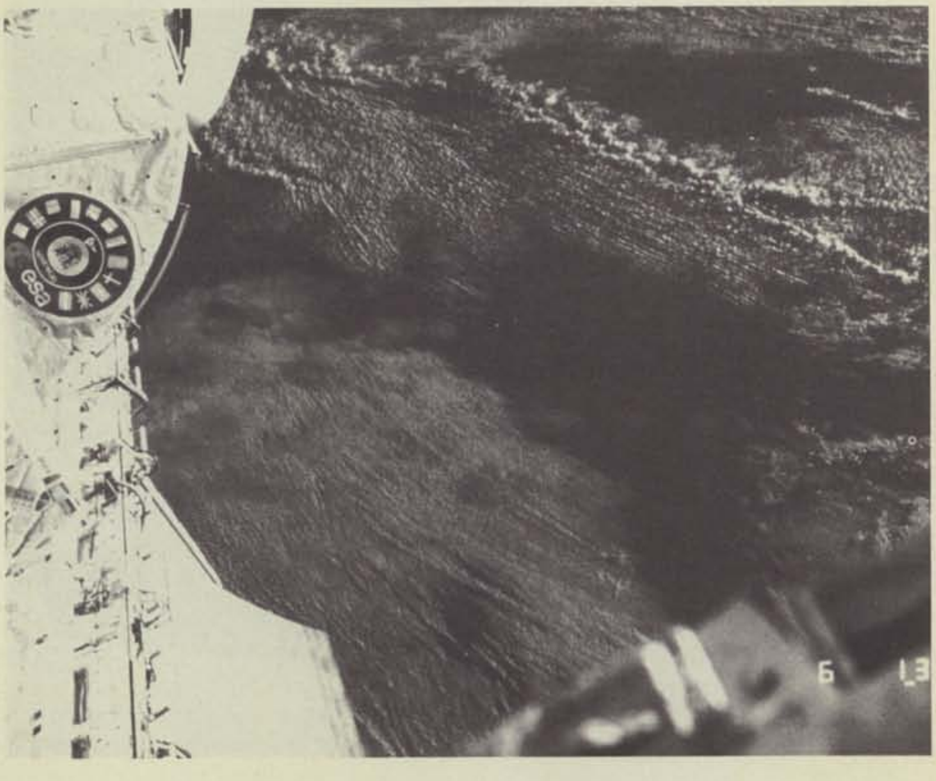
After the landing in California, the instruments were progressively recovered, commencing with critical-life items (such as exposed films and some biological samples) removed at the landing site. After the Orbiter returned to Kennedy Space Center (KSC), Spacelab and its payload were transferred to the Integration Facility, and disassembly proceeded systematically. By the end of February, all hardware had been returned to Europe and re-distributed to the experimenters.

Investigation into the few on-board anomalies has continued. Since a full examination of the hardware is essential, only preliminary results are available so far, but it appears that:

- the power-supply problem that affected the Isothermal Heating Facility was due to a component failure
- the Microwave Remote Sensing Instrument has been tested and found to operate correctly in the laboratory environment.

Spacelab-1 en orbite

Spacelab-1 in orbit



La section 'Expériences' et le cône arrière ont passé avec succès l'Examen de recette au terme des opérations d'assemblage et d'essais. Les certificats de recette ont été signés et le matériel est entreposé en attendant d'être convoyé en août 1984 par un appareil C5A.

Les essais du système de la configuration 'Igloo/Porte-instruments' se poursuivent normalement. On a connu, pendant cette phase d'essais, des problèmes de matériel et de logiciel qui ont retardé la fin des essais d'environ une semaine. Actuellement, la date de livraison n'est pas modifiée.

En ce qui concerne le sous-système de pointage d'instruments (IPS) de la FOP, le programme de développement principal de la phase C/D continue à influencer le calendrier de production. En un premier temps, l'ESA n'a pas réussi à analyser les raisons des retards prévus. le contractant ayant refusé de participer aux revues correspondantes. L'ESA a donc demandé que l'on procède à un examen du calendrier comme cela est prévu dans le contrat FOP. Cet examen a montré que Dornier dispose de suffisamment de données de planning, à un niveau approprié de détail, pour mesurer les progrès effectués et pour évaluer l'incidence des retards lorsqu'il s'en produit. La livraison de l'IPS-FOP devrait avoir lieu, comme prévu, le 31 décembre 1984.

Les accessoires de l'ensemble de fixation de la charge utile (PCA) ont subi avec succès les essais de recette finale FOP et ont été expédiés aux Etats-Unis. Les pièces principales du PCA-FOP ne peuvent cependant être livrées comme prévu car la qualification est inachevée. A titre de solution de repli, un accord de prêt est conclu entre Dornier, l'ESA et la NASA au terme duquel les éléments du PCA-FOP sont remis à la NASA 'dans l'état' pour utilisation provisoire pendant une période maximum de huit mois. A la fin de cette période de prêt, le matériel sera renvoyé à Dornier pour remise en état, achèvement des essais et examens de recette finale.

On envisage actuellement d'utiliser l'IPS-FOP et certains autres matériels FOP dans le cadre des essais de qualification du programme de la phase C/D.

IPS

Le modèle de vol du sous-système de pointage d'instruments (IPS) a été assemblé. Il a satisfait aux essais portant sur le bruit acoustique, les vibrations aléatoires, l'étude des modes et les caractéristiques de masse. Le modèle de vol peut être soumis aux essais d'intégration électrique et de systèmes. Les boîtiers électriques sont prêts à être intégrés à l'exception de la centrale gyroscopique et de accéléromètre qui ont échoué aux essais sous vide thermique à chaud.

L'ensemble du détecteur optique n'est pas encore terminé et son intégration électrique est donc retardée par rapport au calendrier.

Le logiciel IPS est en cours d'essais de qualification (logiciel d'activation, de désactivation, d'acquisition et de pointage) avec un retard d'environ deux semaines par rapport au calendrier prévu.

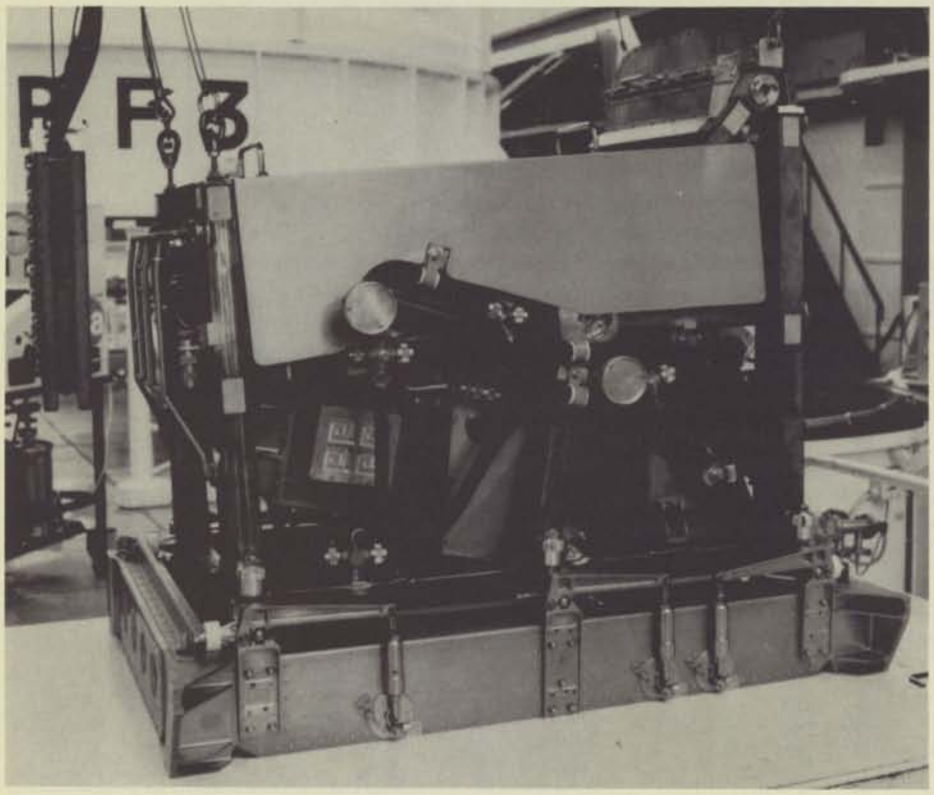
FSLP

La mission Spacelab-1, prolongée d'un jour, s'est donc déroulée du 28 novembre au 8 décembre 1983. L'évaluation initiale des expériences scientifiques et des caractéristiques de fonctionnement du système Spacelab a fait l'objet d'articles dans le bulletin no. 37 (page 6—31).

Les Chercheurs se réuniront au mois de juin pour procéder à une analyse systématique des résultats scientifiques.

Du point de vue des opérations de vol de la charge utile européenne, on peut préciser que:
- *tous les instruments ont fonctionné et ont fourni des données,*
- *la plupart de 57 expériences se sont déroulées conformément au programme, les durées totales d'expérimentations étant proches ou supérieures à celles prévues au calendrier de référence,*
- *plusieurs expériences ont bénéficié de la prolongation de la mission d'une journée qui a fourni des occasions scientifiques supplémentaires ou qui a permis d'améliorer certaines performances.*

Compte tenu de la complexité de cette charge utile pluridisciplinaire, les défauts



FSLP Expt. 1ES022 (Very Wide Field Camera) being prepared for an off-gassing test at ESTEC (Noordwijk)

L'expérience 1ES022 (Chambre à très grand champ) de la FSLP pendant la préparation aux essais de dégazage à l'ESTEC (Noordwijk)

The post-mission data processing has commenced following arrival of the NASA tapes (about 1500 in all) at Oberpfaffenhofen (GSOC) in mid February.

Seven experiments (three from NASA, four from ESA) were judged to have been severely affected by the slippage of the launch to end-November, and were offered compensatory reflights. The ESA instruments are the Very Wide Field Camera, which is to fly again on Spacelab-3 (launch planned for November 1984), the Metric Camera, the Grille Spectrometer, and the Waves in OH Layers experiment, all of which have been offered places on the EOM-1 mission (launch planned for June 1985). Preparations for these reflights are now in progress.

The Sled payload element for Germany's Spacelab D1 mission is progressing well. The flight hardware is being assembled at ERNO Bremen for integration, whilst the training model of the Sled facility has been installed at the Spacelab simulator site at DFVLR in Porz-Wahn. The flight hardware of the Mainz University experiment will be slightly improved, to take advantage of the experience gained during the first Spacelab mission. Delivery of the flight payload element is scheduled for June 1984.

Eureca

The Programme Requirements Review (PRR) for the Eureca system was completed at the end of January 1984, and led to a cost-to-completion projection in excess of the allowable programme cost envelope. Actions are therefore under way to re-assess the requirements baseline for the project, with the intention of reducing the carrier's complexity and cost.

Mid-term presentations of Phase-B (definition phase) studies of the following core payload facilities have been held:

- Solution Growth Facility: 6 February 1984
- Botany Facility: 17 February 1984 at ERNO; 1 March 1984 at Dornier System
- Automatic Mono-ellipsoidal Mirror Furnace Facility: 24 February 1984
- Protein Crystallisation Facility: 29 February 1984.

Mid-term presentations for the Multi-Furnace Assembly are scheduled in April/May.

On the basis of the data presented at these mid-term presentations, the 'Instrument Interface Agreements' (IIAs) between the various facilities and Eureca will be elaborated between the facility developers and the Eureca Prime Contractor MBB/ERNO, under ESA's leadership.

The Request for Quotation (RFQ) for Phases-A/B for the Exobiological Radiation Assembly has been released in January with replies due by 19 March. For all other payloads to be flown on the first Eureca mission, financing assurances from the procuring authorities are required by ESA by the end of March 1984.

As a result of previous discussions and in line with ESA expectations, NASA confirmed in January their price for the first deploy/retrieve flight of Eureca; the retrieval element of the flight will be charged at 30% of the launch cost.

Microgravity

Biorack

The pending design issues (regarding the Incubators and Passive Thermal Units, mentioned in the last report), have been resolved. The manufacturing and integration of units is progressing and unit-level testing is foreseen for the period May–June.

A Spacelab rack has been delivered to Matra for the integration of the harness and air cooling ducts. The negotiations for a contract for the assembly, integration and test activities have been completed.

Several Spacelab D-1 mission reviews were supported during the last quarter, including Payload-Integration-Readiness, Operation-Interface and Crew-Station Reviews.

The implications for the Biorack hardware and its operation resulting from an extension of the duration of the D-1 mission from 7 to 10 days have been investigated.

Schedule remains a serious problem; delays in the procurement of components could result in a mismatch of a few weeks between the earliest possible Biorack delivery dates and the requirement dates for the D-1 mission. The additional provisions required to meet a mission-duration extension would further aggravate this schedule problem.

Ariane

For the latest information and launch manifest, see page 106.

relevés sont peu nombreux; grâce à la disponibilité des données en vol, plusieurs chercheurs ont pu améliorer de manière interactive leurs procédures d'expérimentation. Ce fut particulièrement le cas lorsque le système de télévision de Spacelab a pu être utilisé comme moyen d'assistance.

Après atterrissage de la Navette en Californie, on a procédé à la récupération progressive des instruments en commençant avec les éléments présentant une durée de vie critique comme, par exemple, les films impressionnés et certains échantillons biologiques. L'Orbiter a ensuite été réexpédié au Centre spatial Kennedy où le Spacelab et sa charge utile ont été transférés vers le hall d'intégration pour un démontage systématique. Fin février, tout le matériel avait été réexpédié en Europe et restitué aux expérimentateurs.

L'enquête sur les quelques anomalies constatées à bord s'est poursuivie. Il est essentiel de procéder à un examen complet du matériel et on ne dispose donc actuellement que de résultats préliminaires mais on peut dire, dès à présent, que:

- *le problème d'alimentation qui a touché le four isotherme est imputable à une défaillance d'un composant,*
- *l'expérience de télédétection par hyperfréquences a été soumise à des essais qui ont permis de constater qu'elle fonctionnait correctement dans les conditions de laboratoire.*

Le traitement des données postérieur à la mission a commencé après l'arrivée des bandes de la NASA (environ 1500 bandes au total) au GSOC d'Oberpfaffenhofen à la mi-février.

On estime que sept expériences (trois de la NASA et quatre de l'ESA) ont gravement souffert du report de la date de lancement à la fin novembre. A titre de compensation, on donnera à ces expériences la possibilité de participer à un nouveau vol. Les instruments ESA ainsi affectés sont la chambre à très grand champ qui doit être emportée sur la mission Spacelab-3 (lancement prévu en novembre 1984) tandis que des emplacements ont été alloués sur la mission EOM-1 (lancement prévu en juin 1985) pour la chambre métrique, le spectromètre à grille et l'expérience sur les ondes dans les couches d'OH. Les préparatifs de ces expériences se poursuivent activement.

Les travaux sur l'élément de charge utile Traîneau pour la mission Spacelab-D1 sont en bonne voie. Le matériel de vol est en cours d'assemblage chez ERNO à Brême pour intégration alors que le modèle utilisé pour l'entraînement de l'équipage a été installé sur le simulateur Spacelab de la DFVLR à Porz-Wahn. Le matériel de vol de l'expérience de l'Université de Mayence sera légèrement amélioré de façon à profiter de l'expérience acquise au cours de la première mission Spacelab. La livraison de l'élément de charge utile de vol est prévue pour juin 1984.

Eureca

L'Examen des impératifs du programme (PRR) du système Eureca s'est terminé fin janvier 1984 sur une prévision de coût à achèvement dépassant l'enveloppe financière autorisée pour le programme. On a donc engagé des actions pour évaluer de nouveau les impératifs de référence du projet dans le but de réduire la complexité et le coût du véhicule.

On a présenté l'état des études de Phase B (phase de définition) à mi-parcours portant sur les installations suivantes du noyau de la charge utile:
- *Installation de cristallisation en solution: 6 février 1984*
- *Installation de botanique: ERNO, 17 février; Dornier System, 1er mars*
- *Four à miroir monoéllipsoïdal automatique: 24 février*
- *Installation de cristallisation des protéines: 29 février.*

Les présentations à mi-parcours de l'ensemble de fours multiples sont prévues pour les mois d'avril/mai 1984.

Sur la base des données soumises lors de ces présentations à mi-parcours, les accords sur les interfaces avec les instruments (IIA) entre les diverses installations et Eureca seront élaborés entre les industriels chargés du développement des installations et MBB/Erno, contractant principal d'Eureca, sous le contrôle de l'ESA.

La demande de prix pour les Phases A/B de l'ensemble de rayonnement exobiologique a été lancée en janvier 1984, les réponses devant parvenir pour le 19 mars. Pour toutes les autres charges utiles devant voler lors de la première mission d'Eureca, l'ESA a demandé des assurances financières de la part des autorités d'approvisionnement pour la fin mars 1984.

A la suite des discussions précédentes et en accord avec les aspirations de l'ESA, la NASA a confirmé en janvier le prix de la première mission commune de déploiement et de récupération d'Eureca, l'élément 'récupération' étant facturé à 30% du coût du lancement.

Microgravité

Biorack

Les problèmes de conception en suspens (incubateurs et enceintes thermiques passives) ont été résolus. La fabrication et l'intégration de ces unités progressent et les essais au niveau des unités sont prévus pour les mois de mai-juin. Une baie Spacelab a été livrée à Matra en vue de l'intégration du câblage électrique et des conduits d'air. Les négociations en vue d'un contrat d'activités 'assemblage-intégration-essais' sont terminées.

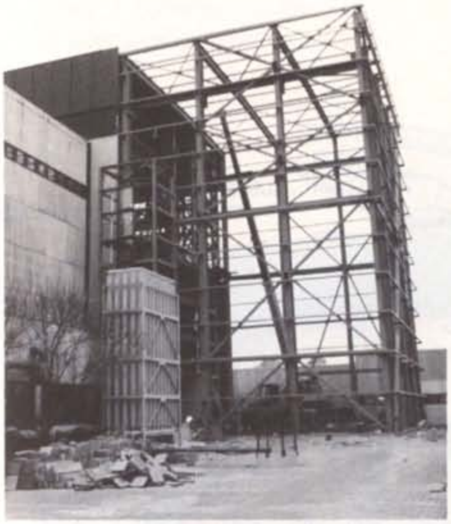
Au cours de cette période, on a procédé à plusieurs examens de la mission D-1 portant, en particulier, sur l'aptitude à l'intégration de la charge utile, les interfaces de fonctionnement du Biorack et les postes de travail de l'équipage.

Par ailleurs, on a étudié les incidences de la prolongation de la durée de la mission D-1 qui passeraient de 7 à 10 jours sur le matériel Biorack et sur les opérations.

Le calendrier reste préoccupant: les retards affectant l'approvisionnement de composants pourraient se traduire par une incompatibilité de quelques semaines entre les premières dates possibles de livraison du Biorack et les dates imposées par la mission D-1. Les dispositions supplémentaires qui seront requises pour que la durée de la mission soit prolongée ne feront qu'aggraver les problèmes de calendrier.

Ariane

Pour les informations et le manifeste Ariane, voir page 106.



New Integration and Test Facilities at ESTEC

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For the new generation of spacecraft constituted by Ariane-3/4 and Shuttle-class payloads, new investment in the ESTEC integration and test facilities has become necessary. Three major facilities are presently being implemented: an additional integration area, a multishaker system and a Large Space Simulator (6 m diameter parallel solar beam). These facilities will serve to meet the most urgent requirements of the Agency's test programmes.

Background
The need for new investment in integration and test facilities was studied in detail in 1980/1981 against programme assumptions for the Agency's ten-year plan [ESA/C(80)80, ESA/C(81)8] and an assessment of the expected developments in national and commercial programmes, in so far as these were known at that time. At the same time, the test philosophy applicable for the new generation of spacecraft constituted by Ariane-3/4 and Shuttle-class payloads was also reviewed, paying particular attention to the minimising of the need for additional facilities in Europe whilst maintaining an appropriate verification approach for the substantial hardware to be developed. The need for European independence, in terms of both launch capability and test capacity, was also taken into account.

The above led to the definition of a proposal for investment in new/upgraded integration and test facilities that ESTEC would require, as a minimum, to cope with future programme requirements. The proposal also took into account all the facilities at the national test centres (CNES, IABG and IAL) that can be used for the Agency's programmes. This was the basis for the ESA Capital Investment Plan [IPC(82)10] which was discussed on various occasions at Industrial Policy Committee level and was eventually approved by Council in April 1982.

As far as ESTEC is concerned, the three major investments approved were:
- extension of the integration area
- installation of a multishaker system (electrodynamic)
- adaptation of the existing Dynamic Test Chamber (DTC) facility for solar simulation.

The total investment will amount to about 27 MAU at 1982/83 price levels (1 AU = ± 1 US$).

The purpose of this article is to outline the new facilities that are either already complete or are in the procurement phase, and also to provide a brief review of future requirements. When the new facilities are fully operational, more detailed descriptions will be the subject of dedicated articles.

Overall layout of the new large facilities
Figure 1 is an artist's impression of the new building complex for the new integration and test facilities of ESTEC's Test Services Division. The large building housing the existing DTC facilities (left of figure) has been extended in three directions. The extension to the north (right-hand side) accommodates the new large multishaker system as well as the physical-measurement machines, and also provides an additional integration and checkout area. The other extensions to the building (east and south) were needed for the adaptation of the DTC facility to provide for solar simulation (see Fig. 2 also).

This extension programme has allowed investment to be kept to a minimum by making as much use as possible of available facilities and infrastructure. In addition, the new layout allows all the integration and test activities needed for future large spacecraft – checkout,

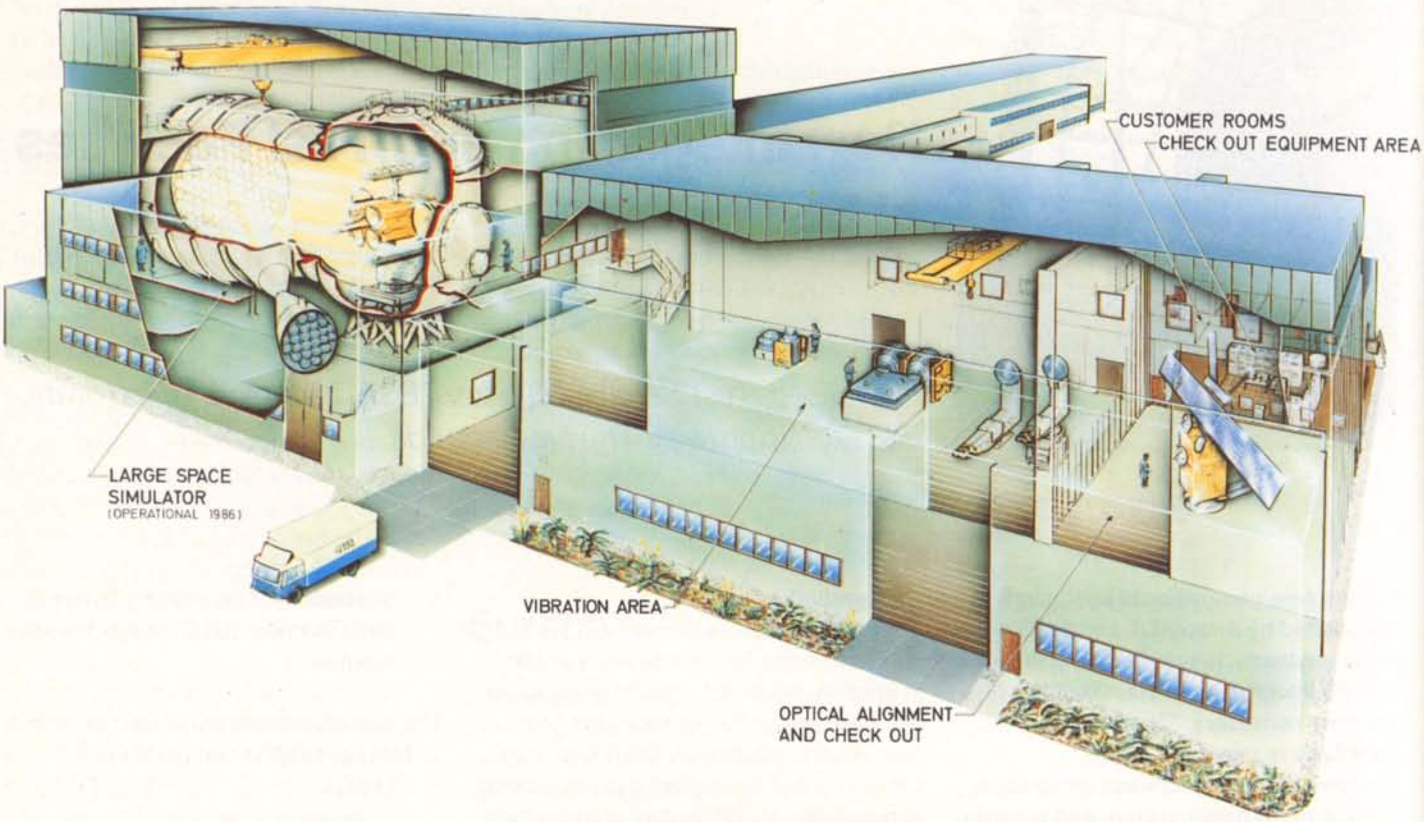


Figure 1 – New building complex for the large integration and test facilities at ESTEC

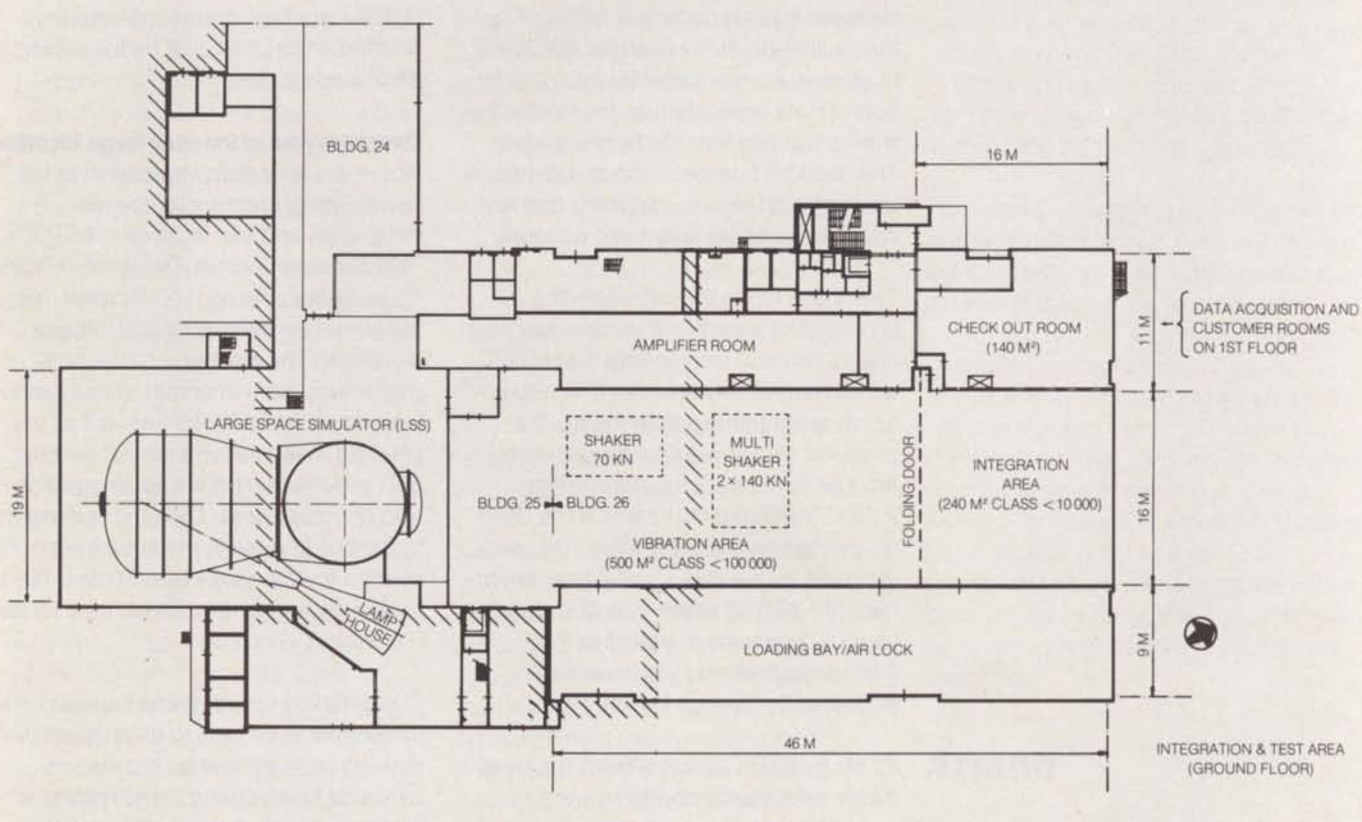


Figure 2 – Plan of new integration and test area

alignment, physical measurement, vibration and solar simulation – to be conducted in a single building, thereby avoiding unnecessary packing and unpacking, transport and checkout activities. The new building includes all the necessary support services, including airlocks, service areas, data-handling systems, customer rooms, storage room for containers, etc.

Integration and test area

Figure 2 is a plan view of the new integration and test area (building 26). The centre part of the building is a clean-room area, about 46 m × 16 m and 12 m high (crane hook).

Two 10 ton overhead cranes are available for the handling of test hardware. The room is subdivided by a folding door. The vibration area (cleanliness less than 100 000) covers about 500 m² and houses the existing 70 kN shaker, the new multishaker system (2 × 140 kN) and various physical-measurement machines. Ample room is available for Ground-Support Equipment (GSE) and for pre- and post-test activities.

The integration area (cleanliness less than 10 000) covers about 240 m². It can be used for general integration or reconfiguration activities and is particularly suitable for optical-alignment tests. For the latter, the floor is mechanically isolated from the surrounding building by separate foundation piles, to keep the area free from external vibrations. The floor itself is finished with a special very flat, hard surface suitable for the stable support of optical-alignment equipment.

When necessary the folding door between the two areas can be opened to provide an extremely large area suitable particularly for large-scale deployment tests. One of the two side buildings, adjacent to the central area, contains a special checkout-equipment room with a floor space of 140 m², as well as customer rooms with office and meeting facilities. It also houses all the service equipment (amplifiers, pumps, etc.) and the data-acquisition systems for thermal and vibration data.

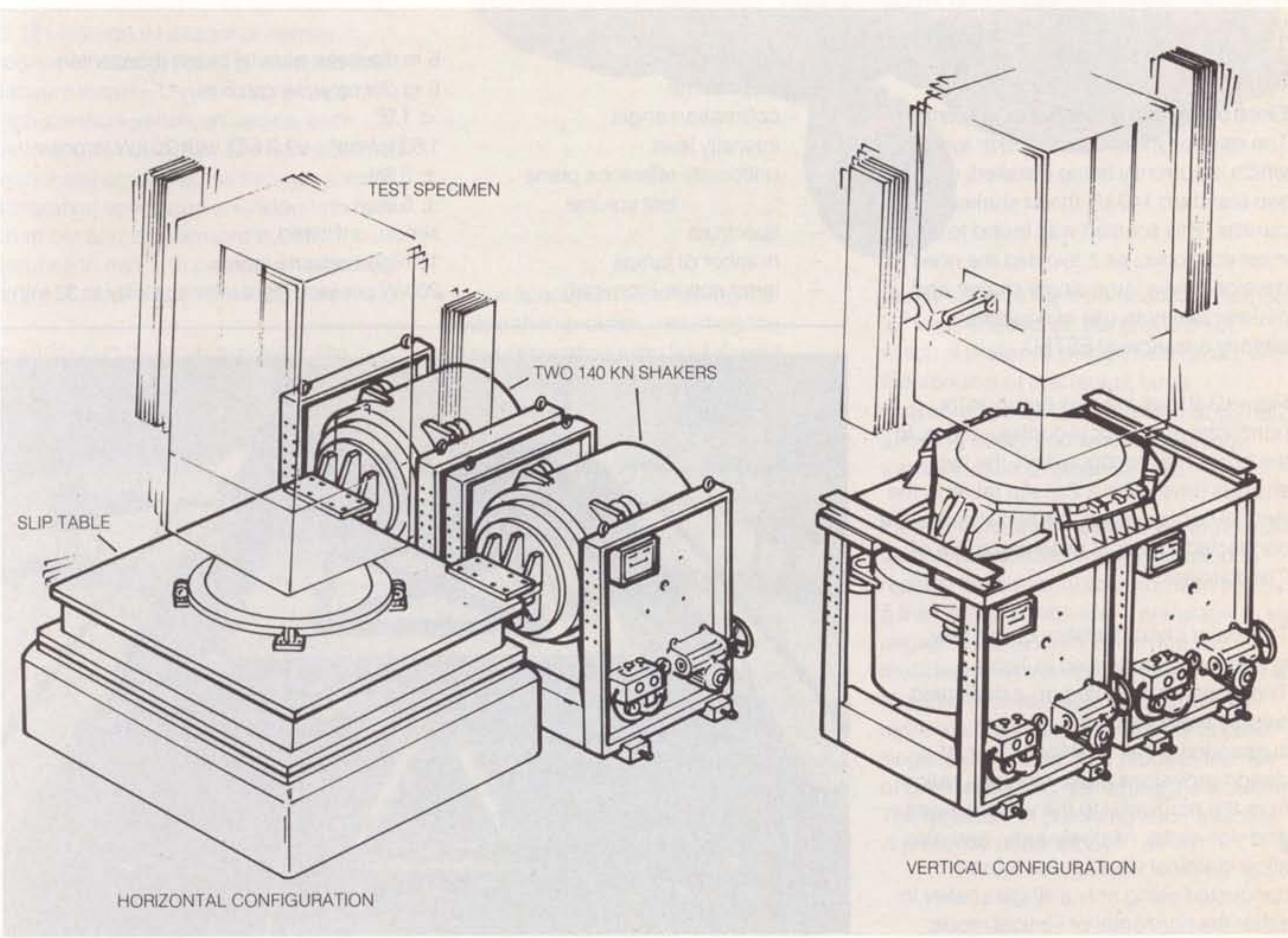


Figure 3 — Schematic of the electrodynamic multishaker system

Table 1

– shakers (LDS 984 LS)	2 × 140 kN thrust
– stroke	2 inch
– mass capability	2500 kg
– overturning moment capability	200 000 Nm
– control console	HP, digital
– frequency bandwidth	sine 5 to 100 Hz random 20 to 2000 Hz
– amplifiers current-phase-controlled in dual configuration.	

The loading bay on the other side of the central area has two large external entrance doors and serves as an airlock for test equipment to be brought into the clean rooms. Three doors from the loading-bay provide entry to the various clean-room areas. During test activities, the test-hardware containers can be stored in the loading bay.

Electrodynamic multishaker system
The electrodynamic multishaker system, which is currently being installed, employs two standard 140 kN thrust shakers in parallel. This solution was found to be the most economic, as it avoided the need to develop a new large single shaker and makes maximum use of equipment already available at ESTEC.

Figure 3 shows the new facility in its horizontal and vertical configurations. In the horizontal configuration, the two shakers drive a 2 m × 2 m slip table; in the vertical configuration, the two shakers are connected to a dual head expander of 2 m diameter.

The major characteristics of this new system are summarised in Table 1.
The system is mounted on a dedicated seismic block (500 ton), which is suspended on air cushions. Special design provisions make reconfiguration from the horizontal to the vertical mode, and vice-versa, relatively easy, and also allow classical vibration tests to be conducted using only a single shaker in either the horizontal or vertical mode.

Except for the dual head expander, all hardware is now in-house and acceptance testing is in progress. The first operational test is planned for the summer of this year.

Figure 4 shows the new system in its horizontal configuration, with the large slip table in the course of installation on the seismic block.

Large Space Simulator (LSS)
The existing large Dynamic Test Chamber (DTC), which has been in use since about 1975 for physical measurements, deployment tests and infrared thermal testing, is being converted into a Large Space Simulator by adding a large solar-simulation capability (whilst still maintaining its present capabilities). The new off-axis solar simulator will have the characteristics shown in Table 2.

Table 2

– solar beam	6 m diameter parallel beam (horizontal)
– test volume	6 m diameter, length 5 m
– collimation angle	< 1.9°
– intensity level	1.83 kW/m² (~ 1.3 SC) with 20 kW lamps
– uniformity reference plane	± 3.8%
test volume	± 5.9%
– spectrum	xenon, unfiltered
– number of lamps	19 high-pressure lamps
– lamp power (nominal)	20 kW per lamp (growth capability to 32 kW)

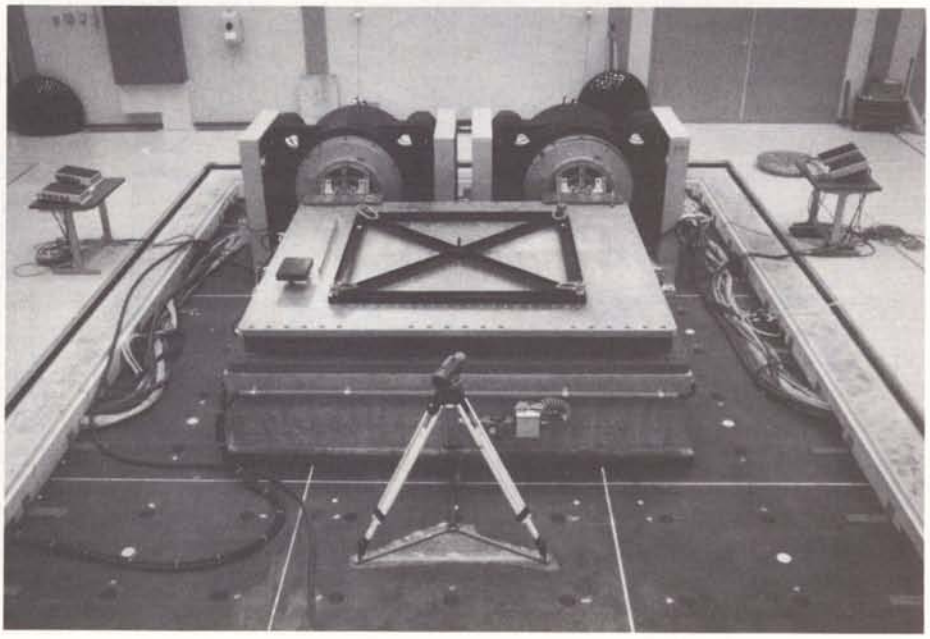
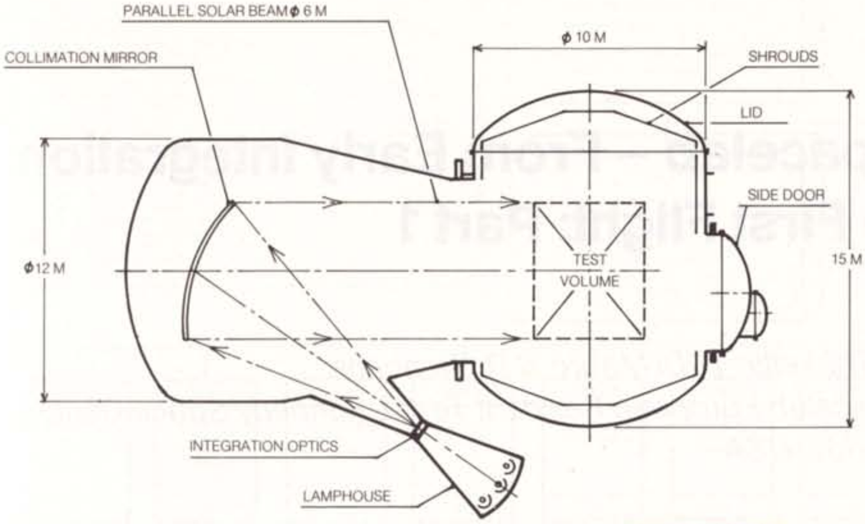


Figure 4 – The electrodynamic multishaker system during installation



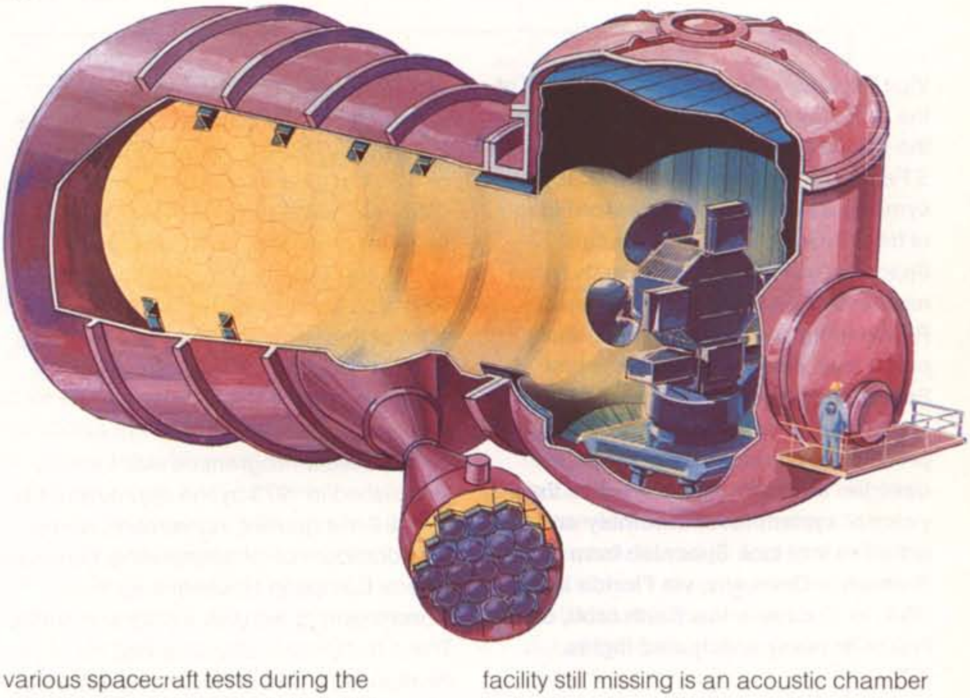


Figure 5 — Schematic and artist's impression of the Large Space Simulator (LSS)

Figure 5 shows a schematic and an artist's impression of the LSS. The vertical chamber is the existing DTC facility, 10 m in diameter and 15 m high. The horizontal one, which will be added, is about 12 m in diameter and will house a large optical collimation mirror. The diameter of the collimation mirror is 7.2 m and it consists of 121 individual hexagonal mirror segments. A lamp housing – outside the vacuum vessel – contains an array of 19 high-pressure xenon arc lamps, each delivering about 20 kW. The light collected from these lamps passes through special integration optics and a window into the chamber and is collimated by the collimation mirror to provide a horizontal beam of parallel light 6 m in diameter.

In addition to the solar simulator, the facility will be equipped with an LN_2-cooled shroud and a special motion system that can support test items weighing up to 5000 kg.

The overall coordination of various subsystems and support contracts and the systems engineering are being carried out by an ESTEC project group. All major contracts for the various systems, including those for the building extension, the vessel extension, the LN_2- and shroud system, and the solar simulator have been placed with European industry. The provision of the basic motion system is currently being studied.

The modification activities had to be planned with great care because the existing DTC facility still had to be used for various spacecraft tests during the modification process, including the fairing-separation tests for Ariane-4, which are planned for this summer.

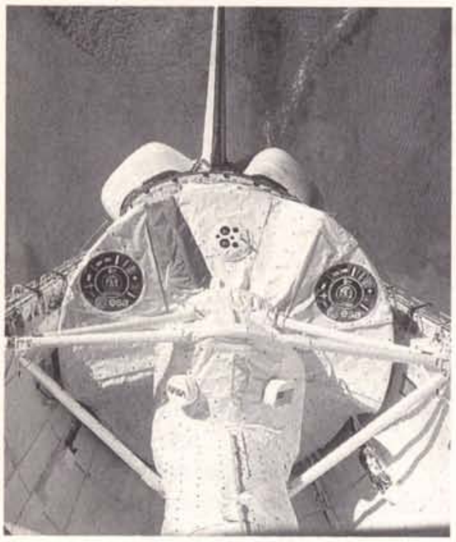
The building modifications were started in November 1983 and the first hardware for the extension of the vacuum vessel is due to arrive in June 1984.

The new LSS facility, planned to be operational in April 1986, will be the largest solar simulator in the world. For comparison, the solar simulator at Jet Propulsion Laboratories in Pasadena (USA) has a beam diameter of about 5.7 m.

Outlook

The new facilities outlined above were identified as being the most urgent requirements for the testing of the new generation of spacecraft. The only major facility still missing is an acoustic chamber for large spacecraft, the provision of which is presently being investigated. With the addition of this facility, large spacecraft could be fully tested at ESTEC, avoiding costly and time-consuming transportation to other centres.

Furthermore, with the evolution in Ariane-4 launch capabilities and the demand to replace the classical sine vibration test by a transient vibration test – preferably in six degrees of freedom – an hydraulic multidegree of freedom vibration facility is required. This test approach would be more realistic than the presently applied single-axis method, and reduces the risk of overtesting and damaging the test item. The feasibility of providing such a facility is presently under study.



Spacelab – From Early Integration to First Flight: Part 1

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Vice President Bush, on the occasion of the Spacelab Dedication Ceremony at the Kennedy Space Center on 5 February 1982, said that '...Spacelab symbolises the unity and determination of free Europe... The knowledge Spacelab will bring back from its many missions will belong to all mankind.' Resounding words that will hopefully prove true. Last December, the first Spacelab mission was successfully completed. Getting there was a long process, and this article attempts to describe and put into perspective the $5^1/_2$ years of system-level assembly and test activities that took Spacelab from Bremen in Germany, via Florida in the USA, to 10 days in low Earth orbit, on the first of its many anticipated flights.

At 11.00 AM Eastern Standard Time on 28 November 1983, Space Shuttle Orbiter Columbia (STS-9) lifted off from launch pad 39A at the Kennedy Space Center (KSC) carrying Spacelab-1 in its payload bay. Ten days later, on 8 December, Columbia landed at Dryden Flight Research Center, ending this historic first flight of Spacelab which, by any measure, was an extremely successful mission for all concerned.

The Spacelab Programme was formally established in 1973 by the approval of the formal Arrangement, Agreements and a Memorandum of Understanding, between several European Governments, the Government of the USA, ESRO and NASA. These documents all concerned the development, procurement and use of a space laboratory in conjunction with the Space-Shuttle System. They were produced following 'the offer of the Government of the United States of America to Europe to participate in the major US space programme which follows the Apollo Programme', to quote the preamble of the Memorandum of Understanding.

With the issuing of these documents, there began the long process by which the Spacelab came about, to culminate more than ten years later in the successful first mission of Spacelab-1. The ESA Member States participating in the Spacelab Programme, Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland and the United Kingdom, later to be joined by Austria, undertook the funding of the development of Europe's first venture into the field of manned space programmes, entrusting the management of the project to ESRO, later to become ESA.

The basic demarcation of responsibilities defined by the above documents was that Europe would define, design, develop, qualify and deliver to NASA one prototype Engineering Model (EM), one Flight Unit (FU), two sets of Ground-Support Equipment and spares/documentation, whilst the USA would support the European effort, produce the Shuttle and Transfer Tunnel, and operate Spacelab within the Shuttle Programme. In addition, NASA would procure a second Spacelab if it met its design requirements and if an agreed price could be established.

Early in 1974, ESRO issued a Request for Proposals (RFP) to industry and, as a result of their subsequent evaluation, a contract was signed with an industrial consortium headed by ERNO (Fig. 1), established specifically for the Spacelab Programme. As Prime Contractor, ERNO was to be responsible for the system-level design, integration, testing and delivery to the USA.

This article presents a history of Spacelab's development, from the arrival at ERNO of EM components to the post-flight landing of the Spacelab-1 configuration aboard the Orbiter Columbia. The project has had a long, and at times troubled, background. We will attempt here to put some perspective into this history and to consider the future in terms of further Spacelab utilisation and its possible evolution into the realm of Space Station.

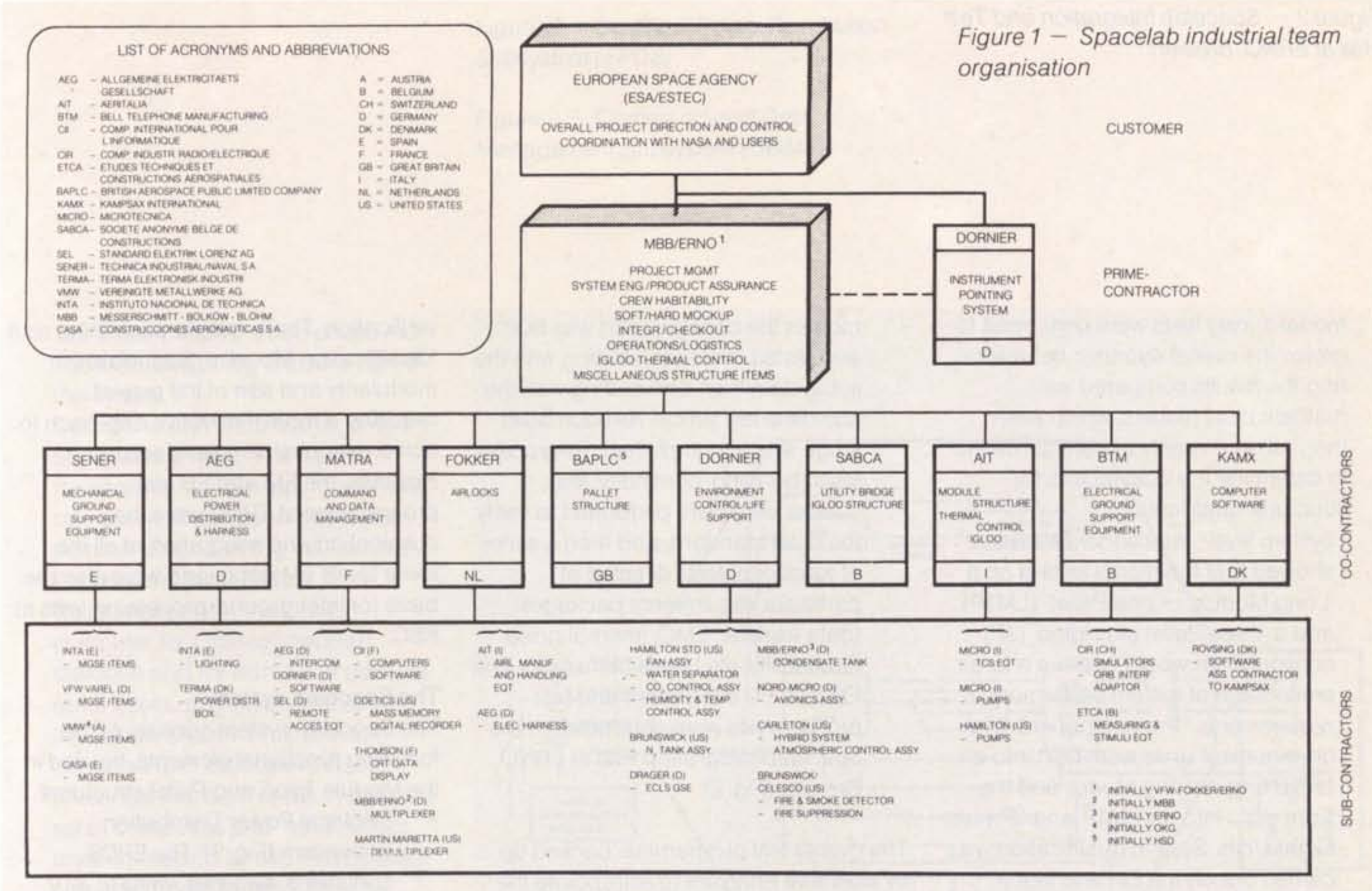


Figure 1 – Spacelab industrial team organisation

Spacelab's development programme

Project test philosophy

Spacelab is not a single entity, like a satellite or an aeroplane, but is rather a set of flight elements that can be 'kitted together' in various configurations. These configurations can involve Long or Short Modules, mixed Module/Pallet modes, or Pallet-only modes. Basic subsystem elements are housed in the forward end (subsystem train) of the Module or, for Pallet-only modes, in an Igloo. Other subsystem elements needed for a particular mission (i.e. mission-dependent equipment) are located throughout the rest of the Module and/or Pallets, along with the payload equipment to be flown.

This fundamental modular feature of Spacelab's design was the determining factor when establishing the overall programme test philosophy. It was clearly not possible, for cost reasons, to consider full-scale system testing of all configurations, and no single configuration enveloped the others in terms of mechanical, thermal, power, data and electromagnetic cleanliness requirements, etc. The size of any configuration (Spacelab was designed to occupy the whole 15 ft diameter × 60 ft long Orbiter payload bay) precluded full-scale environmental testing due to facility limitations. In addition, because the laboratory was designed for a multitude of payloads with totally different characteristics, all of which were in an at best embryonic stage of development, any full-scale environmental testing of a system element would never represent a real flight configuration.

A hybrid programme of testing was therefore developed to qualify the design and accept the flight hardware to all of its requirements, with the following general features:

- Component level: The range of environmental parameters for every component in any system configuration was established analytically and enveloped. Two development models were built, one of which was tested functionally and delivered to ERNO for subsequent integration into the EM, and the other was used for initial subsystem-level testing at the co-contractors. A qualification unit was built to a design standard incorporating changes from the development programme and tested environmentally to levels established from system-level vibrations tests and thermal analyses, and functionally to the individual performance requirements, including all safety factors and design margins. A flight article was built and subjected to acceptance-level testing consisting of unfactored environmental levels and performance requirements.
- Subsystem level: Command and data-management and environmental control/life support subsystems were built (separately) into functional subsystem test articles; internal interfaces within the subsystem, external interfaces (Orbiter and payload) and general performance characteristics were established. The structural elements were developed and qualified at subsystem level.
- System level – mechanical: A Short Module and a Pallet test article were built, and subsystem and experiment mass dummies were installed, together with representative cabling, plumbing and ducting. Each test article was subjected to acoustic noise (corresponding to the Orbiter payload-bay level) to determine the random vibration environment, to which the component qualification tests were performed. Low-frequency

Figure 2 — Spacelab Integration and Test Hall at ERNO, Bremen

modal-survey tests were performed to determine overall dynamic behaviour and the results compared with mathematical models, which were then run in a variety of configurations to determine the load factors for structural qualification.

– System level — functional: Studies showed that functional testing on a 'Long Module — one Pallet' (LM1P) and a 'three Pallet plus Igloo' (3P) configuration would capture a large percentage of system performance requirements. The component-level development units were built into an LM1P Engineering Model, and the flight units into an LM1P and 3P train Flight Units. System qualification was carried out on the EM and flight-hardware acceptance on the FUI and FUII configurations. For all of these models the configuration was built and tested in stages, starting with the subsystem train and ending with the complete test article. As each build stage was accomplished, 'in-process' tests (bonding, continuity, leak checks, etc.) were performed to verify the build standard, and then a series of functional tests directed at particular requirement packages (data transfer, EMC, internal noise, habitability, etc.) were performed. The EM and FU integration and test programmes were conducted in the Spacelab Integration Hall at ERNO, Bremen (Fig. 2).

The overall test programme, backed up by extensive analyses to extrapolate the test results to all required configurations, was the basis for overall requirements verification. There was no such thing as a 'Qualification Model' of Spacelab, the modularity and size of the project requiring a more innovative approach to achieve requirement satisfaction. However, the EM and FU test programmes at ERNO were the culmination and integration of all the lower levels of testing, and were also the basis for later ground-processing tests at KSC.

The Spacelab system

The Spacelab system consists of the following functional elements, housed in the Module, Igloo and Pallet structures:

– Electrical Power Distribution Subsystem (Fig. 3): The EPDS conditions, switches, limits to 32 V and distributes the DC Orbiter fuel-cell supply as 24 – 32 VDC or

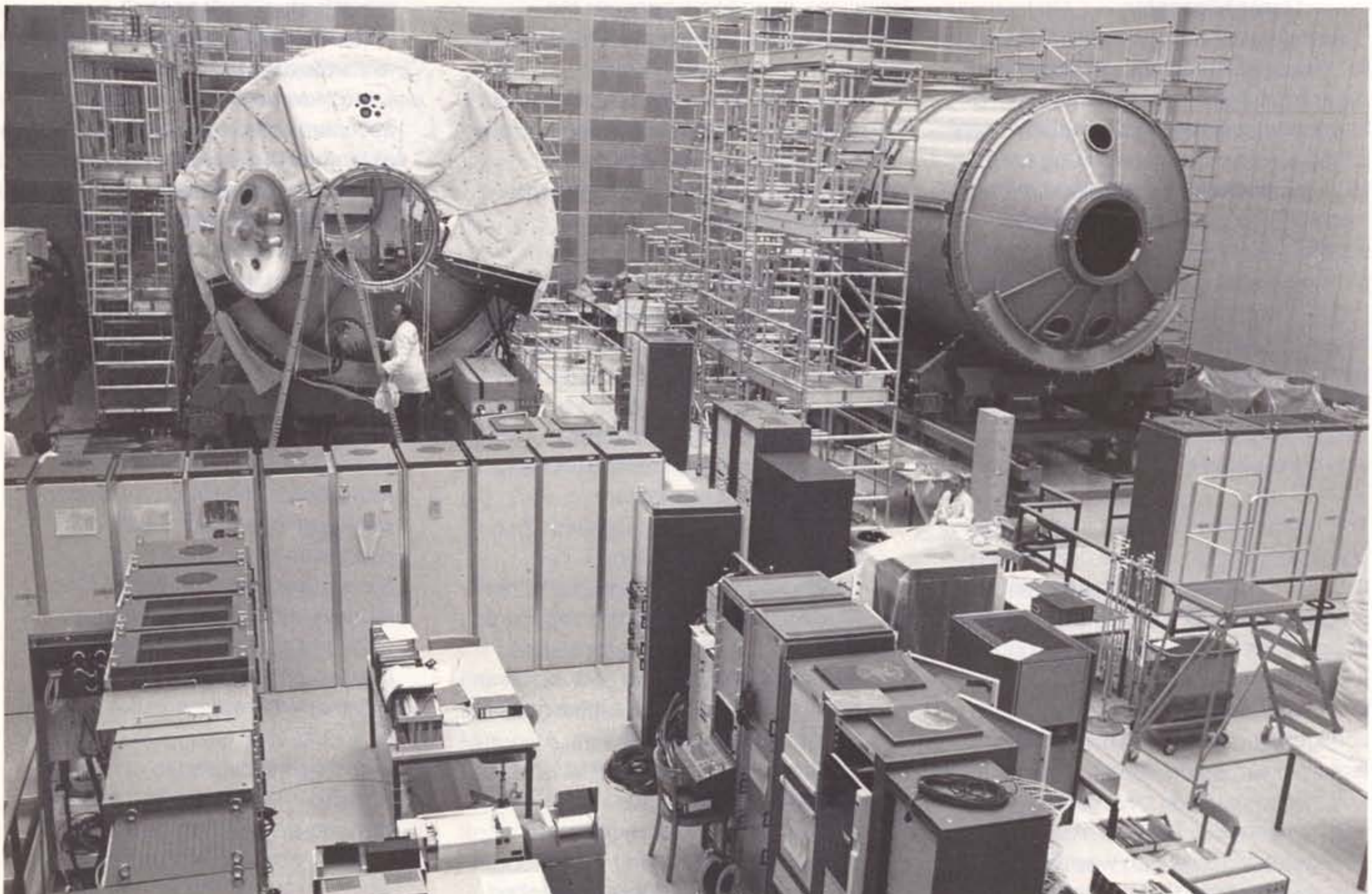
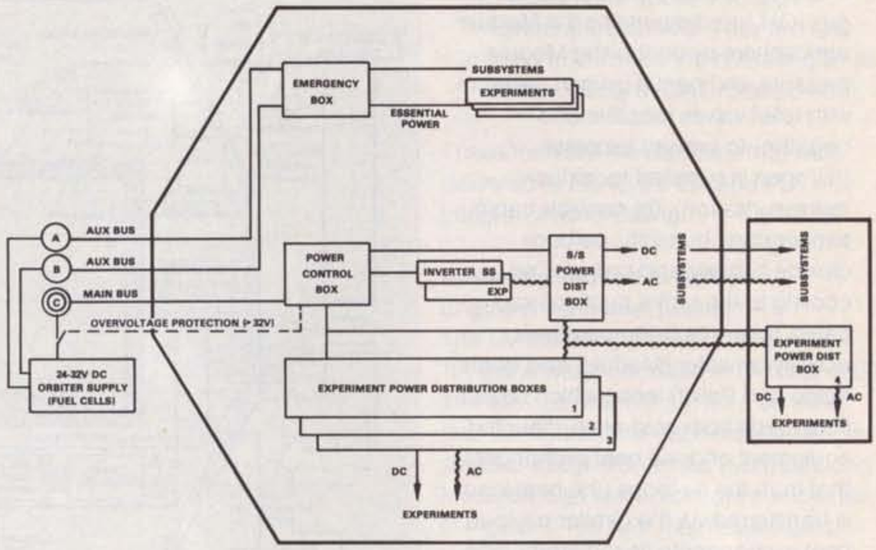


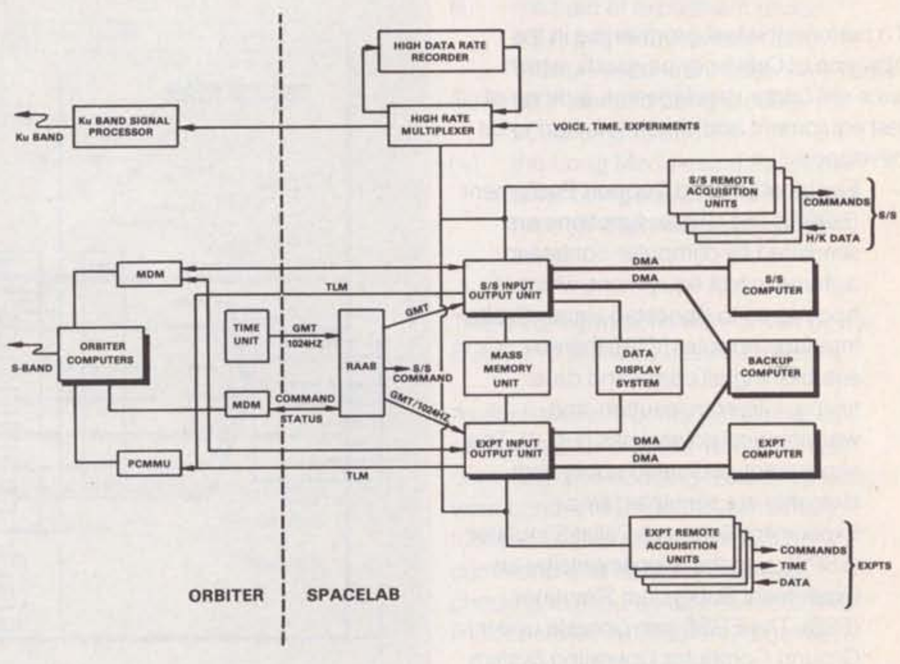
Figure 3 – Electrical Power Distribution Subsystem (EPDS)

Figure 4 – Command and Data Management Subsystem (CDMS)

115 V/200 V 400 Hz three-phase AC. The Module lighting is also a part of this system.

- Command and Data Management Subsystem (Fig. 4): The CDMS (a) acquires housekeeping and low-rate scientific data and distributes commands and timing via Remote Acquisition Units (RAUs), (b) interfaces with the Orbiter computer for Orbiter/Spacelab dialogue and for transfer of data via serial buses, and (c) interfaces with the Orbiter Master Time Unit for Spacelab and experiment clock reference. The core of the system is a set of computers and input/output units connected by two independent command/data buses. The crew access the computers via Data Display Systems (DDSs), and software is stored in a Mass Memory Unit (MMU). High-speed data is acquired by a High-Rate Multiplexer (HRM) and transmitted to the Tracking and Data Relay Satellite System (TDRSS) via the Orbiter. A High-Data-Rate Recorder (HDRR) stores data during orbital times when the TDRSS is not accessible. The essential elements of the Spacelab subsystems are activated under the control of the Orbiter computer via the Remote Advisory and Amplifier Box (RAAB); the experiment-dedicated subsystem elements and the HRM/HDRR are activated by subsystem RAU commands. There are also control panels for backup controls. Voice and video connection to ground is via intercom and closed-circuit TV.
- Software: There are separate Subsystem Computer and Experiment Computer Operating Systems (SCOS and ECOS, respectively).
- Caution-and-Warning Subsystem: The caution-and-warning subsystem monitors critical safety parameters and issues alarms (visual and audible) if limits are exceeded. A manually activated fire-suppression





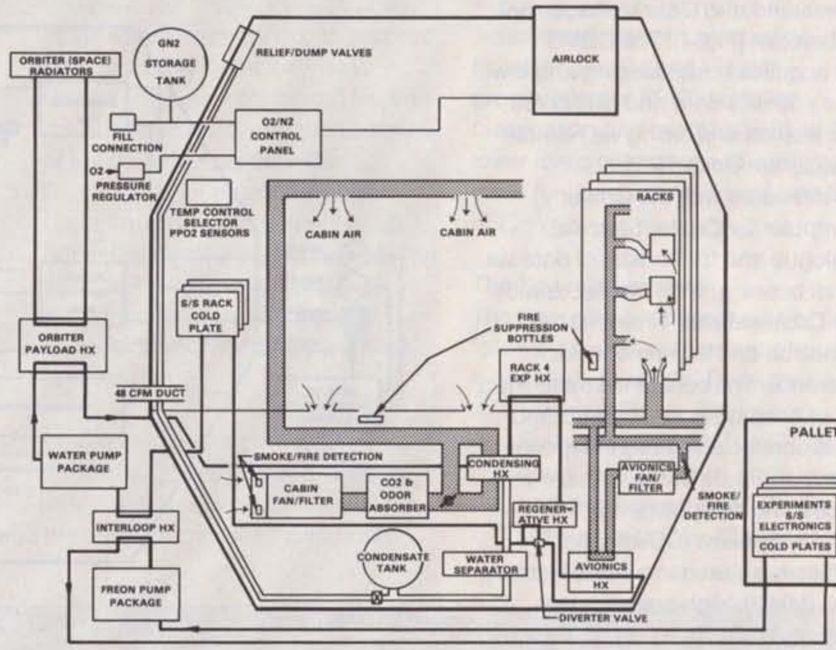


Figure 5 — Environmental Control Subsystem (ECS)

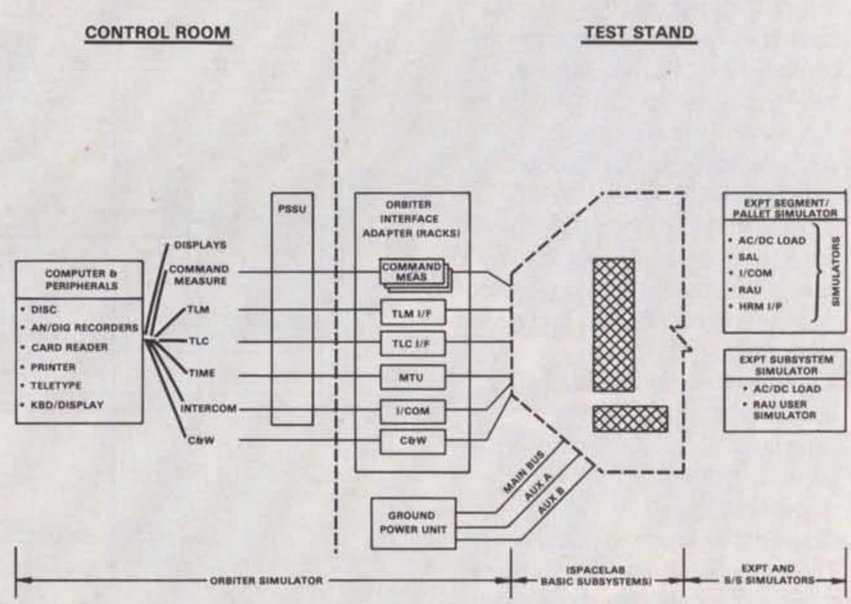


Figure 6 — Electrical Ground Support Equipment (EGSE)

system is provided for the racks and subfloor.

- Environmental Control Subsystem (Fig. 5): The ECS (a) stores make up gas (GN_2) and maintains the Module atmosphere by controlling Module pressure and partial oxygen pressure, with relief valves (positive and negative) to prevent excesses (nitrogen is supplied for airlock repressurisation), (b) controls cabin temperature, humidity, carbon-dioxide content and provides air cooling to the racks, subfloor and cabin, (c) controls temperatures actively by water (Module) and freon (Igloo and Pallet) loops which collect heat loads from cold-plate-mounted equipment and, via heat exchangers, that from the air loops (the heat load is transferred via the Orbiter payload heat exchanger to its radiators), and (d) controls temperatures passively by the use of multilayer high-performance insulation blankets to protect the Module, Igloo and Pallet-mounted equipment from temperature extremes.

To perform the test programme in the absence of Orbiter or payloads, which were still under development, a range of test equipment and simulators had to be developed:

- Electrical Ground Support Equipment (EGSE): The Orbiter functions are simulated by computer-controlled automatic test equipment, which is hooked up to Spacelab via an Orbiter Interface Adapter (OIA), thereby establishing all command data, timing, intercom, caution-and-warning and power links (Fig. 6). The experiment-dedicated subsystem elements are simulated by an Experiment Segment/Pallet Simulator (ESPS), and the experiments by an Experiment Subsystem Simulator (ESS). The EGSE can operate under Ground Computer Operating System (GCOS) software in four modes: checkout, self-test, data playback and data reduction.

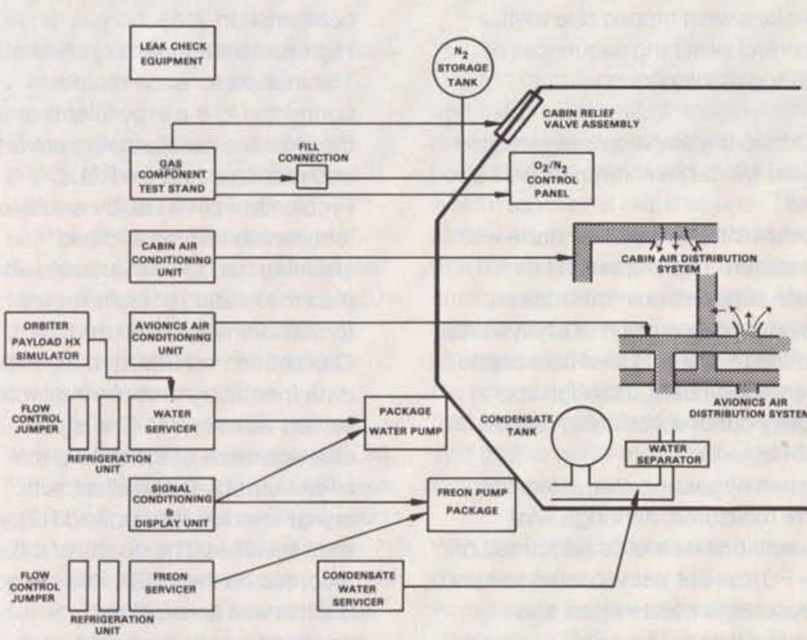


Figure 7 – Servicing Ground Support Equipment (SGSE)

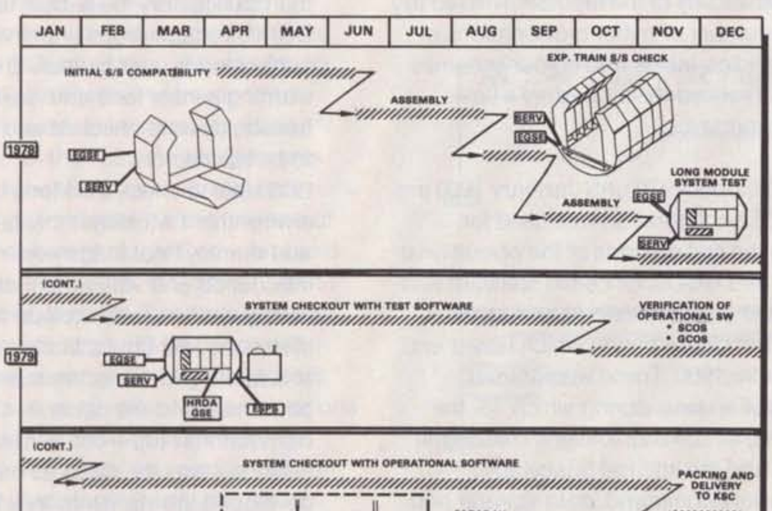


Figure 8 – Engineering-Model (EM) flow at ERNO, Bremen

– Servicers (Fig. 7): a series of 'servicers' simulate the Orbiter equipment with regard to heat rejection and coolant fluid/gas temperature control. They are also used to minimise the operating times of the onboard rotating equipment.

These then are the elements that were delivered to ERNO for EM and FU integration and testing.

Assembly and test in Europe

Engineering-model testing

The EM test programme started in April 1978 and was completed in October 1980. The activities carried out on a series of four configurations, each representing a stage of integration of the eventual Long Module/Pallet test article, are summarised in Figure 8. The four main assemblies tested were:

(i) the equipped control-centre rack, work-bench rack, subsystem floor and subfloor. This, the subsystem train, is the heart of Spacelab and houses the basic elements of the CDMS, EPDS and ECS

(ii) the train of experiment racks equipped with representative mission-dependent subsystem items

(iii) an integrated Long Module containing (i) and (ii)

(iv) the Long Module and Pallet, the latter being equipped with typical mission-dependent subsystem items.

These configurations were driven by the EGSE and servicers described above.

As each element of the test article was assembled, 'in-process' tests, such as continuity and bonding-resistance tests, were conducted, and the elementary functions of the power-distribution, command and data systems were checked to ensure that interfaces and links operated satisfactorily together.

Many fit-check and basic wiring problems were encountered and had to be corrected. Throughout the assembly phase, each gas, liquid and pressure shell joint and each relief valve were leak-checked, as were the airlock hatches. Other than a modification to the freon-line mechanical joints, these checks showed that leakage was not a problem. Before each rack was placed in the configuration, an avionics air-flow balance was performed to obtain the requisite cooling distribution. The whole train of racks inside the Module was checked to ensure sufficient total cooling and its correct distribution. Improvements were made to the rack duct butterfly valves for more reliable locking as a result of these tests.

Once the LM1P configuration was established, in February 1979, the first series of system-level tests took place. These used test software and were generally conducted with little automation. This fact, coupled with problems of the test software itself and many EGSE malfunctions, slowed down the early phases of the programme. The avionics tests conducted in this phase, which lasted until October 1979, included:

- powerline isolation from structure, and DC/AC distribution to racks, airlock and Pallet switching units
- RAU data acquisition and command functions via both subsystem and experiment data buses
- signal characteristics at the Spacelab/EGSE time, telemetry, telecontrol interfaces at RAU outputs
- caution and warning and fire-suppression system functions
- initial electromagnetic-susceptibility and emission evaluation.

A number of significant problems arose which led to design and procedural changes. In addition to EGSE piece part and harness failures, a number of onboard equipment problems were resolved:

- computers were modified to enable software loading to be achieved
- Data Distribution Units (DDUs) failed due to instability in the high-voltage power supply
- inverters were damaged by incorrect modulation of the main-bus voltage
- power-distribution box circuit breakers were tripped due to incorrect switching sequences of rotating machinery.

In addition to the above avionics-related testing, the Module environment was also checked:

- Module internal acoustic noise was measured. This test verified that noise-suppression modifications introduced as a result of analysis had reduced noise to a level acceptable to crew members, although still slightly out of specification above 250 Hz.
- System offgassing characteristics were measured. Although final acceptance was to be performed on the FU, the EM test validated test and measurement techniques and showed that the typical characteristics were favourable.
- Potential NASA mission specialists participated in a 'Crew Compartment Fit and Function' test to check the habitability of the Module. This led to a number of minor modifications of handles, labels and colour schemes, but verified the laboratory's basic ergonomics.

From October 1979 until January 1980 the EM/GSE configuration was used for testing the first versions of the operational SCOS and GCOS. Once the software was stabilised and understood, a second major test phase began which lasted until November 1980. These were formal qualification tests during which, for the first time, all communications links to the EGSE, and the internal Spacelab acquisition, command, data storage and keyboard/display functions were active simultaneously. The following tests took place:

- Power- and data-bus interface tests between the subsystem train and the experiment train, using the ESPS at the physical interface.
- Sensor calibration/accuracy checks on more than 200 sensors which monitor housekeeping data (voltage, current, temperature, pressure, power consumption, etc.).
- High-rate data-assembly checkout. The multiplexer and recorder connected to the experiments and the Orbiter simulators were activated and monitored via the RAUs. Problems of HRM cable-connector termination failures and bad shielding had to be overcome, and then the loading of eighteen test formats from the MMU and the Orbiter into the HRM, and the HRM data formatting/multiplexing, were verified as error free. The signal characteristics of the data at the HRM output were excellent, with signal-to-noise ratio up to 30 dB less than specified. The quality of data recorded on the HDRR was not good, but this was an expected phenomenon because the development model being used had shown poor results at bench level. Modifications were made to later (FU) recorders and their performance was then satisfactory. Data-bus noise, DC/AC voltage drops under various current loads, and caution-and-warning sensor tone and alarm noise thresholds were checked and found to be satisfactory.
- ECS tests to check the Module environment. Multilayer insulation and dummy heat loads were introduced and various experiment configurations, cabin-temperature selections and orbit attitudes were simulated. (No subjective tests were performed and the cabin air-distribution setup – diffuser and duct settings – was the same as had been developed at subsystem level.) These tests confirmed analytical predictions that condensation could potentially occur in deep-space-pointing Spacelab attitudes and a number of modifications had to be added to the FU design (e.g. the 'cold-case fix' diverter valve and regenerative heat exchanger).

- Metabolic condensate removal was verified with functional tests on the water separator and condensate dump components. Functional testing of the O_2N_2 control panel and pressure relief/dump valves was successful.
- The electromagnetic cleanliness (EMC) of the system was checked with the entire configuration surrounded by a Faraday cage. Spacelab's radiated emission at the forward end, the centre of the Module and above the Pallet, and the conducted emission on the power lines were measured. The susceptibility of Spacelab, particularly its High-Rate Data Assembly (HRDA), to Orbiter radiation, power-line spikes and conducted noise was evaluated. The system was found to be clean and tolerant, except for minor current sensor instabilities. A known defect caused by inadequate filtering in the Direct Memory Access (DMA) input-output unit which led to software crashes was confirmed, and this was corrected on later models. During the EMC tests, a deficiency in the telemetry coupler microcode of the Input/Output Unit (IOU) was found and all units had to be modified.
- Hardware/software compatibility. Most of the software requirements had been verified on a 'real-time simulation facility', a compilation of development model Command and Data Management System (CDMS) and EGSE units. The software was then tested on EM/EGSE to verify mass memory loading and access, data management, HRDA operations and DDS displays. A six-hour endurance test was performed via simulated increased traffic for all computer functions – RAU data acquisition, MMU read/write, DDS commands, Orbiter dialogue and data multiplexing. The 'experiment software' used in this test was an adaptation of the subsystem software, as the operational ECOS was not yet available. These tests showed that about 60% of computer processing time was available for additional CDMS application software.

This ten-month period of testing, together with the programme of unit-level testing and system-level analyses, formed the basis for the qualification of the Spacelab system functional requirements. The LM1P results were extrapolated to show that the characteristics of all other configurations were acceptable. Many lessons had been learned, and design changes made, all of which were fed into the ongoing FU programme, to ensure that its build standard would be better, and that its performance would meet all requirements.

With the EM functional testing thus completed, the parallel tasks of Acceptance Review and preparation for shipment to NASA/KSC began. The configuration had to be disassembled into transportable parts. The Module was split into two segments and these, together with two Pallets and some 150 crates of 'smaller' items (including one set of EGSE, servicers and handling equipment), were trucked from Bremen to Hannover. There, a USAF C5A 'Galaxy' transport and a Lufthansa Boeing-747 were loaded for their flights to Cape Canaveral on 5 and 8 December, respectively. Hence the Spacelab EM was delivered some $6^1/_2$ years after initial contract award, at the end of 1980.

Flight-unit testing

As mentioned earlier, two configurations were assembled and tested in Bremen, one a Module – Pallet mode, and the other an Igloo – Pallet train. Although the details of each were quite different, the principles were the same and therefore only the 'FUI' programme is described here.

The test programme started in November 1979 and was completed in October 1981. Figure 9 summarises the main features and shows that, as for the EM, a series of configurations were tested as each assembly was progressively integrated. Again the 'in process' tests of joint leakage, bond resistance, rack air-flow balancing, etc. were performed at the

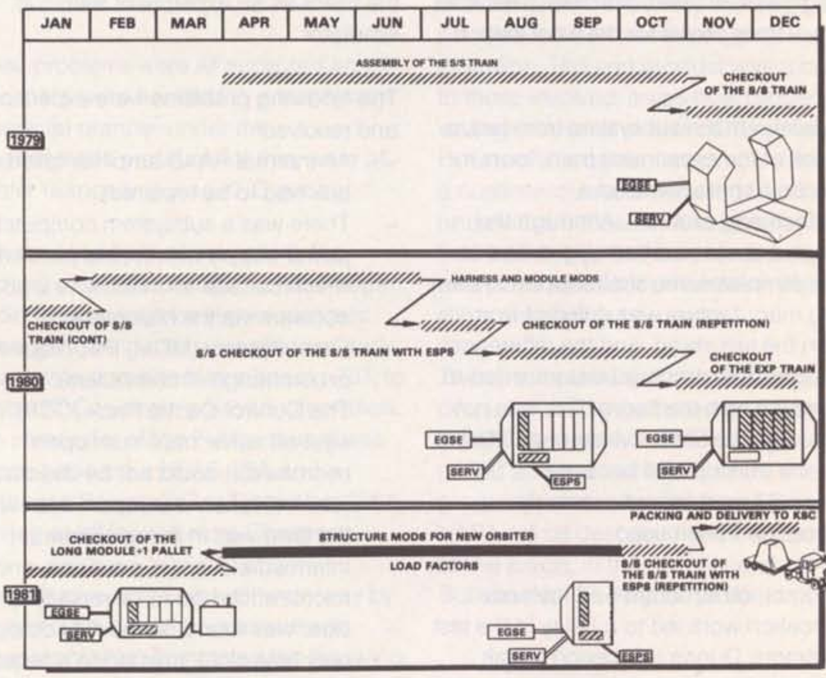


Figure 9 – Flight-Unit (FUI) flow at ERNO, Bremen

Figures 10a&b — First Spacelab Flight Unit (FUI) leaving Bremen for KSC

appropriate times. The same EGSE and servicer set-ups were used, but operational software was used throughout the FU test programme. In fact several versions of this software were used, partly due to its late development and partly as a result of change traffic. The initial version had several missing functions, but development was organised in such a way that each test phase was adequately supported.

The first test was performed on the subsystem train to verify polarity, voltages, hardware commands and basic EGSE — Spacelab communication links. This was followed by extensive tests on the data-handling and transmission functions and by checks on the intercom, caution and warning, power switching and ECS/EPDS sensing devices. During these tests, failures of an IOU, RAAB and DDU were experienced and repairs initiated. Whilst exchanging IOUs in the work-bench rack, the basic DMA harnesses connecting the IOUs with the computers were damaged. The existing routing of these cable bundles was evaluated and judged to be inadequate for a multimission vehicle and so a significant redesign was initiated, which also resulted in a new front profile for the work-bench rack.

In parallel with the subsystem train test, a fit check of the experiment train floors in the Module shells revealed a manufacturing problem. Although the floors and shells had been 'jig-drilled' to master templates, the shell support system during manufacture was different from that on the test stand, and the differences in Module shell structural distortion led to a mismatch with the floors. This was not detected on the EM because of a different tolerance buildup and because somewhat less stringent assembly practices had been used.

The combined structure and harness modification work led to a delay in the test programme. During this period a leak check on the freon pump package on the forward end cone revealed a degradation in its neoprene seals. These seals expand when in contact with freon 21, and contract again when dried, down to an even smaller cross-section. The problem was overcome by injecting freon vapour into the pump package to expand the seals back to adequate size. In July 1980, after the subsystem train had been installed in the core segment, it was successfully retested and its interfaces to the forward end cone were checked. At this stage a test called the subsystem checkout was performed. This test procedure was an agreed ESA/NASA operational ground-processing flow activity, later to be used at KSC, to verify that the core Module was ready for experiment train integration. All subsystem functions were checked extensively using the ESPS as an experiment train simulator.

The following problems were experienced and resolved:

- An internal RAAB amplifier failed (the box had to be repaired).
- There was a subsystem computer power-supply defect (this problem, which caused an inability to load software via the Multiplexer — Demultiplexer (MDM) link, required an exchange of computers).
- The Control Centre Rack (CCR) shut-off valve 'maximum open' microswitch could not be deactivated (the indication was 'open' even when the lever was in the minimum or intermediate 'open' positions, and the microswitch had to be replaced).
- Jitter was found on the IOU output user time clock (this led to a redesign of the IOU at a later stage).

Following this test the experiment train was rolled into the Module and its equipment checked prior to hookup to the subsystem train. The train consisted of only six racks, as two single and two double racks had been delivered to ESA's Spice centre for First Spacelab Payload (FSLP) integration in Bremen. The Pallet was hooked up to the Module and LM1P system testing began in November 1980, with the following main tasks:

- RAU command, data acquisition and time distribution functions testing
- caution- and-warning sensor and alarm-threshold calibration
- Spacelab/Orbiter interface test (using EGSE as an Orbiter simulator)
- crew-station review (a power-up functional test with flight crew member participation to check operability of equipment such as intercom, keyboard and airlock, activation sequences, general habitability parameters and internal noise levels)
- system checkout: the verification of all subsystem hardware located throughout the entire LM1P configuration. This test checks all sensing and alarm equipment, all DC/AC-powered items, all environmental-control-system hardware, HRDA multiplexing and RAU normal and redundant buses. This procedure was also an agreed ESA/NASA common flow, later to be the basis for the system test at KSC
- offgassing test (to verify acceptable material characteristics of the flight hardware).

These tests went quite smoothly, without too many problems. The EGSE and

servicers were, by then, well understood and quite reliable, and the software, although still subject to considerable detail-change traffic, was functionally stable. The following problems had to be resolved:

- a water-pump pressure differential switch was faulty
- a number of labels, decals and handles had to be modified due to crew comments. The viewport hatch lever and lithium-hydroxide storage container also had to be changed
- a computer autorestart failure occurred and was thought at the time to be due to defective IOU power supplies (in fact this problem was to return again in Bremen and at KSC).

These tests completed the package of formal Acceptance Test Requirements and thus, at the end of March 1981, the FUI configuration was ready for shipment to KSC. However, analysis of late increases in the Orbiter lift-off and landing load factors showed that modifications had to be made to the Module structure. The internal floor support structure and the floors themselves had to be strengthened, and to incorporate these changes the subsystem and experiment trains had to be taken out of the shells. Although the changes were simple structurally, the disassembly and reassembly of the Module each took several weeks, and many major functional interfaces had to be broken and had therefore to be reverified.

In October 1981, a rebuilt Short Core Module was ready for a repeat of the subsystem checkout procedure with the ESPS. This was performed under considerable schedule pressure, due to the desire to deliver the FU to KSC before the end of the year, with the following problems:

- a computer power supply failed and the unit had to be repaired
- HRM bit-pattern sensitivity was experienced. This was closed out as an EGSE problem, but was subsequently determined at KSC to be an HRM design problem
- an intermittent failure to set the backup computer to hardware mode could not be repeated and was accepted as a test peculiarity (again it was determined after delivery to be a design failure)
- autorestart of the backup computer did not work and was overcome procedurally without understanding its cause.

These problems were all accepted and, in retrospect, were handled in a technically superficial manner under the programmatic pressure, for they were all to later reappear during KSC testing.

With the Module thus 'reverified', the packing and transportation phase began, as did the Acceptance Review process. The experiment racks were shipped early, in separate containers in a Boeing-707, to enable KSC to begin payload integration. The remainder of the FUI hardware was shipped aboard a USAF C5A and a Lufthansa Boeing-747 in December 1981, arriving at KSC just before Christmas.

The FUII assembly was well underway by this time and its test programme and acceptance were completed the following June, when the Igloo, Pallets, EGSE, servicers and handling equipment were delivered, as yet another C5A/747 shipment.

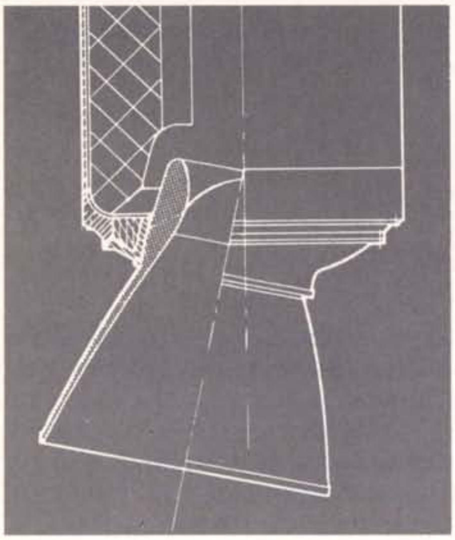
Conclusion

The System Test Phase in Bremen had demonstrated that there was a considerable learning curve for people and procedures on Spacelab. The FU testing had been smoother than EM, for four main reasons:

- the hardware was better than EM
- the team was more familiar with the vehicle
- the procedures were being run for the second time and/or were started much more in advance than was the case for EM
- the test-requirements baseline was formalised ahead of the testing for FU, whereas on EM it was developed in parallel with the hardware flow.

There had been many problems which, by and large, had been dealt with satisfactorily. With the benefit of hindsight, it is clear that some were not properly worked, but on balance the delivery was probably more necessary than the perfection. ERNO, throughout the FU assembly, were extremely thorough and handled the hardware with great discipline. The end product was a credit to those involved, it was built properly, it was very clean and was damage free. However, throughout assembly there was a consistent underestimating of schedule and delays did occur. Also, the paperwork side was not up to the hardware standard and closeout of documentation was, and still is, very time-consuming.

Thus the hardware phase in Europe was over, and activity focussed on processing at KSC towards the 1983 first flight. That period and the manner in which the programme transitioned from ESA to NASA will be described in the second part of this article, in the next issue of the ESA Bulletin (No. 39, August 1984).



Ariane-3: Le développement du Propulseur d'Appoint à Poudre (PAP)

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L'augmentation de la performance du lanceur Ariane-1 permettant de porter la masse de charge utile mise en orbite de transfert géostationnaire de 1825 kg à 2580 kg repose essentiellement sur les éléments suivants:

- **augmentation de la pression foyer des moteurs Viking des 1er et 2ème étages;**
- **accroissement de la performance du 3ème étage (augmentation de la pression foyer et de sa durée de propulsion);**
- **modification de la géométrie de l'avant de la coiffe (biconique) permettant l'emport de deux satellites de la classe PAM-D;**
- **adjonction de deux propulseurs d'appoint à poudre, accrochés au 1er étage au moyen d'un système permettant également, à l'aide de quatre ressorts précontraints, leur éloignement après fonctionnement (DASL = Dispositif d'Accrochage de Séparation et Largage). Lorsque de lanceur n'est pas équipé de ces propulseurs, sa performance n'est plus que de 2175 kg et prend alors la dénomination Ariane-2.**

Nous résumons ci-après les étapes du développement du PAP 'nu' et les résultats finalement obtenus.

Objectif

L'objectif visé est d'obtenir pour chaque propulseur, une impulsion totale de l'ordre de $17{,}2 \times 10^6$ Ns, selon l'axe tuyère, la durée de combustion étant comprise entre 26 et 31,5 s, l'enveloppe maximale de la poussée étant illustrée sur la Figure 1.

Contraintes

Le problème de base posé était l'obtention d'une impulsion totale donnée, avec le respect de certaines contraintes limitant la poussée maximale tolérable, le temps de montée en poussée ainsi que la durée de combustion. Une fois le propergol choisi, les études théoriques ont dégagé les paramètres dimensionnants pour les différents éléments du propulseur (pression interne, température, écoulement dynamique interne).

Ceci a permis d'établir un dossier qui a orienté les choix des matériaux et des dimensions du propulseur, afin qu'il puisse résister:

- aux efforts mécaniques (pression interne, charges dynamiques, transmission poussée)
- au flux thermique interne
- à la dynamique d'écoulement interne des gaz de combustion.

La structure acier du propulseur a pour but de répondre au premier point, alors que la protection thermique interne couvre les deux derniers.

La description des matériaux utilisés ainsi que celle des essais effectués montrent comment les objectifs ont été atteints.

Description du propulseur

La mise au point et la fabrication de ces propulseurs à poudre ont été confiées à la société italienne BPD. Celle-ci possédait déjà une bonne expérience de la propulsion à poudre puisque, outre des propulseurs militaires, elle réalisa ou participa à la réalisation de moteurs d'apogée, tels que ceux destinés aux satellites Météosat, ECS, Sirio et continue de fournir des fusées d'éloignement des étages d'Ariane.

Définition d'avant-projet

Le *propulseur équipé* (Fig. 2) comprend:

- un propulseur nu
- une jupe avant et son cône de carénage aérodynamique
- une jupe arrière
- les fixations associées au système de séparation
- les systèmes pyrotechniques d'alimentation des initiateurs des organes de séparation et de destruction.

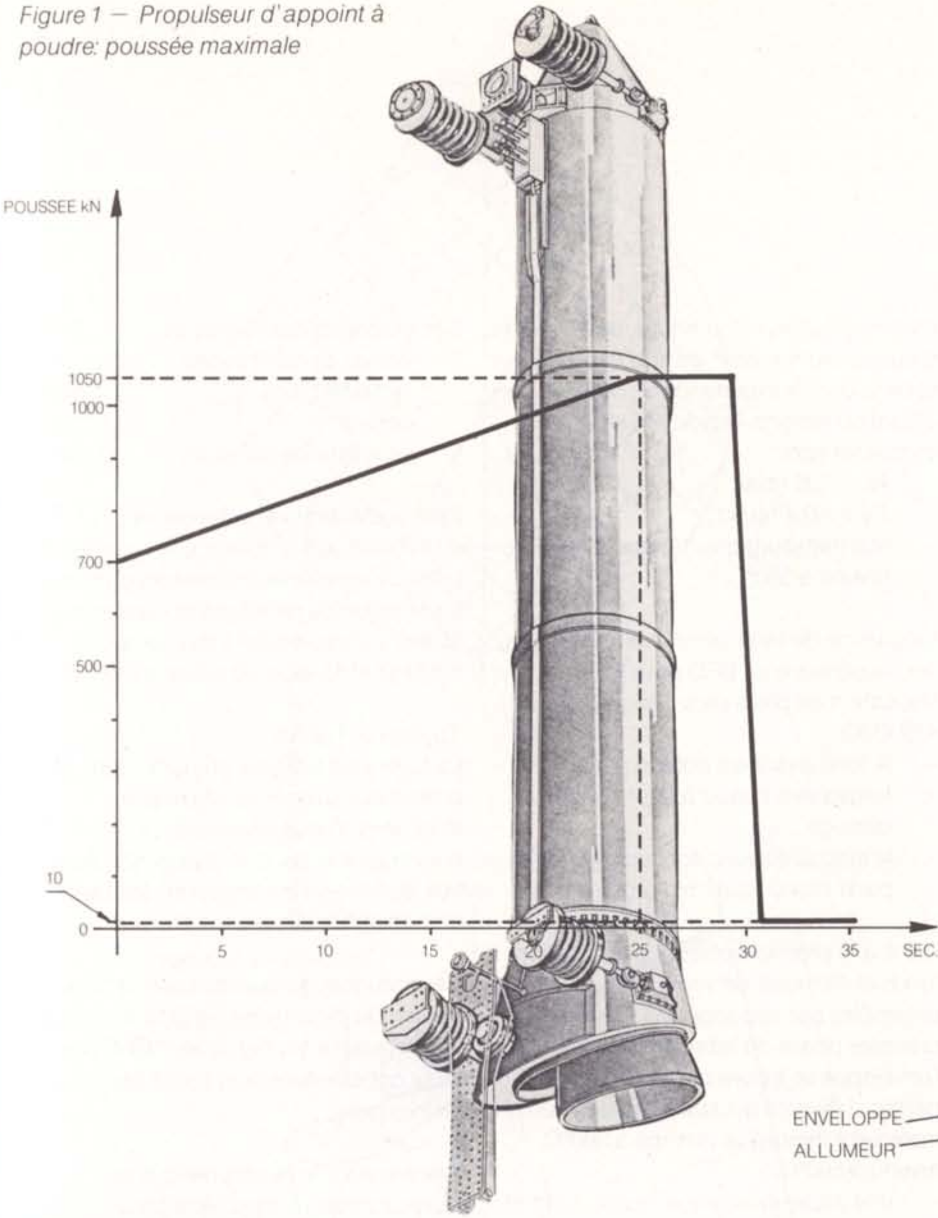
Le *propulseur nu* a été défini à partir des spécifications générales suivantes:

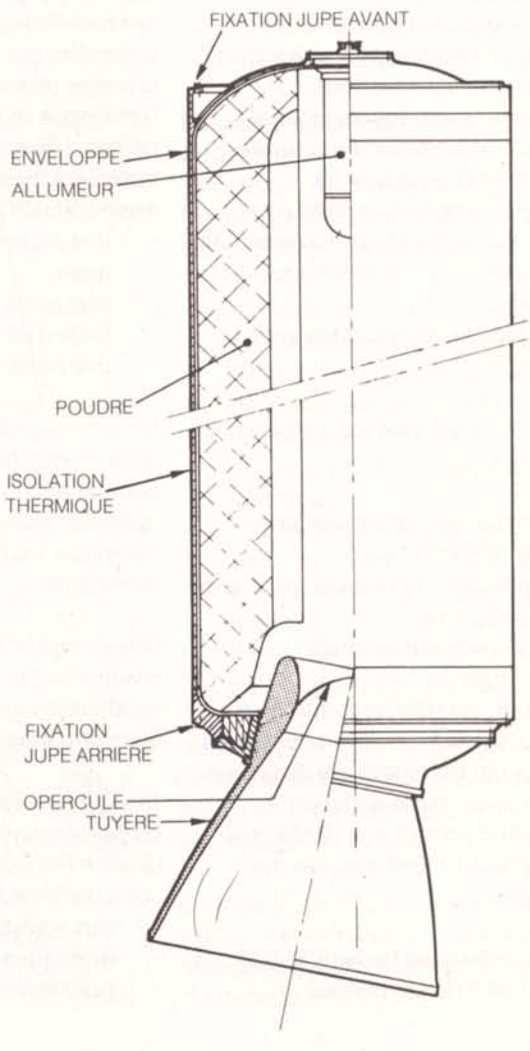
- impulsion totale nominale suivant l'axe tuyère (à 21°C): $16{,}8 \times 10^6\ \mathrm{Ns} \leqslant I \leqslant 17{,}7 \times 10^6$ Ns
- poussée: (voir Fig. 1)
- diamètre interne de l'enveloppe: ~1000 mm
- longueur hors tout: ~7520 mm
- angle de calage de la tuyère: 14°14′ ±20′
- masse de propergol: ~7350 kg
- masse de l'enveloppe: ~1030 kg
- masse totale: ≤9000 kg
- durée de fonctionnement: $26 \leqslant t \leqslant 31{,}5$ s

Figure 1 — Propulseur d'appoint à poudre: poussée maximale

Figure 2 — Propulseur d'appoint aménagé

Figure 3 — Ensemble du propulseur nu





Description sommaire

Le propulseur nu (Fig. 3) se compose essentiellement de:

- une enveloppe cylindrique en acier fermée à l'avant par un fond bombé, dans laquelle le pain de poudre est coulé;
- une tuyère en carbone phénolique dont l'adaptation sur le corps du propulseur réalisée au moyen d'un fond arrière boulonné présente les deux caractéristiques suivantes:
  - un encastrement important dans le corps du propulseur afin de réduire la longueur totale;
  - une forte inclinaison (14°14′) par rapport à l'axe du corps, de façon à ce qu'en fin de propulsion la poussée du propulseur d'appoint passe par le centre de gravité du lanceur;
- une protection thermique d'épaisseur variable, collée sur les parois internes du fond arrière, fond avant et corps

du propulseur afin de les isoler du flux thermique interne dégagé par la combustion de la poudre;
- un allumeur pyrotechnique placé sur le fond avant chargé d'initier la combustion de la poudre.

Choix des éléments du propulseur
Enveloppe
Des considérations de calendrier, de risque technique et de contraintes d'intégration ont conduit à choisir une enveloppe en acier. Le gain en masse (env. 15%) apporté par l'utilisation d'une enveloppe bobinée n'était pas assez significatif pour retenir cette solution.

L'enveloppe du propulseur est constituée:
- d'une partie cylindrique de diamètre extérieur 1070 mm et d'épaisseur 5 mm maximum;
- d'un fond avant elliptique muni d'une embase de fixation pour l'allumeur;
- d'un fond arrière elliptique comportant une double embase permettant la fixation de la tuyère d'une part et de la jupe de raccordement au bâti-moteur 1er étage d'autre part (jupe transmettant la poussée du propulseur d'appoint au lanceur);
- d'une jupette de raccordement à la jupe avant.

La masse de l'enveloppe est d'environ 1030 kg.

Le dimensionnement de l'enveloppe repose essentiellement sur:
- les efforts dûs à la pression interne de fonctionnement,
- les efforts dûs aux charges dynamiques,
- les efforts aux interfaces introduits par la transmission de la poussée au lanceur par l'intermédiaire de la jupe arrière du propulseur et d'un dispositif d'accrochage (DASL) au bâti-moteur L140 et à la jupe inter-réservoirs.

Le matériau retenu est l'acier AISI 4130 (30CD4S) du fait de ses bonnes caractéristiques mécaniques, de sa facilité d'approvisionnement, de son faible coût et de la bonne expérience de BPD sur son utilisation (engins Aspide, Hawk...). Ses propriétés sont:

Rr = 105 hbar
Re = 92,4 hbar
état métallurgique: trempé à 860°C revenu à 560°C.

La gamme de fabrication retenue repose sur l'expérience de BPD pour la réalisation de petits propulseurs en acier AISI 4130:
- le fond avant est obtenu par forgeage à chaud à la presse puis usinage;
- le fond arrière est également usiné à partir d'une ébauche forgée.

Dans une première phase de fabrication, fonds et éléments de virole sont assemblés par soudage TIG. Cette première phase de fabrication terminée, l'enveloppe se trouve constituée de trois parties distinctes qui subissent alors un traitement thermique (trempé à 860°C, revenu à 560°C):
- une partie cylindrique munie du fond avant,
- une partie cylindrique munie d'une bride d'adaptation du fond arrière,
- une partie cylindrique centrale.

Les trois éléments de l'enveloppe sont alors soudés (soudure circulaire) par bombardement électronique. Cette opération est suivie d'un traitement thermique local de relaxation des contraintes.

Un usinage final est alors effectué au niveau des brides avant et arrière pour satisfaire les tolérances géométriques et états de surface spécifiés.

Bloc de poudre (cf. Fig. 4)
Le propergol retenu est de type Flexadyne (licence Rocketdyne) CTPB 16-13, sa composition est la suivante:

– liant (polybutadiène)	13%
– aluminium	16%
– perchlorate d'ammonium	71%

Ses propriétés balistiques sont:

– vitesse de combustion (sous 69 bars)	10 mm/s
– densité	1,739
– exposant de pression	0,304

Il est coulé dans l'enveloppe selon un profil étoilé afin d'obtenir une poussée presque constante en fonction du temps. L'opération de remplissage dure environ 16 jours, comprenant 1 journée de coulage et 15 jours de cuisson à 80°C.

Tuyère (cf. Fig. 5)
La tuyère est intégrée en partie dans le propulseur, afin de satisfaire aux exigences d'encombrement. Le convergent, le col et le divergent (forme très légèrement en coquetier) sont en carbone phénolique.

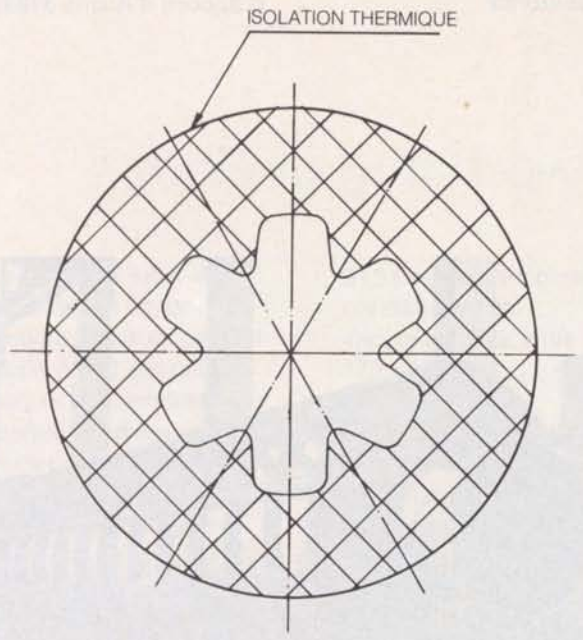
L'armature au niveau du col et la bride de fixation du bloc tuyère sur le fond arrière du propulseur sont en acier AISI 4130. Tous ces éléments sont collés par une résine époxy.

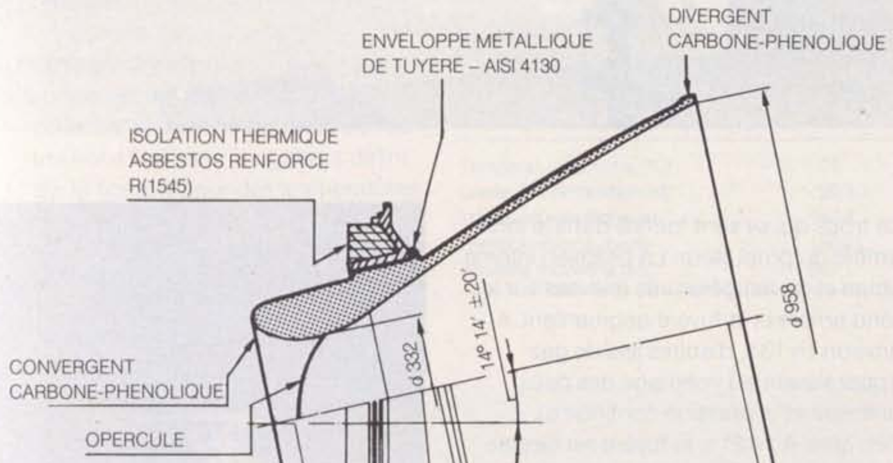
Une membrane hémisphérique en aluminium de 1,5 mm d'épaisseur, collée sur la paroi interne de la tuyère au niveau du col, assure l'isolement de l'intérieur du propulseur vis-à-vis de l'ambiance extérieure.

Allumeur (cf. Fig. 6)
L'allumeur est du type micro-fusée. Il est constitué d'une charge principale contenue dans une enveloppe métallique revêtue extérieurement et intérieurement d'une protection thermique en amiante et résine phénolique.

Sept petites tuyères permettent l'éjection des produits de combustion de l'allumeur vers la surface du bloc de poudre.

L'allumage de la charge principale de l'allumeur est assurée par deux initiateurs du type TBI (Through-Bulkhead Initiator) déjà utilisés sur les impulseurs de séparation Ariane-1, en série avec une charge relais constituée de pastilles en bore-nitrate de potassium.





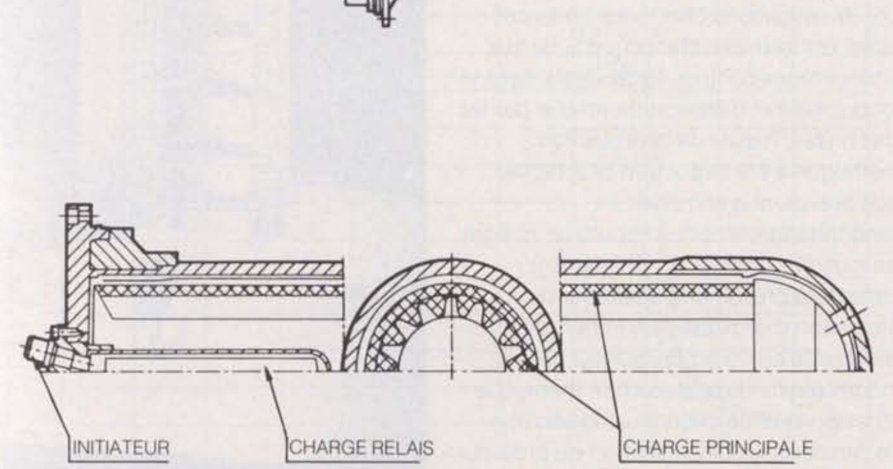


Figure 4 – Section de bloc de poudre

Figure 5 – Ensemble tuyère

Figure 6 – Allumeur

Protection thermique
La protection thermique est un caoutchouc du type EPDM (éthylène propylène – diène monomère) chargé en amiante.

Cette protection thermique est moulée à basse pression, puis collée sur l'enveloppe avec une résine polyamide. Un revêtement interne du type CTPB, introduit avant coulée du propergol, assure le collage de la poudre sur la protection thermique.

Développement – qualification
Il y a lieu de distinguer les essais effectués sur des sous-ensembles qui ont été développés (ou modifiés) spécifiquement pour les besoins du propulseur d'appoint des essais d'ensemble qui ont servi à qualifier des produits déjà développés dans les conditions d'utilisations particulières aux besoins du programme.

Essais de sous-ensembles
Enveloppe
Trois essais de qualification de l'enveloppe ont été réalisés et ont abouti à deux résultats essentiels:

- tenue de l'enveloppe sans aucune fuite ni dégradation à une pression interne de 91 bars, pour une pression maximale attendue (MEOP) de 69 bars, avec, simultanément, application des charges aux interfaces;
- rupture de l'enveloppe sous une pression interne de 119 bars, avec, simultanément application d'une poussée de 1100 kN. Ce résultat se traduit par un coefficient de sécurité de 1,73 par rapport au MEOP.

Allumeur
Quatre essais de mise au point et quatre essais de qualification de l'allumeur ont été réalisés.

La mise au point a conduit à réduire légèrement la masse de poudre de la charge relais, afin de limiter le pic d'allumage.

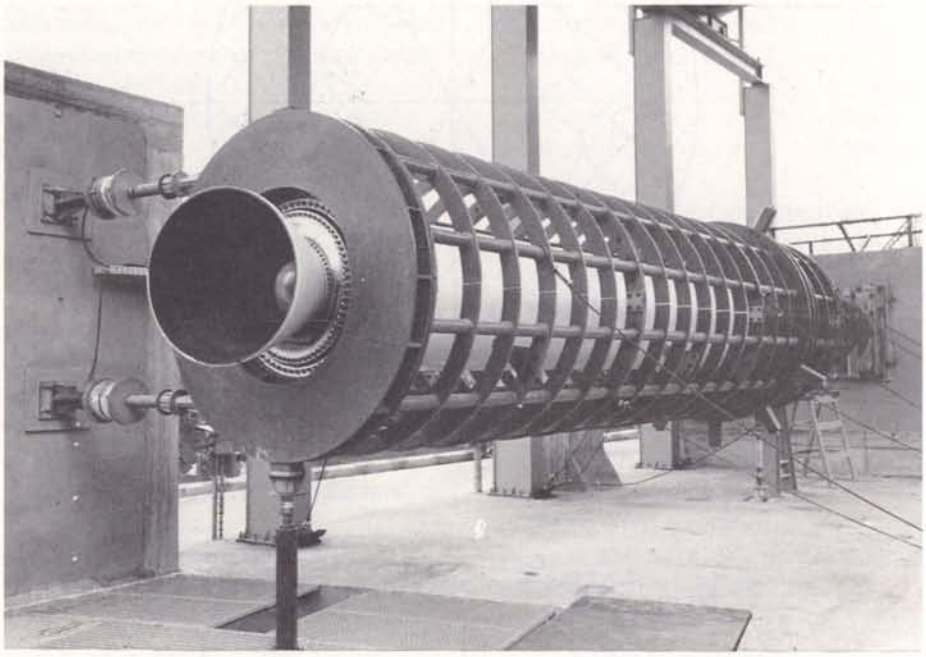


Figure 7 – Propulseur d'appoint sur banc d'essai horizontal

Figure 8 – Tir vertical du propulseur d'appoint d'Ariane-3 (23 juin 1983)

Les essais de qualification ont confirmé le bon dimensionnement de l'allumeur.

Essais d'ensemble
Au total 8 essais ont été effectués, 4 dans le cadre de la mise au point, 4 pour la qualification du propulseur.

Essais de mise au point
Ces essais constituent la phase finale de l'étude du propulseur, destinée à présenter, à son issue, un produit apte à subir avec succès les essais de qualification.

Ils doivent d'une part confirmer que les différentes qualifications effectuées sur des sous-ensembles étaient suffisantes pour assurer une marge de sécurité confortable, d'autre part permettre une évaluation en fonctionnement, dans des conditions proches de celles prévues nominalement, du comportement des éléments pour lesquels seule une étude théorique a été effectuée pour les déterminer.

Ces essais ont été effectués chez BPD/SNIA-Viscosa à Colleferro, en Italie, dans l'enceinte de la zone d'essai réservée aux propulseurs. Le banc d'essai ne permet que des tirs avec le propulseur en position horizontale.

Les principaux paramètres enregistrés sont les suivants:

- pressions internes du propulseur, de l'allumeur et de la charge relais;
- poussées du propulseur (longitudinales et latérales);
- températures sur parois extérieures du propulseur (fond avant, corps, fond arrière, tuyère);
- temps de montée en pression de l'allumeur.

Le premier essai à feu a eu lieu le 22 janvier 1982. Après un allumage correct, la courbe de pression suit un profil légèrement supérieur (10%) à la prévision jusqu'à $t=10{,}3$ s. A cet instant, il y a apparition de deux jets de gaz issus de trous qui se sont formés dans le fond arrière du propulseur. La pression interne chute et les températures relevées sur le fond arrière et la tuyère augmentent. A environ $t=13$ s, d'autres jets de gaz apparaissent au voisinage des deux premiers et la pression continue de décroître. A $t=21$ s, la tuyère est éjectée après découpe complète du fond, la pression interne étant à cet instant d'environ 12 bars. Le propulseur s'éteint complètement au bout de 41 s.

Les investigations effectuées après cet essai, ont permis d'établir que suite aux phénomènes conjugués de vortex dans le fond arrière et d'érosion thermique par les gaz brûlés, l'usure de la protection thermique a été beaucoup plus rapide que prévue, et a entraîné l'endommagement du propulseur, malgré les mesures préventives qui avaient consisté à prévoir une épaisseur de protection thermique plus importante dans cette partie du propulseur. Des modifications de la protection thermique (changement de matériau, modification de l'épaisseur, et modification du profil sur le fond arrière) ont alors été apportées, et les trois propulseurs suivants essayés respectivement les 18 mai, 26 juillet et 24 septembre 1982 dans des conditions de mise en température initiale du pain de poudre différentes (21 à 40°), ont permis, après dépouillement des paramètres enregistrés, et expertise des différents éléments après tir, de conclure que la définition du propulseur pouvait être acceptée et présentée pour les essais de qualification, et donc de figer la configuration définitive du propulseur. Il a notamment été décidé de supprimer les slivers qui sont des bandes de protection thermique supplémentaires collées à l'intérieur de l'enveloppe et destinés à obtenir l'arrêt plus nette de la combustion de la poudre.

Essais de qualification
Performances propulsives principales:

- poussée: le profil de poussée doit se trouver à l'intérieur du gabarit défini sur la figure 1 pour des températures de conditionnement comprises entre 21° et 40°C
- durée de combustion: entre 26 et 31,5 s selon la température de conditionnement
- impulsion totale: entre $16{,}8 \times 10^6$ et $17{,}7 \times 10^6$ Ns.

A l'origine quatre tirs à l'horizontale avaient été prévus. Puis au fur et à mesure de l'avancement du programme Ariane-3, l'intérêt d'un tir à la verticale s'est peu à peu affirmé.

Ce tir effectué sur un site en Sardaigne avait également pour objectif la validation des attaches (DASL) du propulseur d'appoint sur le 1er étage (L140), mais n'a pas permis de mesurer la poussée du propulseur du fait de l'inadaptation du pas de tir.

Les trois tirs à l'horizontale ont eu lieu les 17 janvier, 18 mars et 15 juillet 1983, celui à la verticale le 23 juin 1983 (Fig. 7, 8). Les courbes des poussées relevées lors de tirs montrent clairement que les spécifications sont respectées (Fig. 9).

Les principaux résultats obtenus sont les suivants:

	Essai Q1	Essai Q2	Essai (vertical) Q3	Essai Q4
Température poudre (°C)	21	21	25±2	40
Durée de combustion (s)	29,3	29,3	28,9	28,6
Impulsion spécifique (s)	240,3	240,3	non mesuré	241,4
Pression interne (bars)	50,01	49,62	50,79	50,60
Poussée moyenne (kN)	687,1	682,8	non mesuré	708,2

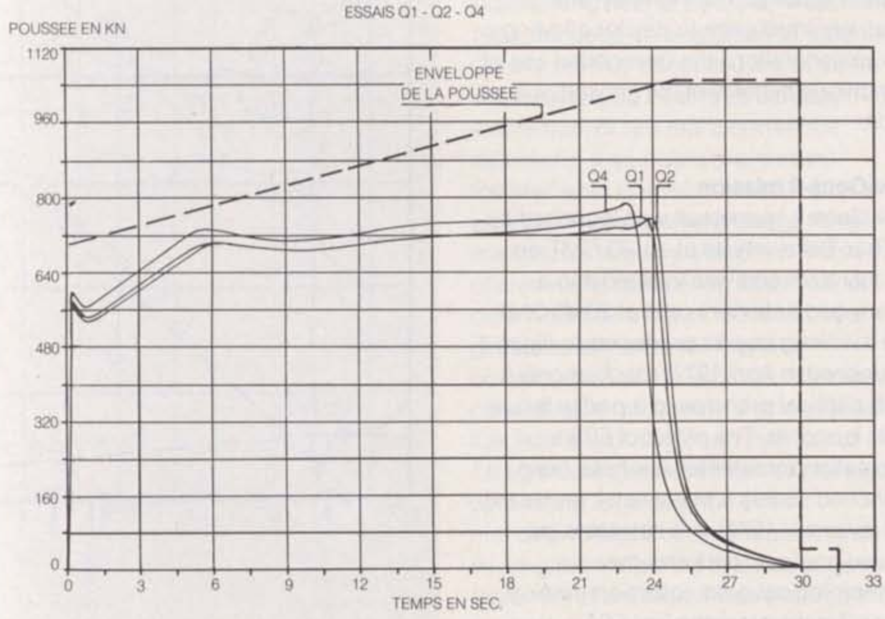
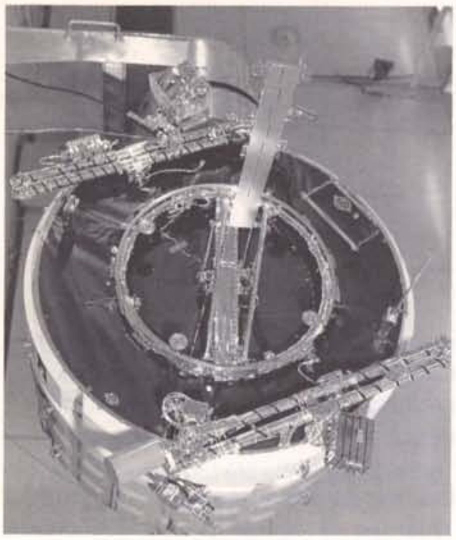


Figure 9 – Relevé des courbes de poussées lors des tirs

Conclusion
La maîtrise technique dont ont fait preuve les techniciens de la société BPD au cours du développement de ce propulseur permet d'aborder avec confiance la phase de production de ces matériels, ainsi que le développement de propulseur de 9,5 t destiné au programme Ariane-4, dont les essais de mise au point et de qualification doivent avoir lieu au cours de l'année 1984 et au début 1985.

Les premiers modèles de vol des propulseurs d'appoint nus sont destinés à équiper le premier lanceur Ariane-3 dont le lancement est prévu au début du mois d'août 1984, et aura pour mission la mise en orbite de transfert des satellites ECS-2 et Télécom-1A.



The De-orbiting of Geos-2

P. Beech, Spacecraft Operations Division, European Space Operations Centre (ESOC), Darmstadt, Germany

M. Soop & J. van der Ha, Orbit Attitude Division, ESOC, Darmstadt, Germany

Geos-2 has become the first ESA satellite to be removed from geostationary orbit. Its altitude has been raised by about 270 km in three manoeuvres carried out on 24 and 25 January 1984.

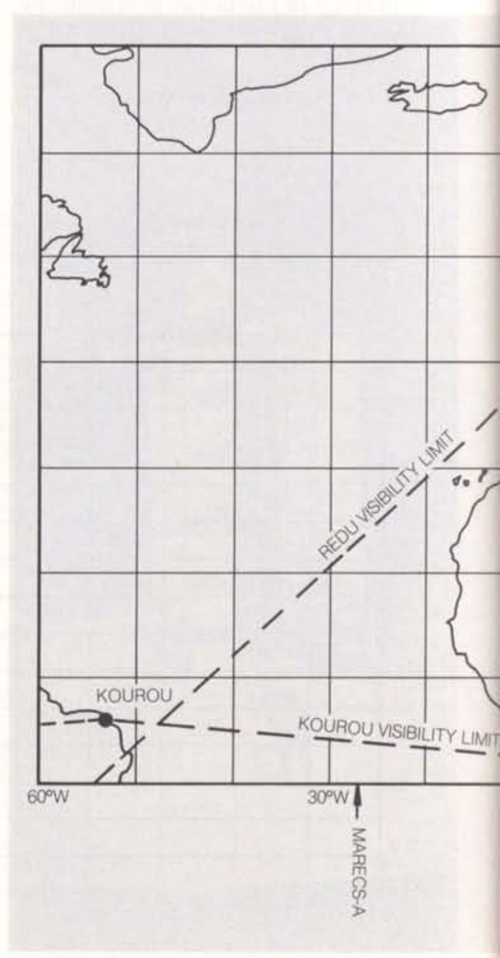
The collision hazard to geostationary satellites is fairly small at present. There is no doubt, however, that if nothing is done the risk will become unacceptable in the future with the increasing number and size of spacecraft in this uniquely valuable orbit. To safeguard the future use of the geostationary orbit, the UN Committee on the Peaceful Uses of Outer Space has made strong recommendations for the moving of satellites away from the geostationary orbit at the end of their useful lifetime. The minimum altitude increase should be 150 km to ensure that collisions with operational spacecraft cannot occur.

The fuel required to raise an orbit by 150 km is the same as that needed for about six weeks of active north/south station-keeping. This represents a relatively small price to pay for allowing future generations the unimpeded use of the unique benefits of the geostationary orbit.

The Geos-2 mission

The Geos-2 spacecraft was launched by a Thor-Delta vehicle at 10:43 GMT on 14 July 1978 and was injected into a nearly geostationary orbit at 23:40 GMT the following day. Its predecessor, Geos-1 (launched in April 1977) reached only a 12 h elliptical orbit due to a partial failure of its launcher. The oldest of ESA's geostationary satellites (six have been launched so far) is Meteosat-1, launched in November 1977. This satellite is still operational and performs the meteorological data-collection mission. Geos-2 is therefore the first ESA spacecraft to be removed from the geostationary orbit, after performing its successful exploration of the Earth's magnetosphere for more than five years. The Geos-2 mission was originally planned to last only two years.

The principal factor responsible for the terminating of the Geos-2 mission is the depletion of the hydrazine fuel that has been used mainly for inverting the



satellite's spin-axis direction at each spring and autumn equinox. The spin axis was pointed north in the summer and south during the winter season in order to prevent shadowing of the solar cells by the short radial booms. The last inversion manoeuvre was carried out in the spring of 1983, and it is estimated that at least 2 kg of fuel remained after this last manoeuvre. Although this would have been sufficient for another inversion in autumn 1983, it was decided to save the fuel for the de-orbiting manoeuvres. The mission was continued in September 1983 after reorienting the spin axis in a direction approximately normal to the ecliptic plane. In this orientation boom shadowing is avoided at the expense of a loss in ground contact time via the UHF antenna.

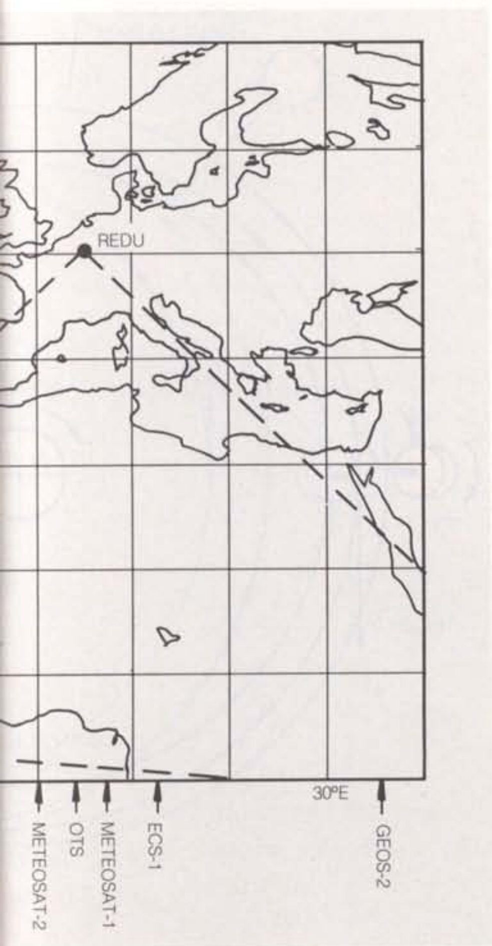


Figure 1 — ESA's geostationary satellites in orbit in February 1984

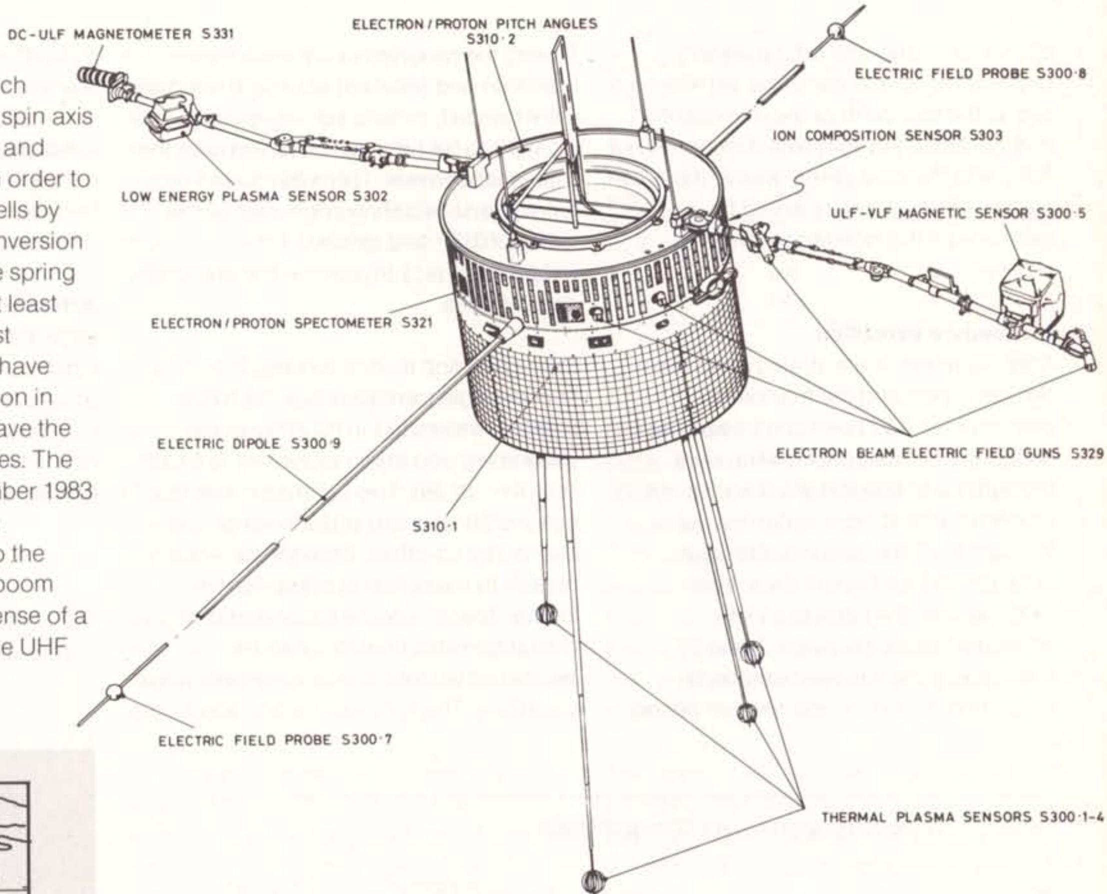


Figure 2 — Orbital configuration of Geos showing the accommodation of all booms and experiment sensors

Manoeuvre strategy

In a meeting held at ESOC on 9 January 1984, the decision was taken to raise the Geos-2 orbit by about 350 km, in three manoeuvres, on 24 and 25 January 1984. A minimum of two manoeuvres are required in a so-called 'Hohmann transfer' from one near-circular orbit to another. For the present task, a three-manoeuvre strategy was preferred as it offered more confidence that the final orbit would be at least 150 km above geostationary altitude. This is a consequence of the fact that there was considerable uncertainty in the available-fuel estimate (2.8 kg), and that about 1.8 kg would be needed for the planned de-orbiting. By timing the three manoeuvre legs about 12 h apart and making the middle leg twice as large as the first and last legs, it was assured that the final orbit would become near-circular.

To raise a satellite's orbit, an acceleration along the velocity vector must be provided. In the case of the spin-stabilised Geos-2 (9.3 rpm spin rate), this is accomplished by firing one of its radial thrusters in pulsed mode. The timing of the pulses is governed by an on-board delay counter triggered when the Sun crosses the Sun-sensor plane. By setting the appropriate delay angle, the effective thrust direction can be made to point in any desired inertial direction normal to the spin axis.

Table 1 provides a summary of the scheduled manoeuvre characteristics. The number of pulses (one every spacecraft revolution) is determined by the desired velocity change, the satellite mass (273 kg), the predicted thrust level (6.4 N) and the pulse duration of 0.5 s.

The start times of the manoeuvres are

chosen such that the orbital velocity vector is perpendicular to the satellite spin axis at the mid-point of the manoeuvre interval. Since the spin-axis direction is not normal to the orbit plane, wasteful out-of-plane velocity changes would be generated if this condition were not satisfied.

Manoeuvre execution

After the appropriate strategy had been decided upon and the manoeuvre preparations had been completed, the necessary operational facilities were brought up to support the manoeuvres. All telecommanding was carried out through the Redu ground station in Belgium and spacecraft data were received from the satellite's VHF communications package. Table 2 summarises the various operations performed during the manoeuvre period.

During the progress of the manoeuvres, spin-rate and solar-aspect-angle changes were carefully monitored. A slight spin-up from 9.3 to 9.4 rpm was observed over the three manoeuvres. This was caused by a small thrust-vector misalignment of the order of 0.02° and resulted in an insignificant (< 1.5°) error in the prepared delay angles.

During the first manoeuvre leg, the solar aspect angle increased from 91.10° to 91.63°; it decreased to 90.71° over the second leg and again increased to 91.15° over the last leg. This behaviour was due to spacecraft spin-axis attitude variations caused by an offset of the thrust vector relative to the centre of mass. As the inertial direction of the thrust is known, the actual spin-axis changes can be reconstructed from the solar-aspect-angle variations. The spin-axis motion amounts to 0.64°, − 1.11° and 0.53° for the three manoeuvre legs in a direction essentially normal to the Earth's equatorial plane. The thrust vector offset with respect to the centre of mass needed to explain this behaviour amounts to about 1.6 mm, which indicates good thruster alignment.

Achieved orbit

Once the three manoeuvres had been carried out, a campaign of intensive ground station-to-spacecraft ranging was commenced, in order to determine the new orbit that had been achieved. The ground stations at Redu in Belgium and

Table 1 — Scheduled manoeuvre characteristics

Manoeuvre number	Start day; time (GMT)	Duration (min: sec)	Number of thruster pulses	Prepared velocity increment (m/s)
1	24 Jan; 06.30	30:13	281	3.26
2	24 Jan; 18.15	60:25	562	6.52
3	25 Jan; 06.30	30:13	281	3.26

Table 2 — Main event sequence

Day/time (GMT)		Event
23.01	08.00	Catalyst bed heater switch ON
24.01	05.30	Acquisition of signal, Redu
		Loss of signal modulation, Odenwald
	05.35	Spacecraft status check
	05.40	Experiments switch OFF
	06.00	Manoeuvre memory load registers loading
	06.30	Execute 1st manoeuvre
	17.15	Spacecraft status check
	17.45	Manoeuvre memory load registers loading
	18.15	Execute 2nd manoeuvre
25.01	05.30	Spacecraft status check
	06.00	Manoeuvre memory load registers loading
	06.30	Execute 3rd manoeuvre
	07.30	Aquisition of signal, Odenwald
		Loss of signal modulation, Redu

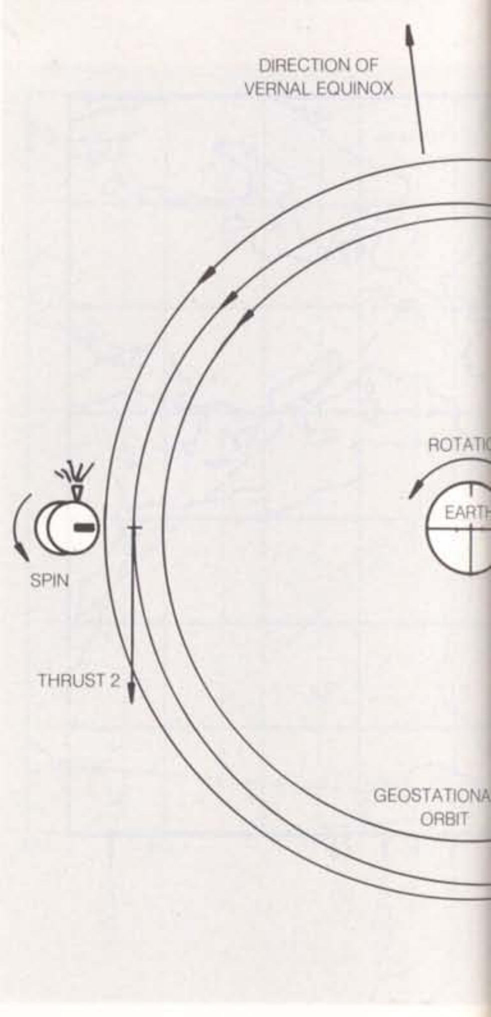
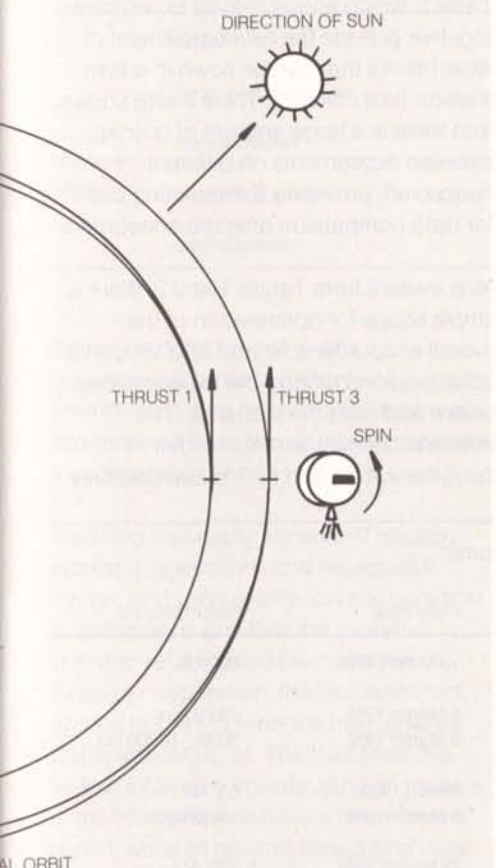


Figure 3 — The three de-orbiting manoeuvre thrusts, seen in an inertial frame in the orbital plane, from the north. The distance between the geostationary and final orbits is exaggerated 25 times in this illustration for reasons of clarity

Malindi in Kenya were used for this purpose.

During the 24 h between the first and last manoeuvre legs, preliminary orbit-determination results on the basis of ranging data indicated a considerable undershoot in the velocity change achieved, of the order of 20%. After the last leg UHF antenna pointing angles also became available so that a definite orbit determination to an accuracy of less than 0.5 km semi-major-axis error could be performed. Table 3 summarises the reconstituted semi-major-axis and velocity changes for the three manoeuvres. The final orbital altitude of 42 426 km is 269 km above the initial orbit of 42 157 km (which was 8 km below the ideal geostationary altitude of 42 165 km). The eccentricity of the final orbit is not significantly higher than that of the starting orbit and induces a daily altitude oscillation of about 15 km amplitude.



The total velocity increment achieved over the three manoeuvre legs was 9.9 m/s, which represents an undershoot of 24% relative to the prepared manoeuvres. This underperformance is probably a consequence of the radial thruster's catalyst bed degradation, since this thruster has exceeded its design lifetime by a factor two. Since the achieved orbit fulfils all requirements, no further altitude-raising manoeuvres will need to be carried out.

As a result of its new orbit, Geos-2's longitudinal position is now drifting westwards at 3.3° per day from its original longitude at 36°E. Its longitude will continue to drift at a practically constant rate, so that one revolution relative to the rotating Earth is completed in about 108 d. Ranging operations will be carried out from the VHF stations in Redu (Belgium) and Kourou (French Guiana). Carnarvon (Australia) and Malindi (Kenya) could be used to facilitate the satellite's re-acquisition by the Odenwald station. All on-board transmitters (UHF and VHF) will be switched off except during periods when ground station-to-spacecraft ranging operations are carried out, at which time the VHF transmitter will be switched on. The UHF link to the Geos-dedicated Odenwald ground station can be established for about three weeks in every return cycle with varying daily intervals. This means that scientific data could still be acquired during these periods.

As all spacecraft subsystems are in good condition and there is perhaps 1 kg of fuel left, the possibility of performing small attitude corrections remains open.

Table 3 – Achieved orbit parameters

Manoeuvre number	Achieved velocity increment (m/s)	Semi-major-axis change (km)
1	2.55	69.1
2	4.93	134.2
3	2.43	67.3

Conclusion

Geos-2's new near-circular orbit is about 260 km above the geostationary altitude. A westward drifting of the satellite at 3.3°/d means that it describes one full revolution of the rotating Earth in 108 d. Scientific data could still be acquired via the UHF link with the Odenwald station over a three-week period during every return.

The operational experience gained in the planning and execution of these manoeuvres with Geos-2 will be very valuable for similar manoeuvres in the future.

Exploration of Halley's Comet from Space: The Inter-Agency Consultative Group (IACG) and its Associated Working Groups

R. Reinhard, Giotto Project Scientist, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

After 76 years, Halley's comet is again approaching the inner solar system. A fleet of six spacecraft, from four space agencies, is being prepared to encounter the comet in March 1986. The four space agencies have agreed to coordinate informally all matters related to the space missions to Halley's comet and have formed the Inter-Agency Consultative Group (IACG) for this purpose. Since its formation in 1981 the IACG has demonstrated an ever-growing usefulness for the various flight projects as a focal point for exchange of information, discussion on common problems and mutual support to enhance the overall scientific return of the space missions to Halley's comet.

The Inter-Agency Consultative Group (IACG)

Four space agencies – the Intercosmos of the USSR Academy of Sciences, the Japanese Institute of Space and Astronautical Science (ISAS), NASA and ESA – are presently working on space missions to Halley's comet. Intercosmos will launch the Vega-1 and 2 spacecraft, ISAS will launch the Planet-A and MS-T5 spacecraft, and ESA will launch the Giotto spacecraft. NASA has already dispatched its ICE (formerly ISEE-3) spacecraft towards comet Giacobini-Zinner, and thereafter to Halley's comet.

Some key data on these missions are given in Table 1. The scientific experiments on the various spacecraft are listed in Table 2; the left part refers to spacecraft that encounter Halley's comet, while the right part refers to spacecraft that fly by at a greater distance.

The Halley encounter spacecraft complement each other in that the two Vega spacecraft are three-axis stabilised, while Giotto and Planet-A are spin-stabilised. Three-axis stabilisation is more advantageous for imaging since longer integration times can be achieved. Spin stabilisation is more advantageous for plasma experiments because an azimuthal range of 360° is provided by the spacecraft spin and full 4π viewing is possible. The scientific experiments on the various spacecraft are summarised in Table 2, which shows that all experiments together provide the full complement of experiments that can be flown in a flyby mission (last column). Table 2 also shows that there is a large amount of overlap between experiments on different spacecraft, providing a stimulating basis for data comparison after the encounters.

As is evident from Tables 1 and 2, there is ample scope for optimisation of the overall encounter scenario and for useful collaborations among the experimenters before and after the launches. The missions complement each other in instrumentation and flyby distances, they

Table 1 – Key data on missions to Halley's comet

Agency	Project	Launch	Flyby date	Flyby distance
ESA	Giotto	July 1985	13 March 1986	500 km
Intercosmos	Vega-1	December 1984	6 March 1986	10 000 km
	Vega-2	December 1984	9 March 1986	3000–10 000 km
ISAS	MS-T5	January 1985	March 1986	0.1 AU
	Planet-A	August 1985	8 March 1986	100 000 km
NASA	ICE	22 December 1983*	28 March 1986	0.21 AU

* Lunar swingby manoeuvre to inject ICE (formerly ISEE-3) into a heliocentric trajectory to comet Giacobini-Zinner (flyby on 11 September 1985, 15 000 km on the anti-sunward side)

Table 2 – Scientific experiments on the Halley spacecraft

CLOSE FLYBYS

		Vega-1&2 (three-axis stabilised)	Giotto (spin-stabilised)	Planet-A (spin-stabilised)	Combined complement
Remote Sensing	Camera – Wide Angle	X			X
	Camera – Narrow Angle	X	X		X
	UV Camera			X	X
	IR Sounder	X			X
	Photopolarimeter		X		X
	Three-Channel Spectrometer	X			X
Gas/Dust In-Situ Measurements	Neutral Mass Spectrometer	X	X		X
	Ion Mass Spectrometer	X	X		X
	Dust Mass Spectrometer	X	X		X
	Dust Impact Detector	X	X		X
Plasma In-Situ Measurements	Solar-Wind Ions	X	X	X	X
	Solar-Wind Electrons	X	X	X	X
	Plasma Waves	X			X
	Energetic Particles	X	X		X
	Magnetometer	X	X		X

DISTANT FLYBYS

	ICE	MS-T5
Solar-Wind Ions		X
Solar-Wind Electrons	X	
Plasma Composition	X	
Magnetometer	X	X
Plasma Waves	X	X
Energetic Particles	X	
Radio Waves	X	

extend the total time of in-situ observations in the cometary environment, and provide simultaneous observations from two or more spacecraft for some time periods.

Realising that many aspects of mission planning, spacecraft and experiment design, and data evaluation are common to all missions and that the overall scientific return could be increased through cooperation, the four agencies agreed in 1981 to form the Inter-Agency Consultative Group. The IACG has the task of informally coordinating all matters related to the space missions to Halley's comet, while all ground-based and near-Earth Halley observations will be coordinated by the International Halley Watch (IHW). A detailed article on the IHW and its observing nets will appear in the next issue of ESA Bulletin (No. 39, August 1984).

The first meeting of the IACG took place on 13–15 September 1981 in Padua, Italy (see summary in ESA Bulletin 29, February 1982, pp. 64–83). At this meeting numerous details on the various space missions were exchanged for the first time and the general principles of cooperation were established. Three working groups were formed in which many of the problems common to all space missions to Halley's comet are discussed, resulting in recommendations to the flight projects or actions to carry out specific tasks. The three working groups are:

- the Halley Environment Working Group (WG-1)
- the Plasma Science Working Group (WG-2)
- the Spacecraft Navigation and Mission Optimisation Working Group (WG-3).

These working groups each have between 10 and 20 members from the various flight projects, and they meet twice per year, on average. One of their meetings is held just prior to an IACG meeting, which allows the chairmen to report back to the IACG and obtain an immediate decision. The activities of the working groups are described in more detail below. To minimise travel time and expense and in view of the difficulty of holding meetings with all working-group members from the four agencies, it was agreed:

- to try to make as much use as possible of existing major conferences when arranging working-group meetings
- to communicate results achieved by sub-groups in regional meetings to all other working-group members who could not participate and to a representative of each agency
- to encourage flexibility of membership depending on the

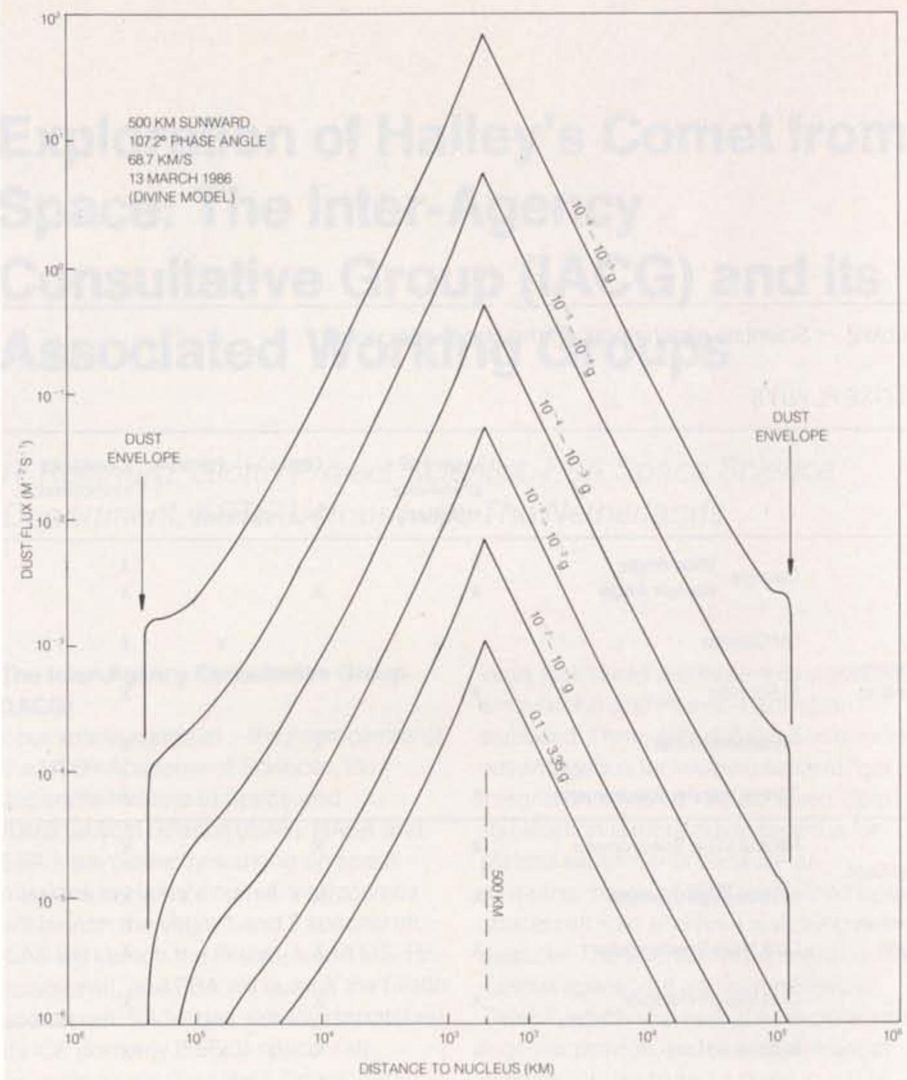


Figure 1 – Dust fluxes for large and intermediate sized dust particles ('Nov. 1983' Halley reference dust model)

interest and changes in the subject matter of the discussions and depending on the meeting place.

The IACG meets annually, with the task of organising the meeting, and consequently the meeting place, rotating within the four agencies. The second IACG meeting took place in Dobogoko, Hungary on 21 – 22 November 1982 at the invitation of Intercosmos, and the third meeting in Kagoshima, Japan on 18 – 19 December 1983 at the invitation of ISAS. The next three meetings are already scheduled to take place in Tallinn (USSR), Washington DC (USA) and again in Padua (Italy).

The Halley Environment Working Group (WG-1)

This group has the task of providing the scientific community and the spacecraft engineers with data on the nucleus of Halley's comet and with dust and gas models. Its first meeting took place on 21 October 1980 at NASA/GSFC; the eighth will take place on 3 and 4 July in Graz, Austria at the time of the COSPAR Meeting. Over the last $3^1/_2$ years the group has agreed on a set of data for Halley's comet (Table 3) that is continuously being updated as new observations become available, on an estimate of the composition of the gas and its density in the coma, and on a dust model.

A major part of the work went into improving the dust model, essentially by including more and more details in the computer program used to produce it. WG-1 is presently working with the fifth generation of dust models. As an example, Figure 1 shows dust flux profiles for various dust-particle masses for a 500 km sunward flyby, a phase angle of 107.2° with respect to the Sun-comet line and an encounter velocity of 68.7 km/s (Giotto flyby).

DELEGATION MEMBERS AT THE THIRD IACG MEETING IN KAGOSHIMA, JAPAN

Chairman: M. Oda, ISAS

Secretary: R. Reinhard, ESA

Intercosmos Delegation
R.Z. Sagdeev, Head of Delegation
G.S. Balayan
A.A. Galeev
L.I. Gussev
B.A. Stroganov
A.A. Sukhanov
A.I. Tsarev

ESA Delegation
R.M. Bonnet, Head of Delegation
D.C. Dale
J.A. Jensen
V. Manno
R. Reinhard

ISAS Delegation
K. Hirao, Head of Delegation
Y. Kozai
T. Nomura
H. Oya
M. Shimizu
H. Yamamoto

NASA Delegation
G.A. Briggs, Head of Delegation
J.A. Dunne
C.T. Force
J.W. Head
J.F. Jordan
D.P. Rausch
F. Scarf
L.L. Wilkening

IHW Representatives
R.L. Newburn
J. Rahe
D.K. Yeomans

Table 3 – Model parameters for Halley (March 1984)

Comet brightness	$m_1 = H_0 + 2.5\, n \log r + 5 \log \Delta$ r = distance to Sun in AU; Δ = distance to Earth in AU
	pre-perihelion: $H_0 = 5.47$, $n = 4.44$; *post-perihelion*: $H_0 = 0.335$, $n = -4.44$ for $r < 0.71$ AU; $H_0 = 3.13$, $n = 3.09$ for $r \geqslant 0.71$ AU
Nucleus: radius	$R_N = 3$ km
mean bulk density	$\rho_N = 1$ g/cm^3
surface temperature	$T_N = 185$ K
albedo	$P_N = 0.15$
shape	spherical
rotation period	42 h
Composition of the volatile component	83.4% H_2O; 16.6% all other molecules with mean molecular mass 44 amu
Ratio of dust to gas production rates by mass	$\mu = 0.5$
Dust size distribution	$g = \frac{(a - a_1)^M}{[M(a - a_1) + N(a_0 - a_1)]^{M+N}}$; $M = 16$, $N = 4.2$, $a_1 = 0.1$ µm, $a_0 = \frac{M + N}{N} a_1 = 0.48$ µm (distribution peak)
Dust bulk density	$\rho = 3 - 2.2\,(\frac{a}{a+2})$ a = particle radius in µm
At 0.9 AU post-perihelion	
Total gas production rate	$Q_g = 6 \times 10^{29}$ molecules/s
Gas molecule lifetime	$\tau_g = 1.6 \times 10^4$ s (corresponding to H_2O)
Other useful parameters derived from above set	
Nucleus mass	$M = \frac{4\pi}{3} R_N^3\, \rho_N = 1.13 \times 10^{17}$ g
Escape velocity	$(\frac{2\,GM}{R_N})^{\frac{1}{2}} = 2.25$ m/s
Gas terminal velocity	$V_g = 1.8\,(\frac{8\,KT}{\pi\, m})^{\frac{1}{2}} = 754$ m/s
Mean molecular mass	$0.834 \times 18 + 0.166 \times 44 = 22.3$ amu
At 0.9 AU post-perihelion	
Total gas production rate	$M_g = 2.2 \times 10^7$ g/s
Total dust production rate	$M_d = \mu\, M_g = 1.1 \times 10^7$ g/s
Variation of the density of gas molecules with distance r from the nucleus	$n_g(r) = \frac{Q_g}{4\pi r^2 V_g} \exp(-\frac{r}{\tau_g V_g})$

The dust model is provided to the flight projects and the scientific community in the form of tables, which include fluxes, fluences, and the impact angle on the spacecraft for direct (emitted from the nucleus) and reflected (turned around by the solar radiation pressure) particles. These data are given for about 80 points along the spacecraft trajectory. Dust-model tables have been produced for 16 different possible Giotto flyby trajectories to study the effects of dust impact on the spacecraft. Another table has been produced for Intercosmos based on a 10 000 km sunward flyby and the Vega flyby geometry.

Up to now, all dust models have assumed homogeneous emission of dust particles from the nucleus surface. In the future, the main emphasis will be on models of inhomogeneous emission of dust from the nucleus. By rotating and shifting images and then differencing them it is possible to enhance structures that are otherwise too faint to be observed (Fig. 2). This technique has allowed IHW Discipline Specialists Larson and Sekanina to make visible and to analyse jets in Halley 1910 plates. It turned out that the dust density in these jets is much greater than in the ambient coma, so much greater that a spacecraft entering one of the jets would either be quickly destroyed or its attitude would be disturbed so that no more data could be transmitted back to Earth.

Presently, WG-1 is trying to achieve a better understanding of the physics of the dust jets and to develop three-dimensional models of them. 'Activity maps' showing the location of areas with enhanced dust emission have been derived previously by Sekanina for comet Swift-Tuttle (Fig. 3). There are strong indications that the active regions on a nucleus prevail for many rotations so that their mapping may be a useful tool in deciding where the spacecraft should be targeted, or rather not targeted.

The Plasma Science Working Group (WG-2)

This group has the task of:

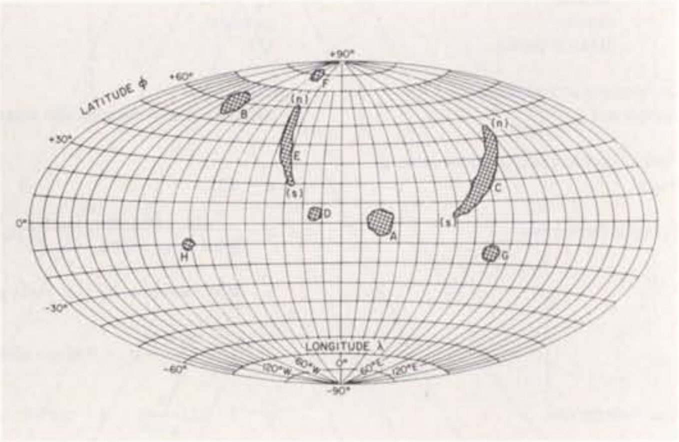
- studying the various plasma physical processes resulting from the solar-wind/comet interaction
- optimising the scientific return from the cruise phase by making use of the exceptional close co-existence of seven spacecraft in interplanetary space, and characterising the interplanetary medium during the various flybys
- stimulating discussion between the plasma experimenters on the various spacecraft
- investigating the effects of the impact-generated plasma around the spacecraft.

As part of the activity of this working group, R. Farquhar (NASA/GSFC) has produced plots that show the trajectories of the various Halley spacecraft relative to a fixed Sun-Earth line (Figs. 4a & b). These plots have been useful in identifying special time intervals during which the acquisition of plasma data should be maximised. These intervals are:

- *15 May–30 June 1985:* During this period Vega-1, -2, MS-T5, Pioneer-Venus and ICE will be closely aligned with the expected position of the Venus magnetotail and wake.

Figure 2 – Digitally processed, high-resolution photograph of comet Halley taken on 9 May 1910, showing 'jet' activity (bright arcs in the coma) (photo. courtesy of Mt. Wilson Observatory)

Figure 3 – 'Activity map' for comet Swift-Tuttle showing the locations of areas with enhanced dust emission. Sizes of emission areas show relative prominence of activity and not actual shapes, which are unknown (courtesy of Z. Sekanina)



- *1 September–30 September 1985:* This period will include the ICE traversal of the Giacobini-Zinner tail. In addition, Giotto, Planet-A, MS-T5, Vega-1, -2 and ICE will all be near 1 AU, and they will be spread out in solar longitude so that almost one quarter of the inner solar system (about one sector) will be covered.
- *1 March–20 March 1986:* During this period, which includes the Halley encounters, five spacecraft will be very closely aligned in a small solar longitude interval near 1 AU, while ICE will be able to provide precursor information on co-rotating streamliners.

Characteristic features of the solar wind (high-speed streams, sector boundaries, etc.) co-rotate with the Sun (sidereal rotation period 25.38 d) and are therefore observed successively by different spacecraft at different azimuthal positions around the Sun. It is important to monitor these solar-wind features with this network of interplanetary spacecraft as the solar-wind/comet interaction processes depend on them. To give an example, ion-tail disruption events (Fig. 5) are believed to be caused by sector boundaries interacting with comets.

Intercalibration of the plasma experiments onboard the various spacecraft is important because the experiments are all different. Experience has shown that even carefully but independently calibrated experiments on different spacecraft can give different results. Intercalibration could be achieved in some cases.

The studies on the impact-generated plasma have largely been carried out to support the plasma experiments onboard Giotto because they are most directly concerned. As Giotto will fly 20 times closer to the comet nucleus than any of the other spacecraft, it will experience an impact-generated plasma density around the spacecraft 400 times higher (the cometary dust and gas fluxes increase quadratically towards the nucleus). The impact plasma leads to spacecraft charging and will produce an ambient plasma more than 1000 times denser than the cometary plasma to be measured. Fortunately, the impact-generated ions can be distinguished from the cometary ions by their distinctly different velocity distributions.

Extensive studies are being carried out to calculate the degree of ionisation of dust-particle impacts, to measure the secondary electron and ion yield after neutral and ion impact and to computer-simulate the spacecraft plasma environment.

The Spacecraft Navigation and Mission Optimisation Working Group (WG-3)
This working group has the following tasks:

- Improvement of spacecraft encounter targeting accuracies through:
  - dissemination of Halley ephemeris information obtained by the IHW Astrometry Network to all flight projects
  - use of Vega-1 and 2 as pathfinders for Giotto.
- Optimisation of flyby trajectories through:
  - real-time dissemination of information on cometary behaviour obtained by the IHW (e.g. jets) to all flight projects and by the earlier arriving spacecraft (e.g. dust fluxes) to the later-arriving spacecraft
  - exchange of information on shield design to reduce mission risk.
- Optimisation of spacecraft data acquisition during encounters through:
  - cooperation in sequencing the experiment-active times and investigation of the possibilities of simultaneous observations from two or more spacecraft
  - real-time dissemination of information on cometary phenomena (bow shock and dust envelope) obtained by earlier-arriving spacecraft.

Targeting of the spacecraft with respect to the comet nucleus is a major problem as the nucleus, being disguised by the gas

Figure 4 — Trajectories of the various Halley spacecraft relative to a fixed Sun-Earth line (courtesy of R. Farquhar)

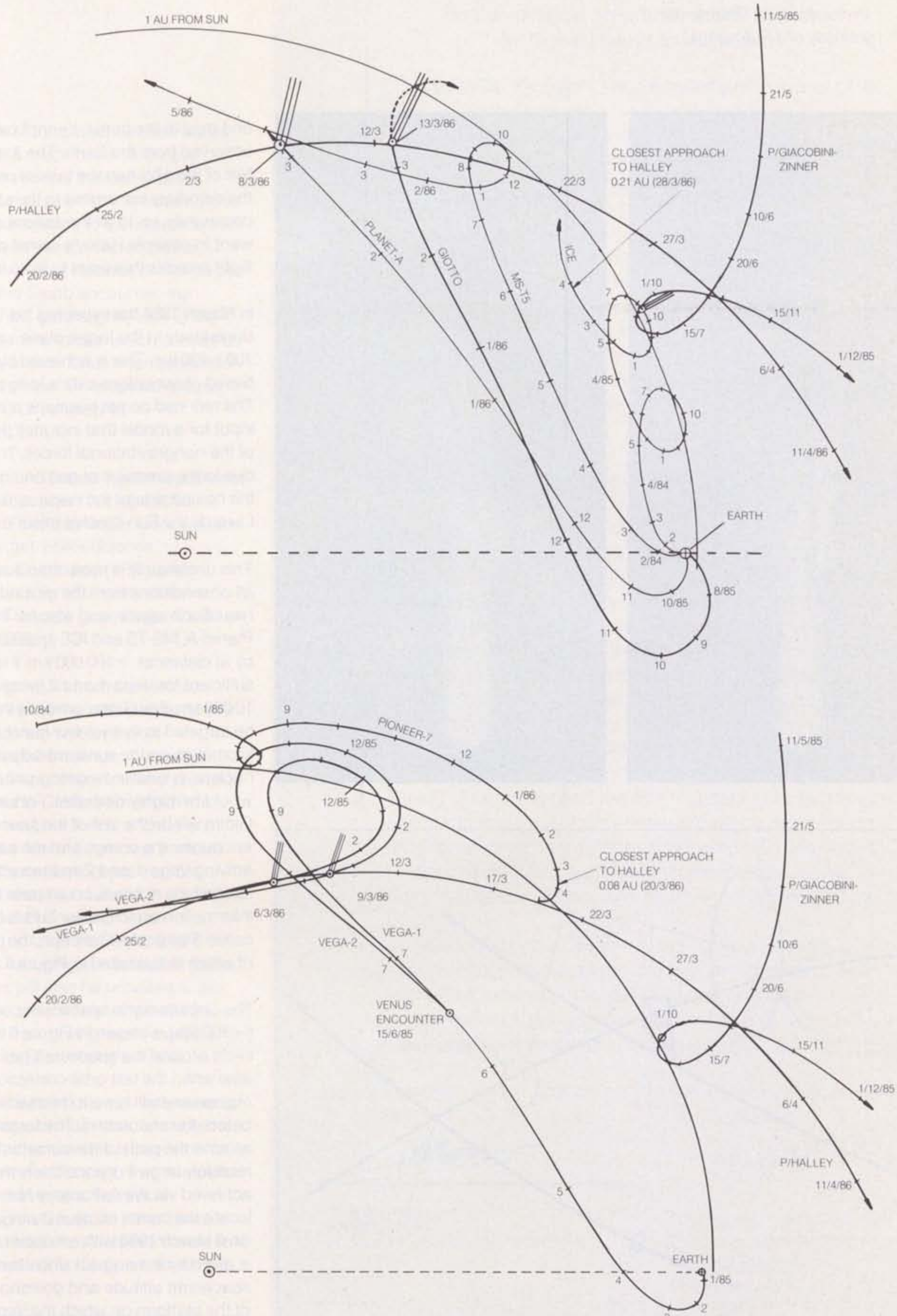
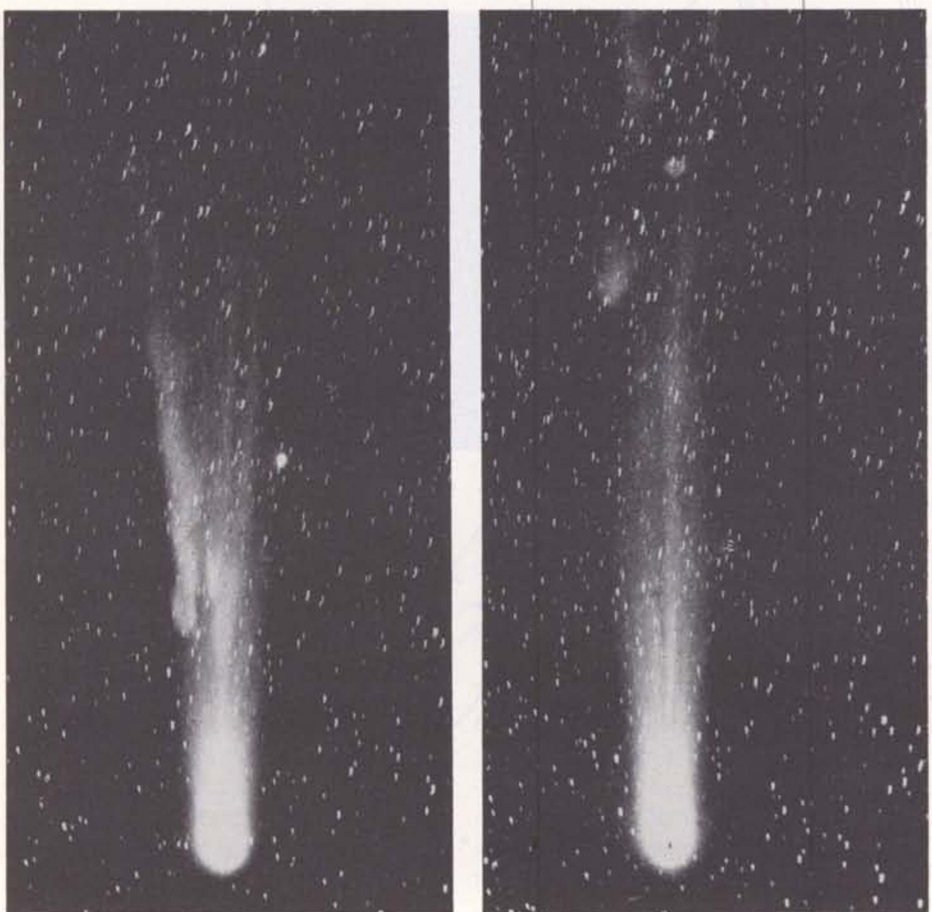
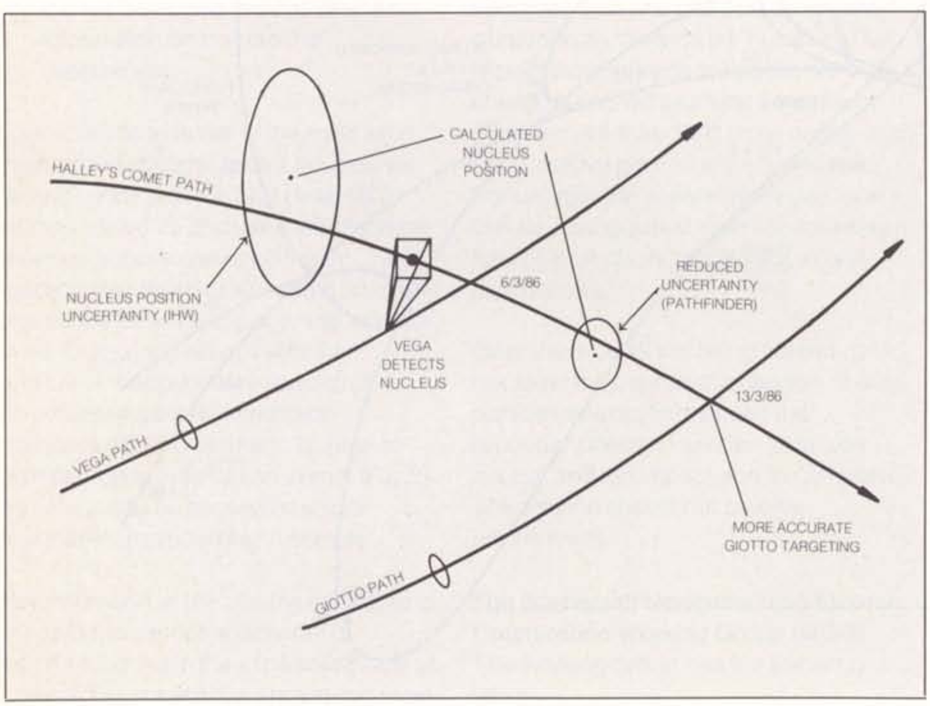


Figure 5 — Photograph of comet Halley taken on 6 June 1910, showing an ion-tail-disruption event (courtesy of Lick Observatory, University of California)

Figure 6 — Principle of the 'Pathfinder Concept' (courtesy of J.F. Jordan)





and dust in the coma, cannot be observed from the Earth. The Astrometry Net of the IHW has the task of providing the cometary ephemeris to the scientific community, i.e. to all the astronomers who want to observe Halley's comet and to the flight projects that want to fly to it.

In March 1986 the expected 1 σ uncertainty in the target plane will be 700×400 km. This is achieved by ground-based observations over a long period. The reduced comet positions are used as input for a model that includes the effects of the nongravitational forces. These are due to the emission of gas and dust from the heated side of the nucleus, i.e. towards the Sun ('rocket effect').

This uncertainty is more than sufficient for all observations from the ground and near-Earth space, and also for the Planet-A, MS-T5 and ICE spacecraft flying by at distances $>100\,000$ km. It is even sufficient for Vega-1 and 2 flying by at 10 000 km. For Giotto, which is intended to be targeted to fly by a few hundred kilometres on the sunward side of the nucleus, a smaller targeting uncertainty would be highly desirable. Fortunately, Giotto will be the last of the spacecraft to encounter the comet, and the earlier-arriving Vega-1 and 2 spacecraft, having located the nucleus, could pass this information on to Giotto. This is the so-called 'Pathfinder Concept', the principle of which is illustrated in Figure 6.

The uncertainty in spacecraft position (~ 100 km) is shown in Figure 6 as a small circle around the spacecraft path, at the time when the last orbit-correction manoeuvre will have to be made (1-2 days before the encounter). The large circle around the path of the comet reflects the relatively large 1 σ uncertainty that can be achieved via the Astrometry Net. Vega will locate the comet nucleus during its flyby on 6 March 1986 with an uncertainty that is given by the angular uncertainties in spacecraft attitude and pointing direction of the platform on which the Vega camera is mounted. After processing of the data, the position of the comet nucleus will be known with a much better accuracy (small circle around the Halley path). Giotto will be targeted to the centre of the small circle projected to the intersection of the comet and the spacecraft paths. Between the time of nucleus detection by Vega and the Giotto encounter, the uncertainty will grow slightly due to the non-gravitational forces, which cannot be modelled precisely. It has been estimated that the Pathfinder Concept will reduce the targeting uncertainty to 130 km (1 σ)*.

At the recent IACG meeting in Kagoshima, Japan, the four agencies agreed to proceed with the Pathfinder Concept (see previous page). ESA's Science Programme Committee (SPC), after reviewing the scientific merits of the Pathfinder Concept, gave its go-ahead on 12 March 1983.

The scientific return from the various missions to Halley's comet can be further optimised by real-time and post-encounter data exchange. Currently under discussion is the real-time provision of Vega data to Giotto from which the position of the bow shock and the dust envelope, the flux of large dust particles and any observations of jets can be deduced. It was also realised that all flight projects would benefit from post-encounter (no later than 2 years after encounter) exchange of data-pool tapes. These tapes will also be provided to the IHW Archive, where they will be stored together with all other ground-based and near-Earth data on Halley's comet.

WG-3 was dissolved after its last meeting in Kagoshima. Its main task, to study the feasibility and achievable improvements of the Pathfinder Concept, was completed and handed over to a Technical Implementation Group. Its other tasks, in the area of mission optimisation, were split into a scientific definition part, which will

* See article on page 42 of this issue.

AGREEMENT

between the European Space Agency and
the Academy of Sciences of the USSR
on Coordination of the International Projects
for Comet Halley's Investigation

The European Space Agency and Academy of Sciences of the USSR,

- taking guidance from the Agreement between the European Space Agency* and Academy of Sciences of the USSR of 12 February 1971, and considering mutual interest in promoting collaboration in peaceful exploration of outer space,
- proceeding from the fact that the European Space Agency and Academy of Sciences of the USSR are interested in obtaining the most complete scientific data on Comet Halley from their Giotto and Vega space missions,
- following up the preliminary understanding reached between technical experts from the European Space Agency and Academy of Sciences of the USSR on the subject, have agreed on the following:

1. Necessary efforts will be made to coordinate the international space missions for Comet Halley's exploration carried out by the European Space Agency (the Giotto project) and by the Academy of Sciences of the USSR (the Vega project).
2. With the aim of improving the Comet Halley ephemeris and Giotto spacecraft trajectory, the Academy of Sciences of the USSR will make efforts for timely delivery of the navigation information obtained with the help of technical means onboard the Vega spacecraft to the European Space Agency. The European Space Agency will make efforts for timely delivery of the data on ground-based astrometric observations of Comet Halley and VLBI observations of the two Vega spacecraft.
3. Timing of exchange and the extent of data to be exchanged according to para 2 of the Agreement will be determined by technical experts of both sides supervised by a Steering Committee including authorized representatives of the European Space Agency and Academy of Sciences of the USSR.
4. In the course of coordination of the Giotto and Vega international projects, as provided by the Agreement, each side will assume scientific technical and financial responsibility for the implementation of its own project only.
5. This Agreement becomes effective upon signing.

for European Space Agency	for Academy of Sciences of the USSR
R.M. Bonnet Director of Scientific Programmes for ESA	R.Z. Sagdeev Director of Space Research for USSR Academy of Sciences

* European Space Research Organisation before 1975

PATHFINDER IMPLEMENTATION

Technical Steering Committee

D. Dale, Chairman (ESA/ESTEC)
J. Jensen (ESA/ESOC)
R.Z. Sagdeev (IKI)
G.S. Balayan (Intercosmos)
J.F. Jordan (NASA/JPL)
C.T. Force (NASA/HQ)
K. Hirao (ISAS)

Technical Coordinators

R. Münch, F. Hechler (ESA/ESOC)
R. Kremnev, K. Sukhanov (Intercosmos, IKI)
C. Stelzried, J. Ellis (NASA/JPL)

Responsibilities

ESOC:
for overall technical coordination and Giotto terminal navigation
IKI:
for Vega inertial pointing angles
JPL:
for DSN/VLBI tracking and orbits of the Vega spacecraft

be carried out in the future by WGs-1 and 2, and a technical part (means of data transfer), which will be under the responsibility of the Technical Implementation Group, because the same lines of communication will be used for these data as for the Pathfinder data.

The 1986 Symposium on Halley's Exploration
In order to limit the amount of travelling by scientists in the post-Halley-encounter period and at the same time allow all scientists from the various space missions to get together, the IACG has already now decided to support only one major conference on the exploration of Halley's comet. This Symposium will take place from 27–31 October 1986 in Heidelberg, Germany and is being jointly organised by the Space Science Department of ESA and the Max-Planck-Institut für Kernphysik in Heidelberg. It is sponsored by the IACG and the IHW and co-sponsored by COSPAR and the IAU. It will be preceded by a number of topical workshops. A plasma-science workshop will be held from 20–24 October 1986 at the Max-Planck-Institut für Aeronomie in Lindau, Germany, and further workshops in the areas of imaging, dust, and coma chemistry are under discussion.

Conclusions
Since the IACG was formed $2^1/_2$ years ago, it has demonstrated an ever-growing usefulness for the various flight projects as a focal point for exchange of information, discussion on common problems, and mutual support to enhance the overall scientific return of the space missions to Halley's comet. The IACG and its counterpart on the ground, the IHW, form the cornerstones of a global effort to explore Halley's comet as completely as possible during its present apparition.

By the end of the 1980's, when Halley's comet will disappear again into the outer solar system, it will be the most thoroughly studied comet ever. More data will have been collected on Halley than on all other comets put together.

All four agencies, noting the good cooperative spirit in the IACG and its achievements and the fact that the IACG is presently the only body involving all of them, have expressed a desire to continue the IACG beyond 1986. A large number of projects with sufficient overlap to allow selection of another solar-system object for a cooperative study at a later stage, are presently under consideration in the various agencies.

Legal Status of Memoranda of Understanding in the United States

W.M. Thiebaut, Legal Affairs Department, Directorate of Administration, ESA, Paris

NASA and ESA have a long standing and successful history of cooperation in space, mainly in the area of space science. The modalities of such cooperation are laid down in legal instruments which, in the majority of cases, take the form of Memoranda of Understanding. There is no doubt that under international law such MOUs constitute international agreements which are binding upon the parties. However, questions can be raised regarding the order of precedence under national law between international agreements and, in this case, US domestic legislation.

Questions regarding the validity of international Memoranda of Understanding came to the fore particularly when ESA was confronted with difficulties in the execution of the Intergovernmental Agreement on Spacelab and the Memorandum of Understanding on the International Solar-Polar Mission (ISPM).

The Intergovernmental Agreement signed on 14 August 1973 provided that the United States would procure additional space laboratories, components and spares that substantially duplicate the design and capabilities of the first Spacelab delivered by the European partners.

In 1973 ESA learned that the United States Air Force intended to procure a Sortie Support System, which could be considered as substantially duplicating a large number of Spacelab components. The Agency therefore requested the application of the Intergovernmental Agreement. The US Air Force replied that the national law of the US has precedence over Intergovernmental Agreements which have not been ratified by the US Senate. In particular the Intergovernmental Agreement could not take precedence over the 'Defence Appropriations Act of 1973' (known as the Bayh Amendment), which prohibits the award of research and development contracts to foreign organisations when there is a United States corporation, organisation, person or other entity equally competent to carry out such research and development and willing to do so at a lower cost.

In the Memorandum of Understanding on ISPM signed on 29 March 1979, NASA and ESA undertook to send two instrumented spacecraft far out of the ecliptic plane of the solar system to conduct coordinated observations of the interplanetary medium and the Sun, simultaneously in the northern and southern hemispheres of the solar system. In 1981 NASA informed ESA that cuts of 22% of the Office of Space Science Budget over the next several years made it necessary to cancel one of their major on-going projects. For various reasons it was decided to cancel the NASA ISPM satellite. NASA based its decision to cancel on Article 13 of the MOU, which states that the ability of NASA and ESA to carry out their obligations under the MOU is subject to their respective funding procedures.

We will first discuss the legal status of on MOU under United States domestic law; namely

1. Is it an International Agreement?
2. What is its value before conflicting domestic legislation?
3. What is the value of the escape clauses that it contains?

and then go on to discuss possible ways of alleviating the inconveniences of such MOUs.

Legal status of Memoranda of Understanding in the United States

Definition of MOUs

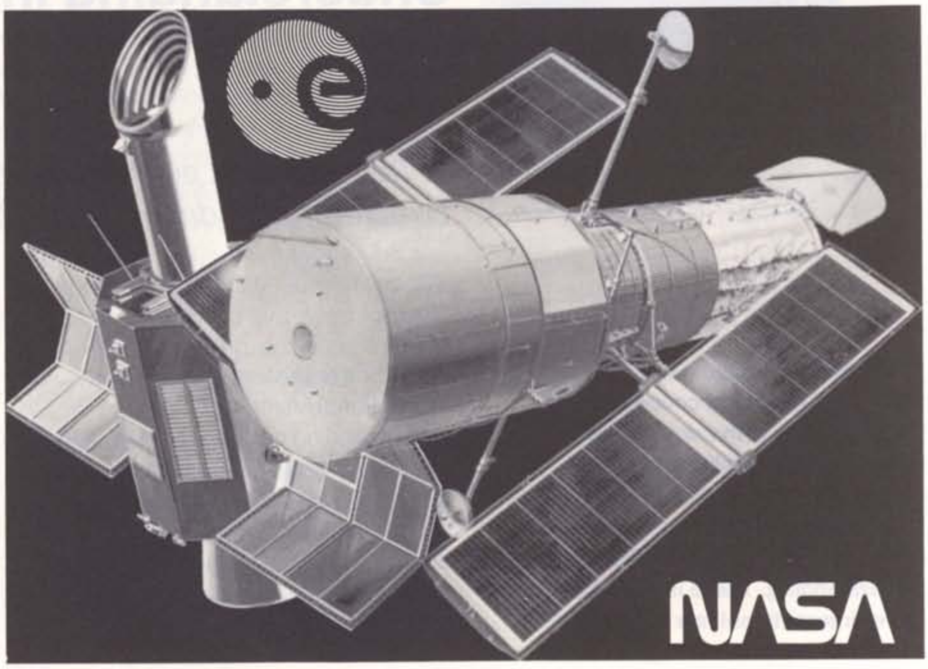
Under international law, a Memorandum of Understanding can be defined as an agreement between subjects of international law intended to produce obligations between the parties. These agreements can take different forms, but due to US law the MOUs between NASA and ESA are characterised by a certain number of specific provisions which are common to all MOUs concluded to date by the two parties.

Indeed the MOU aims at establishing a form of cooperation between the partners based on the principle of no exchange of funds. The partners do not enter into a contractual relationship, but commit to use their best efforts to achieve the subject of the cooperation. Moreover, the MOUs provide for a clause that makes their commitments subject to the availability of funds or to their respective funding procedures.

There is no mandatory arbitration procedure, but there is a mechanism for settlement of disputes between the Director General of the Agency and the Administrator of NASA, who, should they fail to resolve the dispute, may submit, by mutual agreement, to other forms of resolution or arbitration.

The Agency has concluded several MOUs with NASA (including Spacelab, IUE, ISEE, Space Telescope, ISPM, Seasat, Nimbus-G, Landsat), but it has also used this form of cooperation with other US agencies such as NOAA on Landsat and FAA on Aerosat, for which the same principles govern the conclusion of MOUs. The Agency has also concluded MOUs with European countries or organisations such as Sweden in the case of the Kiruna centre, Spain on the use of Maspalomas, and the Commission of the European Communities for Euronet.

In these cases it can be questioned whether the use of the term MOU was judicious for these agreements, as they do not contain the clauses that are characteristic of MOUs. A more appropriate term might have been chosen, such as International Arrangement or Agreement, leaving the term MOU for the cooperation with



partners who, according to their national laws, have to include in their international agreements the specific clauses mentioned above.

Legal basis and form of cooperation

The Agency's ability to conclude international agreements is based on Article XIV, 1 of the ESA Convention which states that: 'The Agency may, upon decisions of the Council taken by unanimous votes of all Member States, cooperate with other international organisations and institutions and with governments, organisations and institutions of non-Member States, and conclude agreements with them to this effect.'

These agreements can take several forms without altering, as far as the Agency is concerned, the binding effect of the legal instrument. This situation might be different for potential partners of the Agency, who are subject to constraints placed on them by their national laws.

NASA's ability to conclude international agreements is based on the power of the President of the United States, who according to Article II, §2 of the US Constitution 'shall have the power, by and with the advice and consent of the Senate, to make treaties, provided two-thirds of the Senators present concur'.

The National Aeronautics and Space Act of 1958, Section 205, states accordingly:

'The Administration under the foreign policy guidance of the President may engage in a program of international cooperation in work done pursuant to this act, and in peaceful application of the results thereof, pursuant to agreements made by the President with the advice and consent of the Senate'.

Most international cooperation, however, is not executed pursuant to an agreement made with the advice and consent of the Senate, but on the basis of less formal agreements, the existence of which is implicitly recognised in Section 10 of Article I of the US Convention. NASA therefore utilises three main forms of international agreement:

- Intergovernmental Agreements, which are signed between governments; for example,

'The Agreement between the Government of the United States and certain Governments, Members of the European Space Research Organisation, for a Cooperation Programme concerning the development, procurement and use of a Space Laboratory in conjunction with the Space Shuttle System'.
- Memoranda of Understanding, signed between the Administrator of NASA and its counterpart; for example, the MOUs on ISPM, on Space Telescope, on IUE, on Spacelab, etc.
- Exchange of letters, usually signed by the Heads of the International Affairs Departments; for example, Deposit Accounts Agreements.

In order to assess the legal value of these agreements, it is necessary to define what an international agreement is according to US law and how such agreements are classified under domestic law.

Definition of the term 'International Agreement'
The Case Zablocki Act on coordination with the Secretary of State and the reporting to Congress of international agreements of the United States requires the Secretary of State to transmit the text of all international agreements, other than treaties, to Congress not later than 60 days after their entry into force.

The Act also provides that no international agreement may be signed or otherwise concluded without prior consultation with the Secretary of State. The International Agreement Regulations, which implement the Case Zablocki Act, are applicable to all Agencies of the US Government that negotiate and conclude international agreements. The regulations outline the criteria applied by the Department of State to decide what constitutes an international agreement, and provide that determination of such questions is made by the Legal Adviser of the Department of State. The criteria to be applied in deciding whether any undertaking, oral agreement, document or set of documents, including an exchange of notes or of correspondence, constitutes an international agreement within the meaning of the Case Zablocki Act are the following:

- *Identity and intention of the parties*
  A party to an international agreement must be a State, a State Agency, or an intergovernmental organisation.

  The parties must intend their undertaking to be legally binding. Documents intended to have political or moral weight, but not intended to be legally binding, are not international agreements. An example of the latter is the Final Act of the Helsinki Conference on Cooperation and Security in Europe.

  In addition, the parties must intend their undertaking to be governed by international law, although this intent need not be manifested by a third-party dispute settlement mechanism or any express reference to international law.

- *Significance of the arrangement*
  Minor or trivial undertakings, even if couched in legal language and form, are not considered international agreements. In deciding what level of significance must be reached before a particular agreement becomes an international agreement, the entire context of the transaction and the expectations and intent of the parties must be taken into account.

- *Specificity, including objective criteria for determining enforceability*
  An international agreement requires a certain degree of precision. Undertakings couched in vague or very general terms normally do not constitute binding agreements. More often such terms reflect an intent not to be bound. For example, a promise to 'help develop a more viable world economic system' lacks the specificity needed to constitute a legally binding international agreement.

- *Necessity for two or more parties*
  Even though unilateral commitments can on occasion be legally binding, they do not constitute international agreements.

  For example, a statement by the President of the United States promising to send money to country X to assist earthquake victims would not be an international agreement.

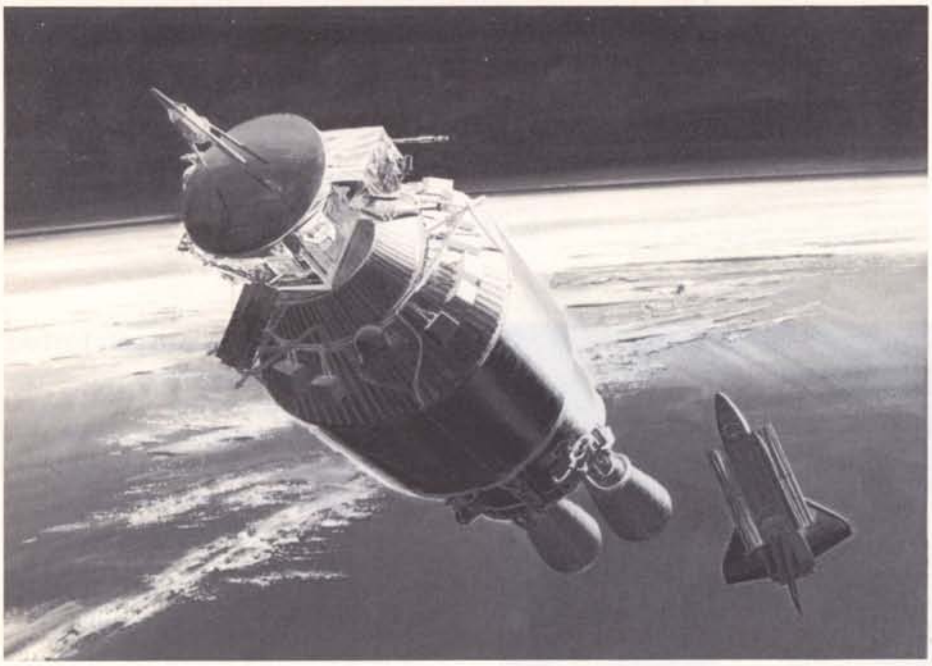
- *Form*
  Form as such is not normally an important factor. Documents that do not follow the customary form for international agreements, as to matters such as style, final clauses, signatures or entry into force dates, may or may not be international agreements.

Each of these criteria, except the last, must be complied with in order for any given undertaking of the United States to constitute an international agreement.

Classification of 'international agreements'
For the purposes of United States law, all 'treaties', 'conventions', 'acts', 'protocols', 'agreements', 'Memoranda of Understanding' and 'modus vivendi' may be reduced to two categories: treaties and executive agreements.

Under the Constitution of the United States, any international agreement, however denominated, that is made by the President and that becomes binding upon the United States only after 'the advice and consent' of 'two-thirds of the Senators present' is a treaty (US Constitution Article II,2). Only international agreements that fulfil these requirements are classified as treaties.

All other international agreements are executive agreements. Executive agreements may be further subdivided



into two categories depending on whether they become effective by action of the President alone, or by action of the President and both Houses of Congress.

The latter type of executive agreements are more appropriately designated 'Congressional-executive agreements'. They are approved by a majority vote of both Houses of Congress.

On the other hand, those that will become effective by action of the President alone are called 'Presidential-executive agreements'.

Legal status of treaties and executive agreements

Before the US domestic legal status of treaties and executive agreements can be defined, it is first necessary to define the term 'self-executing' in relation to international agreements.

A treaty or an executive agreement is 'self-executing' wherever it operates by itself without the aid of any legislative provision; in other words, when it manifests an intention that its provisions shall be effective under the domestic law of the parties at the time of its effect.

Consequently, the general principles on precedence of treaties and executive agreements in relation to domestic law can be summarised as follows:

- A self-executing treaty overrides prior inconsistent federal law.
- A self-executing executive agreement based on a statute or a treaty overrides prior inconsistent federal law.
- A self-executing agreement based exclusively on the President's constitutional powers will probably be held to be subordinate to prior inconsistent federal law.
- A non-self-executing treaty or executive agreement has no US domestic legal effect until implementing legislation is enacted by Congress. When such legislation is enacted, it will override prior inconsistent federal law under the rule that 'last in line prevails'.
- A treaty or executive agreement is subordinate to subsequent inconsistent federal law.

As a conclusion, it can be ascertained that MOUs between ESA and NASA are appropriately classified as Presidential-executive agreements, which will be held to be subordinate to prior inconsistent federal law. It should be remembered, however, that a validly executed executive agreement constitutes a binding obligation under international law, regardless of the US domestic legal effect of the executive agreement.

Legal value of specific provisions in MOUs

As mentioned earlier, the constraints put on NASA by US domestic law, which result in the best-efforts clause and the availability-of-funds clause, weaken the binding value of the international agreement.

The 'best efforts' clause

The use of the term 'best efforts' in the MOUs between NASA and ESA does not independently render those agreements unenforceable under either United States domestic law or international law. Under United States law, a 'best efforts' clause requires a good-faith undertaking by the party to perform its contractual obligation. Under international law, the intention of the parties to create or define relationships determines whether an international agreement is in force.

The determination of whether a party has fulfilled its obligations under a 'best efforts' clause will necessarily take into consideration that party's 'capabilities', a term which under United States law includes not only 'financial ability' but the 'expertise and experience attributable' to an 'average, prudent, comparable' organisation. The burden of proof with respect to 'best efforts' is placed on the party asserting the failure to utilise best efforts. Under international law, an international agreement is binding in accordance with its terms, and each party has a duty to give them effect.

The 'availability of funds' clause

NASA or any other government Agency in the US is prohibited by the Anti-Deficiency Act from obligating funds in the absence of a specific Congressional authority or appropriation. The Anti-Deficiency Act states, inter alia:

'.... nor shall any such offices or employee involve the Government in any contract or other obligation, for the payment of money for any purpose, in advance of appropriations made for such purpose, unless such contract or obligation is authorised by law'.

Therefore, any contract or obligation entered into by NASA must contain a 'subject to availability of funds' clause.

A clause stating that the obligations of the parties are 'subject to their respective funding procedures', which appears in the existing MOUs, has the effect of incorporating into the MOUs the domestic law and procedures of the parties with respect to funding. Thus, if Congress refuses to appropriate funds for a particular obligation, NASA is excused from performing under the MOU and has breached neither United States nor international law. On the other hand, the US budgetary system provides mainly for yearly appropriations and thus NASA is only to contract within the limits of these appropriations; hence the proviso 'subject to availability of funds'.

Any deviation from this, in order for an MOU to constitute an unconditional obligation by NASA, requires some form of legislative action.

The presence of a 'subject to availability of funds' clause in the MOU raises the question of whether the MOU is legally binding and whether the agency has an obligation to seek the necessary funding. Case law demonstrates that a contract that is subject to the availability of funds is a binding contract, and that it is not a mere option. *In Varo, Inc. versus the United States*, the Government cancelled a multiyear procurement by informing the contractor that funds would not be 'allotted to' its contract. The Government sought to justify its action by relying on the 'subject to funds' clause in the contract, and the contractor sued for breach. The Armed Services Board of Contract Appeals ruled that the Government was not entitled to decide unilaterally to allot no funds to the contract, and that the Government was under an obligation to purchase the items in question from the contractor as long as funds were available.

Case law also indicates that the 'subject to availability of funds' clause does not exonerate an agency when if fails to seek adequate appropriations. In *S.A. Healy Co. versus the United States*, the contract contained a clause that made the Government's liability contingent upon the necessary funds being made available by Congress, and expressly disclaimed liability due to delays in funding. The agency failed to request funding sufficient to cover the contractor's work. The Court of Claims held that the Government was liable for the damages caused by the agency's failure to request sufficient funds. The Court stated that 'the protective umbrella of the "funds available clause" .... does not extend to an exhaustion of funds occasioned by the agency's decision to request funding grossly inadequate to support the level of earnings approved by the agency for the fiscal year'.

This result is consistent with the general principle that the Government has an implied duty to cooperate in the performance of contracts. The Government cannot refuse funds, since the Government would be frustrating the completion of the contract.

What is valid for contracts is equally valid for MOUs, and NASA is under an obligation to seek funds from Congress and can only invoke the 'non-availability of funds' if Congress has refused to allocate the funds as requested.

Alternatives for obtaining assurances of adequate funding

There are several ways in which the inconvenience of the availability of funds clause could be avoided:

Congressional authority for NASA to contract with ESA

The Anti-Deficiency Act prohibits the Government from making any contract or obligation in advance of appropriations unless 'such contract or obligation (MOU) is authorised by law'. If Congress explicitly grants an agency the power to enter into a contract, then the contract need not be made subject to the availability of funds.

The major obstacle to this alternative is the Congressional Budget and Impoundment Act of 1974 ('Budget Act'). One of the principal purposes of the Budget Act was to curtail the prior congressional practice of authorising agencies to enter into contracts without following the normal appropriations procedures. These grants of spending power, known as 'backdoor spending', were perceived as 'a principal impediment to comprehensive budget control'.

In order to curb backdoor spending, the Budget Act made it more difficult for Congress to authorise contracts outside the appropriations process.

Thus, Congress may now be blocked from considering any new request for contract authority outside the appropriations process if a *single member of the House or the Senate objects.*

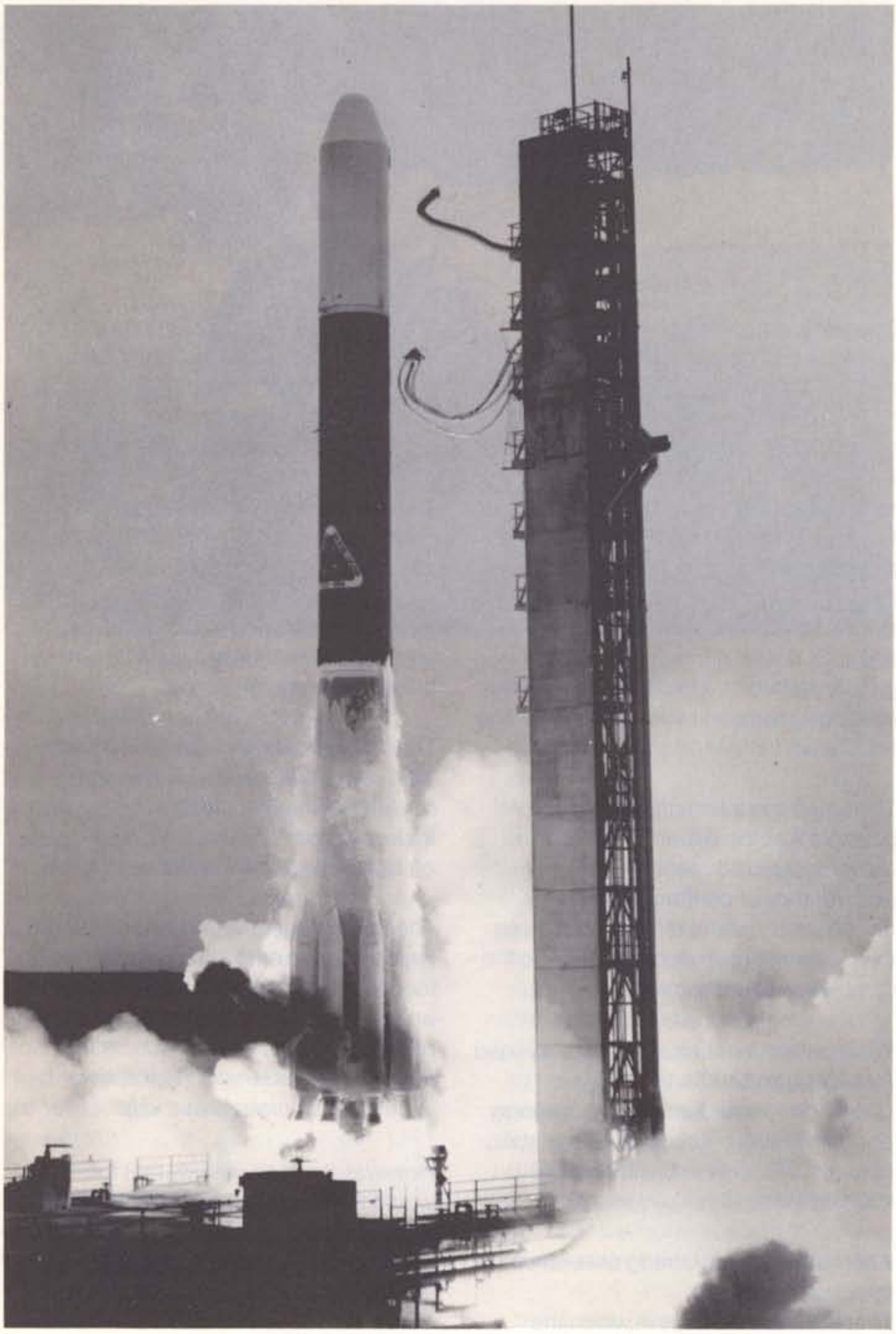
The Budget Act does not make it impossible to enact authorising legislation for an MOU or contract in the absence of an appropriation. If such legislation were passed without objection in both the House and the Senate, the resulting statute would probably be valid.

However, it seems unlikely that there would not be a single Senator or a Congressman to object to this alternative and therefore it does not appear to have any likelihood of success.

Congressional appropriation for future years

The problems presented by the Budget Act may be avoided by requesting appropriations of funds for expenditure in future years. The Budget Act specifically contemplates that Congress may appropriate funds for expenditure in subsequent fiscal years. The Senate Committee that reported the Budget Act recognised that:

'... contract authority is often utilised in situations where, for predictability and planning purposes, advance funding is desirable. It is intended that in such circumstances the necessary advance funding will be provided in an Appropriations Act, which will be enacted



a year or several years in advance of the time the budget authority provided therein becomes available.'

The availability of such appropriations would enable NASA to enter an unconditional contract or MOU with a funding schedule consistent with the appropriation schedule. Such appropriations, however, must be obtained through the normal appropriations process, i.e. consideration by the Authorisation Committees, the Appropriations Committees, and the House and the Senate.

Safety clauses in the MOUs
The measures mentioned in the last two subsections aim at the intervention of the Congress of the United States in order to ensure adequate funding. However, outside this intervention of Congress, which might prove difficult to achieve, it seems possible to introduce into the MOUs clauses that would avoid or limit the inconvenience of the 'subject to availability of funds' clause, such as

- a clause that contains a commitment from NASA to seek the necessary appropriations during the execution of the programme
- mandatory consultations in case of funding difficulties
- inclusion of a clause for reparation of damages suffered by the other party
- a mandatory arbitration clause.

Conclusion
It can be concluded that the Memoranda of Understanding between ESA and NASA have to be considered international agreements under international law as well as under United States' domestic law. Under international law, however, they are binding upon the parties, whereas under United States' domestic law their execution might be dependent on the precedence of conflicting legislation.

The success of a cooperative project depends largely on the good-faith understanding of both parties to the MOU, as the history of cooperation between NASA and ESA has proved.

In brief

20 Years of European Cooperation in Space

The Conventions of ESA's two forerunner organisations, the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO) entered into force twenty years ago this year, on 20 March and 29 February 1964, respectively (see article on page 20 of this issue). To celebrate this milestone in European space cooperation, a number of events are planned at the Agency's European Space Research & Technology Centre (ESTEC) at Noordwijk in The Netherlands in the second week in May.

On the morning of 9 May ESTEC will host a Panel Discussion and Teleconference (via ECS-1) with the theme 'Europe in Space'. The panel members will include: Prof. Hubert Curien, Chairman of ESA Council; Mr. Erik Quistgaard, Director General of ESA; Drs. Nelie Smit-Kroes, The Netherlands Minister of Traffic and Public Works; Dr. Gerhard Haerendel, Director of the Max-Planck Institute for Extraterrestrial Physics; and Dr. Andrea Caruso, Secretary General of Eutelsat.

On the afternoon of 9 May there will be an official 'Twenty Years Ceremony', with the following presentations:

- Welcome and introduction by Prof. Hubert Curien, Chairman of the ESA Council
- Video presentation entitled '20 Years of European Cooperation in Space'
- 'The Scientific Programme, Cornerstone of European Space Activities', by Prof. Cornelis de Jager, Chairman of COSPAR and of the ESA Science Programme Committee
- 'ESRO, from Science to Applications', by Sir Hermann Bondi, former Director General of ESRO, and Chairman of the UK Natural Environment Research Council
- 'An Achievement of European Space Policy: The Creation of ESA', by Minister Charles Hanin, former Chairman of the European Conference and a Member of the European Parliament
- Video presentation entitled 'Spacelab-1 Flight Highlights', with commentary by the European astronauts Ulf Merbold, Wubbo Ockels and Claude Nicollier
- 'ESA and Europe's Future in Space' by Mr. Erik Quistgaard, Director General of ESA.

The Ceremony, which will take place in ESTEC's new Test Hall, will be attended by Her Majesty Queen Beatrix of The Netherlands. Several hundred guests are expected, along with representatives of the European press and other media.

The texts of the presentations made at the Ceremony are to be published in the next issue of the ESA Bulletin (no. 39, August 1984).

Ariane Launches Second Intelsat-V

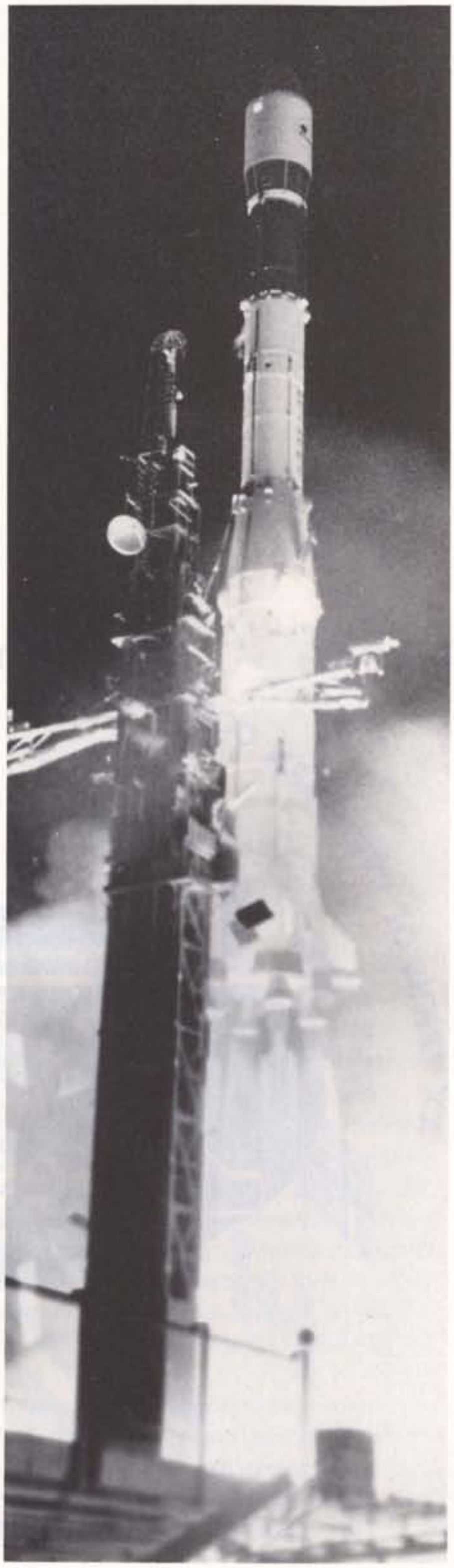
The International Telecommunications Satellite Organisation's Intelsat-V F8 was successfully launched by Ariane V8*, from ESA's Kourou launch base in French Guiana at 21.50 local time on 4 March (00.50 on 5 March GMT).

Separation of the satellite was nominal and, according to first reports received from Intelsat, it was placed by Ariane in a near-perfect transfer orbit, with a perigee of 186.5 km (against 184.9 specification), an apogee of 36 045 km (against 35 988 specification) and an inclination of 8.53° (against 8.50° specification).

Satellite orbital operations proceeded nominally, and the apogee boost motor was fired at 11.10 GMT on 7 March.

This was the second successful launch of an Intelsat-V satellite by Ariane under the auspices of ESA. The launch of the third Intelsat-V, the last in ESA's 'promotion series', has been subcontracted to Arianespace, who then take over all future launch-activity responsibility. The accompanying table shows the provisional schedule for future Ariane launches.

* Ariane launches are now identified by the serial number of the flight ('vol') rather than that of the launcher.



Ariane Manifest 1984 –1987

Year	Month	Flight serial no.	Spacecraft	Launcher orbit
1984	March	V8 (AR-1)	Intelsat-V F8	GTO
	May	V9 (AR-1)	Spacenet-1	GTO
	July	V10 (AR-3)	ECS-2	GTO
			Telecom-1A	GTO
	September	V11 (AR-3)	Marecs-B2	GTO
			G-Star 1B	GTO
	November	V12 (AR-3)	Arabsat-A	GTO
			Spacenet-2	GTO
1985	January	V13 (AR-3)	Telecom-1B or SBTS-1	GTO
			G-Star 1B	GTO
	March	V14 (AR-3)	SBTS-1 or Telecom-1B	GTO
			Spacenet-3	GTO
	May	V15 (AR-1 or -2)	SPOT-1/Viking or Intelsat-V	Heliosynchr. or GTO
	July	V16 (AR-1)	Giotto	Escape
	August	V17 (AR-3)	SBTS-2	GTO
			ECS-3	GTO
	September	V18 (AR-2)	TV-Sat	GTO
	October	V19 (AR-2 or -1)	Intelsat-V or SPOT-1/Viking	GTO or Heliosynchr.
	November	V20 (AR-2)	TDF-1	GTO
1986	January	V21 (AR-2)	Intelsat-VA F15	GTO
	March	V22 (AR-4)	Ariane 4 - 01 (demonstration)	GTO
	May	V23 (AR-2)	Intelsat-VA F13	GTO
	June	V24 (AR-3)	Flight Opportunity	GTO
	August	V25 (AR-4)	Unisat-1 (R)	GTO
			Flight Opportunity	GTO
	November	V26 (AR-3)	STC (R)	GTO
			Flight Opportunity	GTO
	December	V27 (AR-4)	Intelsat-VI (R)	GTO
1987	February	V28 (AR-4)	Tele-X (C)	GTO
			Unisat-2 (R)	GTO
	March	V29 (AR-3)	DBSC-1 (R)	GTO
	April	V30 (AR-4)	Intelsat-VI (R)	GTO
	May	V31 (AR-3)	TDF-2 (R)	GTO
	June	V32 (AR-3 or -4)	DFS-1 (R) or Anik (R)	GTO
			Operational Meteosat-1 (C)	GTO
	July	V33 (AR-3)	Olympus (C)	GTO
	August	V34 (AR-4)	Intelsat-VI (R)	GTO
	September	V35 (AR-3)	DBSC-2 (R)	GTO
	October	V36 (AR-4)	Italsat (R)	GTO
			Rainbow (R)	GTO
	December	V37 (AR-2)	SPOT-2 (C)	Heliosynchr.

Up to V23 incl.: all firm contracts — After V23: (C) = Contract (R) = Reservation

GTO: Geostationary Transfer Orbit

Spacelab-1 Astronauts' Tour of Europe

ESOC, Darmstadt

Copenhagen

Stockholm

Brussels

Madrid

Rome

Delft

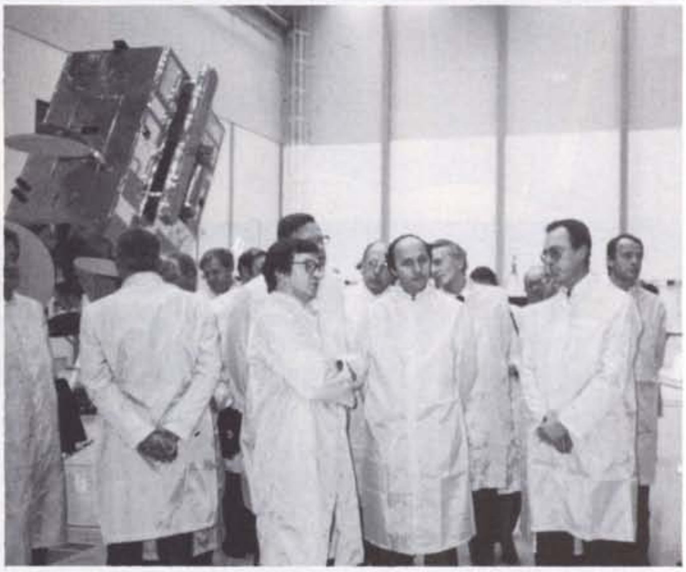
US Embassy, Brussels

Geostationary Orbit Slot Freed by ESA

On 24 and 25 January, ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, carried out a series of operations designed to boost the Agency's Geos-2 spacecraft into a higher orbit, where it will present no collision risk for other spacecraft in transfer or geostationary orbit. Geos will now continue to drift westward around the Earth at a rate of about 3° per day in its new orbit, making a complete revolution once every 108 days. If desired, scientific data can still be acquired during the limited periods of ground contact with the Geos ground station.

This decommissioning and removal from geostationary orbit of one of its satellites by ESA frees a valuable slot in the busy geostationary orbit for further use. The Agency will repeat the process in the coming months with its OTS-2 spacecraft.

A detailed account of the de-orbiting of Geos-2 can be found on page 86 of this issue.



M. Laurent Fabius, Ministre français de la Recherche et de l'Industrie, en visite à l'ESTEC

M. Fabius écoutant les explications du Professeur Bonnet (au centre) sur les satellites scientifiques de l'ESA

Devant le modèle du futur satellite Olympus

Dans le cadre de la visite d'Etat de M. François Mitterrand, Président de la République française, aux Pays-Bas du 6 au 8 février dernier, M. Laurent Fabius, Ministre de la Recherche et de l'Industrie, a rendu une brève visite au Centre européen de Recherche et Technologie spatiales (ESTEC) à Noordwijk. Accueilli par M. E. Quistgaard, Directeur général, et le Professeur M. Trella, Directeur technique de l'Agence et Directeur de l'ESTEC, M. Fabius – accompagné de M. G.M.V. van Aardenne, vice Premier Ministre néerlandais et Ministre des Affaires économiques, du Professeur Curien, Président du Conseil de l'ESA, et du Professeur P. Bonnet, Directeur des Programmes scientifiques – a pu visiter les installations et équipements du Centre, en particulier le nouveau bâtiment des essais en cours de construction, qui sera l'un des plus grands et des plus avancés du monde.

Soigneusement minutée, cette première visite faite un Ministre français à l'ESTEC s'est achevée par un bref dialogue entre M. Fabius et les travailleurs français du Centre qui lui ont fait part de leurs conditions d'existence et de travail.

New Head of ESRIN Appointed

The Director General has appointed Mr. Francis Roscian as Head of the Agency's Establishment in Frascati, Italy, with effect from 1 March 1984.

Mr. Roscian, a French national, began his career as an engineer with the Equipment Department of the French rocket range at Colomb-Béchar. He was subsequently with the Centre National d'Etudes Spatiales (CNES), until his appointment, in May 1975, as Head of the Ground Equipment Engineering Department at ESOC in Darmstadt. Since 1 April 1980, Mr. Roscian has been based at the Agency's Headquarters in Paris, as the representative of the Director of Operations.

and twenty years ago . . .

EUROPEAN SPACE RESEARCH ORGANISATION

ESRO 36, rue la Pérouse, tel. 225.24.02

No. 3

22 May 1964

NEWS IN BRIEF

I. ESRO MEETING

- 15 April : the APPOINTMENTS COMMISSION made appointments to 3 technical posts at ESTEC, 3 administrative posts at Headquarters and 1 at ESDAC.

- 16-17 April : the INTERIM AWG (Interim Legal, Administrative, and Financial Working Group), under the chairmanship of M. Sassot (Spain), approved the award of supply contracts :

- High tension power line at Kiruna (Swedish Electric Power Supply Company);
- Wind measuring tower for Kiruna (CERCI, France);
- Tracking and telemetry receiving antennae (Electrometall, RFA);
- Ground equipment for Centaure launchings in Sardinia (Sud Aviation, France)
- Centaure launcher (Sud Aviation, France)
- A batch of 20 Skylark rockets (U.K.) and 24 Centaure rockets (France)

The AWG approved the Regulations concerning the ESRO Social Security Scheme and Provident Fund respectively, and also an internal tax system similar to that applied in the W.E.U.

- 23 April : Under the chairmanship of Dr. Lüst, the LPSC (Launching Programmes Sub-Committee) discussed the proposals in respect of payloads for the satellites and sounding rockets to be launched after the launching campaign of this summer.

- 24-25 April : COLLOQUIUM on the scientific purposes of ESRO'S LARGE ASTRONOMICAL SATELLITE project. Over a hundred astronomers discussed the astronomical aspects of the European space research programme with a view to preparing the Large Astronomical Satellite which will be launched by ESRO in 6 years' time.

Professors Biermann, Charlotte Pecker-Wimel and de Jager, and Dr. Butler presented reports concerning the basic requirements of modern astronomy, ultraviolet radiation from the stars and X-ray and gamma radiation.

P/315.

page 2

- 27-28 April : Under the chairmanship of Dr. Vranken the ad hoc Group to study the Rules of Procedure, composed of delegates from Member States, finalised the wording of these Rules which will be submitted to the AWG for approval at its next meeting.

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2. ELDO

First Session of the ELDO Council : 5 and 6 May in Paris (attended by Delegates from Australia, Belgium, France, Italy, Netherlands, Federal Republic of Germany, United Kingdom; Denmark was represented by an observer).

Professor Gunther BOCK (Germany) was elected Chairman; Sir Allen BROWN (Australia) and M. PATERNOTTE de la VAILLEE (Belgium) Vice-Chairmen. Ambassador Renzo di CARROBIO (Italy) was appointed Director-General.

The Council approved a) a Draft Agreement with ITALY defining the co-operation between that country and ELDO, pending the deposit by Italy of its instrument of ratification; b) a temporary Draft Agreement with AUSTRALIA concerning the launchings of the booster ("Blue Streak") due to take place at Woomera in the near future.

The Council also approved the Rules of Procedure and the Financial Regulations.

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3. SATELLITE TELECOMMUNICATIONS

- 23-24 April : London, Meeting of the Organisation Committee of CETS (European Conference on Satellite Telecommunications). The INTERIM DRAFT AGREEMENT between CETS, the UNITED STATES and CANADA was amended. A further meeting to be attended by representatives of these countries will be held at the end of May in order to finalise the drafting of the last articles.

The interim Agreement relates to the first two "generations" of satellites :

- 1 or 2 24-hour satellites to be launched at the beginning of 1965, as experiments; it is hoped that these satellites can be used for Trans-Atlantic and possibly Trans-Pacific communications for commercial purposes.

page 3

- a second generation of satellites of a type not yet determined, which would widen the scope of transmissions.

A final Agreement for a world-wide network of satellite telecommunications will be negotiated at a later date.

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4. METEOROLOGICAL SATELLITE

The Executive Committee of the WMO (21 experts, of whom 6 are nationals of ESRO Member States) will discuss the report of the WMO Advisory Committee (12 experts) in May-June and also the question of world weather watch relating to research in the upper atmosphere and meteorological satellites. The WMO will submit a report on this subject to the U.N.

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5. CHANGES IN STAFF COMPOSITION

- Staff members having joined after 1 April 1964

in Paris : M. L. HUCHON, engineer, Technical Installation and facilities.

in Delft : Messrs. FARLEY (U.K.), MAKKINK (Netherlands), SCHUTZ (Germany), engineers in the Environmental Testing Division; Messrs. OKKES (Netherlands) and LOTHALLER (Austria), engineers in the Instrumentation Division; Mr. VERWIJNEN (Netherlands), Administrative Assistant to Dr. Lines; Mr. NELLESEN (Germany), engineer in the Projects Division; Mr. MULLINGER, Assistant to the A.D., Projects.

in Darmstadt : Mr. BENGESER (Germany), Head of the Administration.

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page 4

6. MISCELLANEOUS

4 March : AGREEMENT FRANCE/UNITED STATES concerning the launching of a satellite to study the propagation properties of very low frequency electro-magnetic waves in the atmosphere.

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According to the press, a ROCKET OF PLASTIC MATERIAL, "NIKO", has been developed in the Federal Republic of Germany. Cheap in production, it appears to be capable of high performances.

At the Aeronautics Exhibition, Hanover (23 April-3 May), recoverable sounding rockets were shown.

x

U.S.A. : between 1960 and 1970, the AEROSPACE INDUSTRIES, America expect the number of its EMPLOYEES to increase by 29%, or from 1 086 000 employees in 1960 to 1 400 000 in 1970 (report of the American National Scientific Foundation).

NASA's BUDGET for 1964: 5 116 351 $, as compared with 3 695 888 for 1963.

x

EUROCAE (European Organisation for the ELECTRONICS INDUSTRY of Civil Aviation, 23, rue de Lubeck, Paris) : The General Assembly, Zürich, 10 April, asked for international co-ordination in order to define the requirements and specifications of the electronics industry.

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4 and 5 May : Meeting of the Joint Committee EUSEC/FEANI (Conference of the Engineering Societies of Western Europe and the United States of America/Federation of European Engineering Societies), has been requested by the CECD to undertake an enquiry concerning the training of technicians.

Publications

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

ESA Journal

The following papers have been published in ESA Journal Vol. 8, No. 1:

THE ACTIVE MICROWAVE INSTRUMENTATION FOR ERS-1
COX R P & JOYCE H

ORBIT DETERMINATION FOR COMET HALLEY BY MEANS OF OPTIMALLY SELECTED OBSERVATIONS
ELYASBERG P E ET AL

SPECTRAL CONDENSATION: A NEW CONCEPT IN NUMERICAL STRUCTURAL DYNAMIC ANALYSIS
ARDUINI C

ESL: A SIMULATION LANGUAGE FOR THE SPACE INDUSTRY
HAY J L, CROSBIE R E & PEARCE J G

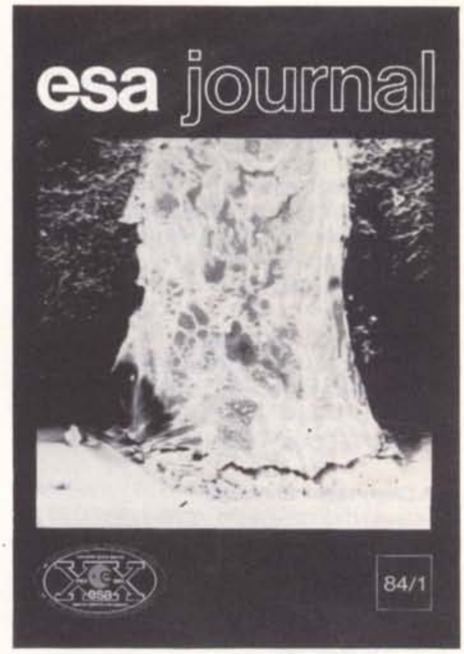
A PASCAL IMPLEMENTATION OF A PORTABLE INTERACTIVE LANGUAGE
KERR G W

SELECTION AND CONTROL OF MATERIALS FOR SPACE APPLICATIONS
DAUPHIN J

EFFECT OF HIGH-DISPERSION COMPONENTS ON THE SOLDER JOINTS OF CERAMIC CHIP CARRIERS ATTACHED TO THICK-FILM ALUMINA SUBSTRATES
LYNCH J T, FORD M R & BOETTI A

ECS-1 IN-ORBIT MEASUREMENTS PROGRAMME AND RESULTS
MOENS C & KOOTER C

AN EXTENSION TO PROPOSED POSSIBILITIES FOR CALIBRATING OPTICAL IMAGING INSTRUMENTS IN SPACE
KRIEBEL K T & REYNOLDS M L



Special Publications

ESA SP-219 // 90 PAGES
THE EFFECT OF GRAVITY ON THE SOLIDIFICATION OF IMMISCIBLE ALLOYS, PROC OF AN RIT/ESA/SSC WORKSHOP HELD IN STOCKHOLM, SWEDEN, 18-20 JANUARY 1984
ROLFE E J & BATTRICK B (EDS)

ESA SP-1052 // 476 PAGES
IUE LOW-DISPERSION SPECTRA REFERENCE ATLAS – PART 1. NORMAL STARS
HECK A, EGRET D, JASCHEK M & JASCHEK C

ESA SP-1063 // 22 PAGES
SECOND-GENERATION METEOSAT: SYSTEM STUDY EXECUTIVE SUMMARY (JANUARY 1984)
STEWART K H

Contractor Reports

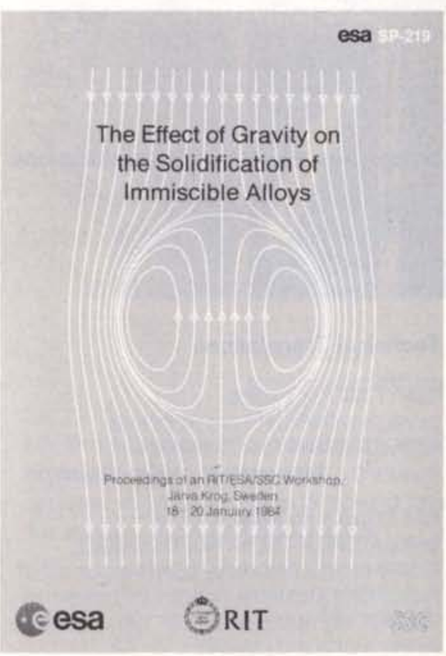
ESA CR(P)-1826 // 162 PAGES
DEVELOPMENT OF PROCEDURES FOR COMPONENT MODE SYNTHESIS – FINAL REPORT (MAR 1983)
DFVLR, GERMANY

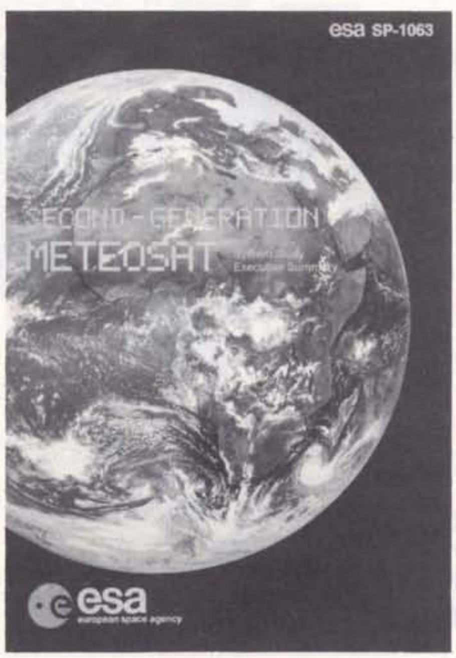
ESA CR(P)-1827 // 358 PAGES / 87 PAGES
RELIABILITY ASSURANCE USING TEST STRUCTURES – PHASE II: FINAL REPORT; PHASE III: REPORT (MAY & JUL 1982)
SIEMENS, GERMANY

ESA CR(X)-1828 // 86 PAGES
MODULAR SOLAR ARRAY SIMULATOR – DESIGN MANUAL (SEP 1983)
IIRS, IRELAND

ESA CR(P)-1829 // 34 PAGES
FIELD EMISSION ELECTRIC PROPULSION – FURTHER TESTING OF MERCURY AS A PROPELLANT – FINAL REPORT (SEP 1983)
IRA (UNIV STUTTGART), GERMANY

ESA CR(P)-1830 // 54 PAGES
THE INTRODUCTION OF CLAMP-BANDS IN SPACECRAFT STRUCTURAL MATHEMATICAL MODELS – FINAL STUDY REPORT (MAR 1983)
DORNIER SYSTEM, GERMANY





ESA CR(P)-1831 // 54 PAGES / 166 PAGES
ERS-1 MISSION – FUCINO STATION. VOLUME 1: TECHNICAL ADDENDUM; VOLUME 2: MAIN REPORT (JUL & SEP 1983)
TELESPAZIO, ITALY

ESA CR(P)-1832 // 53 PAGES / 248 PAGES
STUDY OF WIND SCATTEROMETER ANTENNA FOR ERS-1: 1. EXECUTIVE SUMMARY REPORT, 2. FINAL REPORT (SEP 1983)
L M ERICSSON, SWEDEN

ESA CR(P)-1833 // 452 PAGES
MULTIPATH LINK AND MODEM DESIGN FOR SATELLITE-MOBILE COMMUNICATIONS (AUG 1983)
GARDNER RESEARCH CO, USA

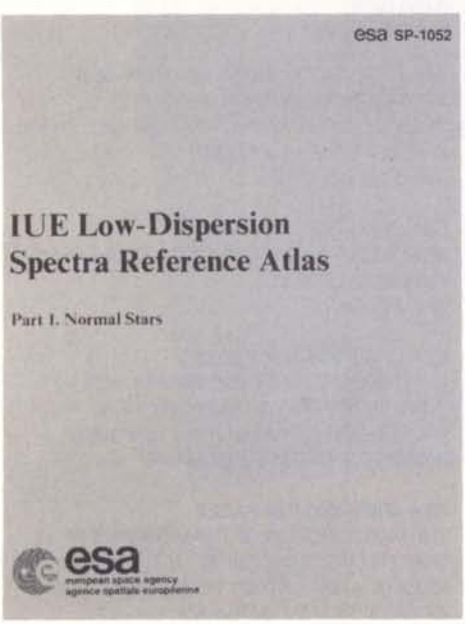
ESA CR(P)-1834 // 61 PAGES
EXPERIMENTAL SPHERICAL NEAR-FIELD ANTENNA TEST FACILITY, PHASE 3 - FINAL REPORT - VOLUME II: STUDY OF AN OFFSET REFLECTOR ANTENNA WITH A SAGGING FEED SUPPORT (JUN 1983)
TICRA A/S, DENMARK

ESA CR(P)-1835 // 211 PAGES
GUIDE POUR LA CONCEPTION DES SYSTEMES PYROTECHNIQUES DESTINES AUX CHARGES UTILES EMBARQUEES SUR DES VEHICULES HABITES OU NON HABITES (AUG 1983)
AEROSPATIALE, FRANCE

ESA CR(P)-1836 // 72 PAGES
SURVEY OF TECHNIQUES EMPLOYED IN THE ANALYSIS OF ROCKET MOTOR SOLID PROPELLANTS (NOV 1980)
ENGINEERING SYSTEM INTERNATIONAL, FRANCE

ESA CR(P)-1837 // 43 PAGES
STUDY OF ANALYSIS METHODS CONCERNING LAUNCH VEHICLE AND SPACECRAFT STRUCTURAL INTERACTION (OCT 1980)
ENGINEERING SYSTEM INTERNATIONAL, FRANCE

ESA CR(P)-1838 // 11 PAGES
REVIEW REPORT OF THE THIRD YEAR'S ACTIVITIES ON THE STUDY OF ADVANCED MATERIALS (SEP 1983)
FULMER RESEARCH LABORATORIES, UK



ESA CR(P)-1839 // 154 PAGES
STUDY OF A SATELLITE COMMUNICATION SYSTEM FOR WIDEBAND COMMUNICATIONS (AUG 1983)
THOMSON-CSF, FRANCE

ESA CR(P)-1840 // 41 PAGES // 168 PAGES
PERFORMANCE ASSESSMENT OF SERIAL MINIMUM SHIFT KEYING (SMSK) MODULATION TECHNIQUE. VOLUME 1: EXECUTIVE SUMMARY; VOLUME 2: FINAL REPORT (SEP 1983)
ANT NACHRICHTENTECHNIK, GERMANY

ESA CR(X)-1841 // 100 PAGES
APPLICATION STUDY FOR HYBRID MICROCOMPUTER (JUL 1983)
LABEN, ITALY

ESA CR(P)-1842 // 304 PAGES
PRECISE ORBIT DETERMINATION FOR ERS-1 (AUG 1983)
TH DELFT, THE NETHERLANDS

ESA CR(X)-1843 // 319 PAGES / 166 PAGES / 64 PAGES
STUDY ON A HIGHLY SHAPED BEAM ANTENNA FOR ERS-1 - FINAL REPORT. VOLUME 1: REPORT; VOLUME 2: SUPPLEMENTARY FIGURES; VOLUME 3: EXECUTIVE SUMMARY (MAY & JUN 1983)
SPAR AEROSPACE LIMITED, CANADA

ESA CR(X)-1844 // 95 PAGES
ASTP - 20/30 GHZ RF SENSING, PHASE 1 - FINAL REPORT (AUG 1983)
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