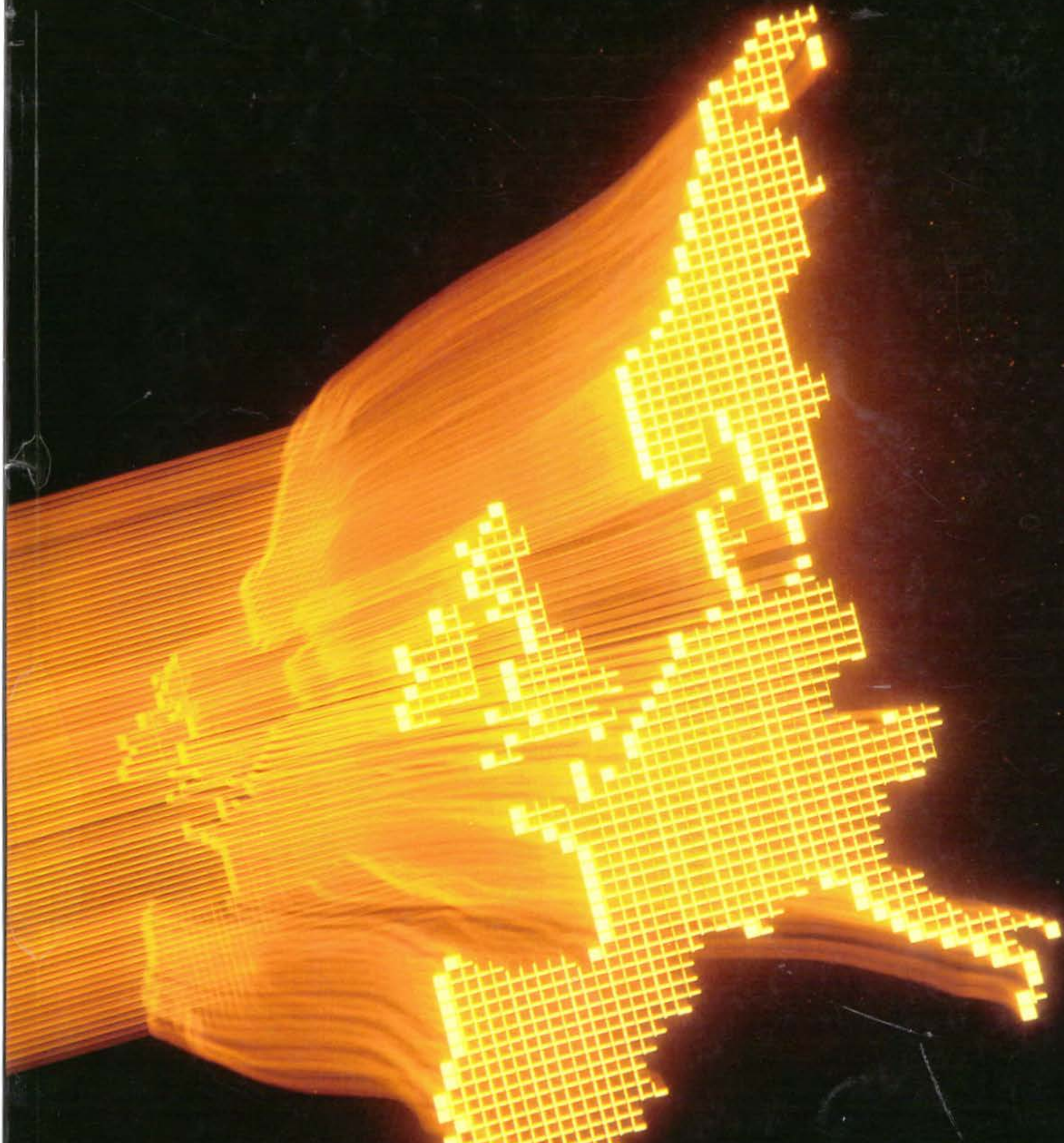
europe's place in space



esa

EUROPEAN SPACE AGENCY

Summary

Paris, January 1981

per ardua ad astra

An enquiry into Galileo's trial is being opened at the request of Pope John Paul II. In 1633 the Inquisition had obliged Galileo to abjure the disturbing theory that the Earth moved around the Sun, and not vice versa as traditional authorities upheld. Thanks to the then recently invented telescope, which he developed for use in astronomy, Galileo had been able to verify by his own observations the validity of the century-old Copernican heliocentric theory of the universe. His determination to justify this theory, despite the contrary indications of certain Biblical texts, led him into a head-on confrontation with the Church.
The three and a half centuries separating Galileo's trial (and apocryphal recantation — "and yet it moves") and the present day, have seen advances in our knowledge of space science which are paralleled in few other domains. Many of the most exciting discoveries in space have in fact been made in the past 20 years, during the lifetime of the European Space Agency, ESA, or its predecessors ESRO and ELDO. Throughout the past decade, especially, ESA has been in a position to make significant contributions to space science research, thanks to its spacecraft, the ESRO and Heos series, TD-1, Cos-B, Geos, IUE and ISEE, as well as through its meteorological satellite Meteosat.

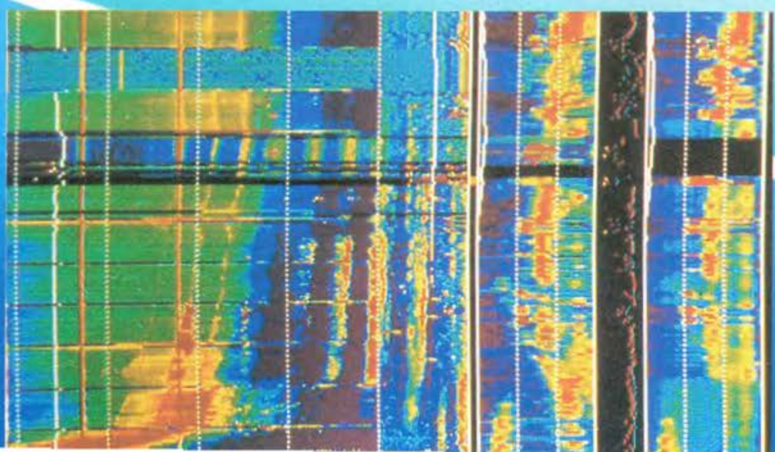
New methods for space sciences

It was a new scientific instrument, the telescope, which enabled Galileo to make his astronomical observations with greater accuracy, and to produce sounder results than his predecessors. But his observations, and those of succeeding generations of scientists until very recent times, were limited to objects which could be seen in the relatively narrow visible waveband.
In the past half century the scope of scientific exploration in space has been immeasurably increased by the development of techniques for observing phenomena in other wavebands. The results obtained by means of optical telescopes have been reinforced and surpassed by information produced by radio telescopes and most recently by investigations in the infrared, ultraviolet, X-ray and gamma-ray wavebands. The rainbow is a visible sample of a small section of the vast spectrum which is now available to scientists. Their observations over as many wavelengths as possible help to build up increasingly complete images of objects in space.

Many of the most interesting wavelengths are, however, absorbed by our atmosphere, which also blurs images even in the visible. Thus satellites have become an essential vehicle for investigations in these wavebands, ever since the first of them was launched in 1958. Spacecraft not only provide the means to explore deep space; they also offer an invaluable tool for studying our own planet, its environment, atmosphere and climate, and for telecommunications.

Sun and Space

Assembly of an experiment



Data from Geos

ESA's contribution

ESA has launched and operated 14 satellites between 1968 and the beginning of 1981, and is developing others, along with its own launcher and space laboratory, for use in its space science programme and for applications such as telecommunications, Earth observation and meteorology, and life and materials science research. Its satellites have become increasingly ambitious in design over the years. Such advanced technology demands extensive resources of scientific and technological expertise, as well as the ability to finance major programmes. The Agency alone in Europe is in a position to meet these requirements as part of a regular, balanced and continuing programme. In the following chapters a brief account is given of ESA's efforts and achievements in space science and applications.

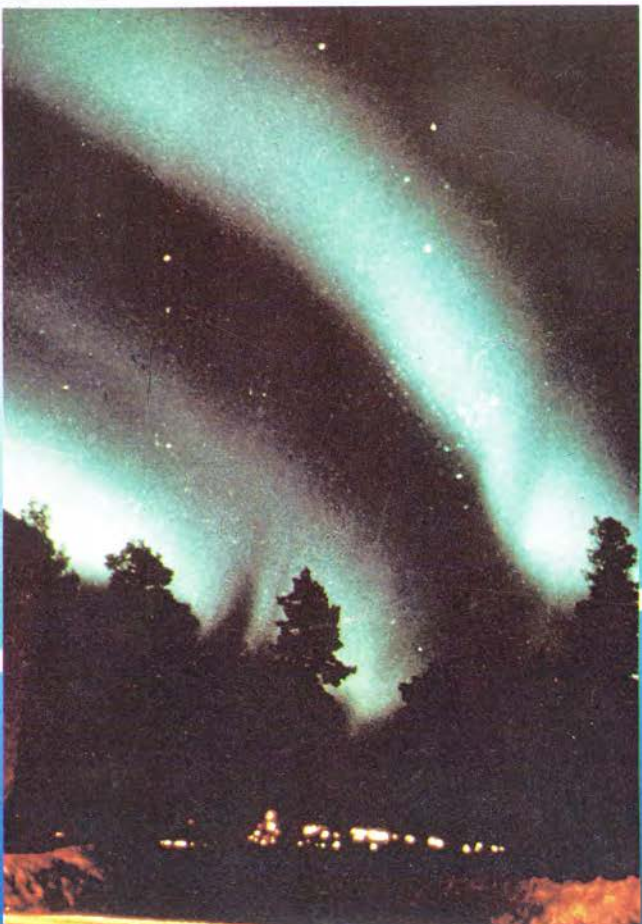
The Agency's programmes have not only served to widen our horizons in the realm of space research, study of the galaxies and interplanetary space, but will contribute to a fuller exploitation of the Earth's resources, to sounder weather forecasting and to better communications. Investigations of Sun/Earth relationships and the development of meteorological and climatological studies, should produce a better understanding of the factors which affect our climate, and play so decisive a role in crop formation.

By fostering the design and construction of its considerable range of space systems, ESA has encouraged the development of European space science and technology and brought important opportunities within the grasp of European industry. Through ESA contracts these industries have been able to develop their own ability to compete in the world market for space technology. The Agency has thus played a decisive role by matching the ambitions and requirements of its eleven Member States and by putting the European space effort on a sound and substantial footing.

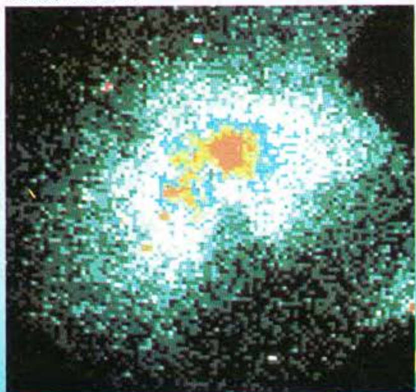
ESA also fosters fundamental research in an area which has seized man's imagination and aroused his intellectual curiosity. From the earliest times of which we have any record, man has pondered the wider questions of the nature of the universe, the existence of a divinity, of how life began and where it would end. Today the answers to some of the questions seem just a little nearer to our grasp; astronomers' discoveries of echoes of the big bang with which the universe began, or of the black holes in which stars end, have become the stuff of popular fiction.

The challenge and stimulus of space research can attract some of today's best intellects to devote their career to the sciences. By providing facilities which its individual members would perhaps not be able to offer, ESA contributes to preserving the European intellectual heritage and ensuring a dynamic scientific community for the future.

Aurora borealis



Data from IUE



Barium cloud

esa - european space agency

With the ratification of its Convention on 30th October 1980, the European Space Agency, which de facto came into being in May 1975, acquired its legal existence. The Agency groups in a single body the complete range of European space activities previously conducted by ESRO and ELDO in their respective fields of satellite development and launcher construction.
The ten founder members of ESA are Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Ireland, although not a member of the previous space organisations, also signed the ESA Convention in December 1975 and thus is now a full member of the Agency. Three other states are closely associated with the Agency: Austria is an associate member, with the status defined in the Convention; Canada has an agreement for close cooperation; Norway has observer status but negotiations are under way for this state to acquire associate membership.
The Agency's purpose, as described in its Convention, is to provide for and to promote, for exclusively peaceful purposes, cooperation among European states in space research and technology, and their space applications, with a view to their being used for scientific purposes and for space applications systems. To fulfil its mission the Agency:

a) elaborates and implements a long term space policy, recommends space objectives to its Member States, concerts the policies of the Member States with respect to other national and international organisations and institutions;

b) elaborates and implements activities and programmes in the space field;

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

d) elaborates and implements the industrial policy appropriate to its programme, and recommends a coherent industrial policy to the Member States.

Organisation and functioning

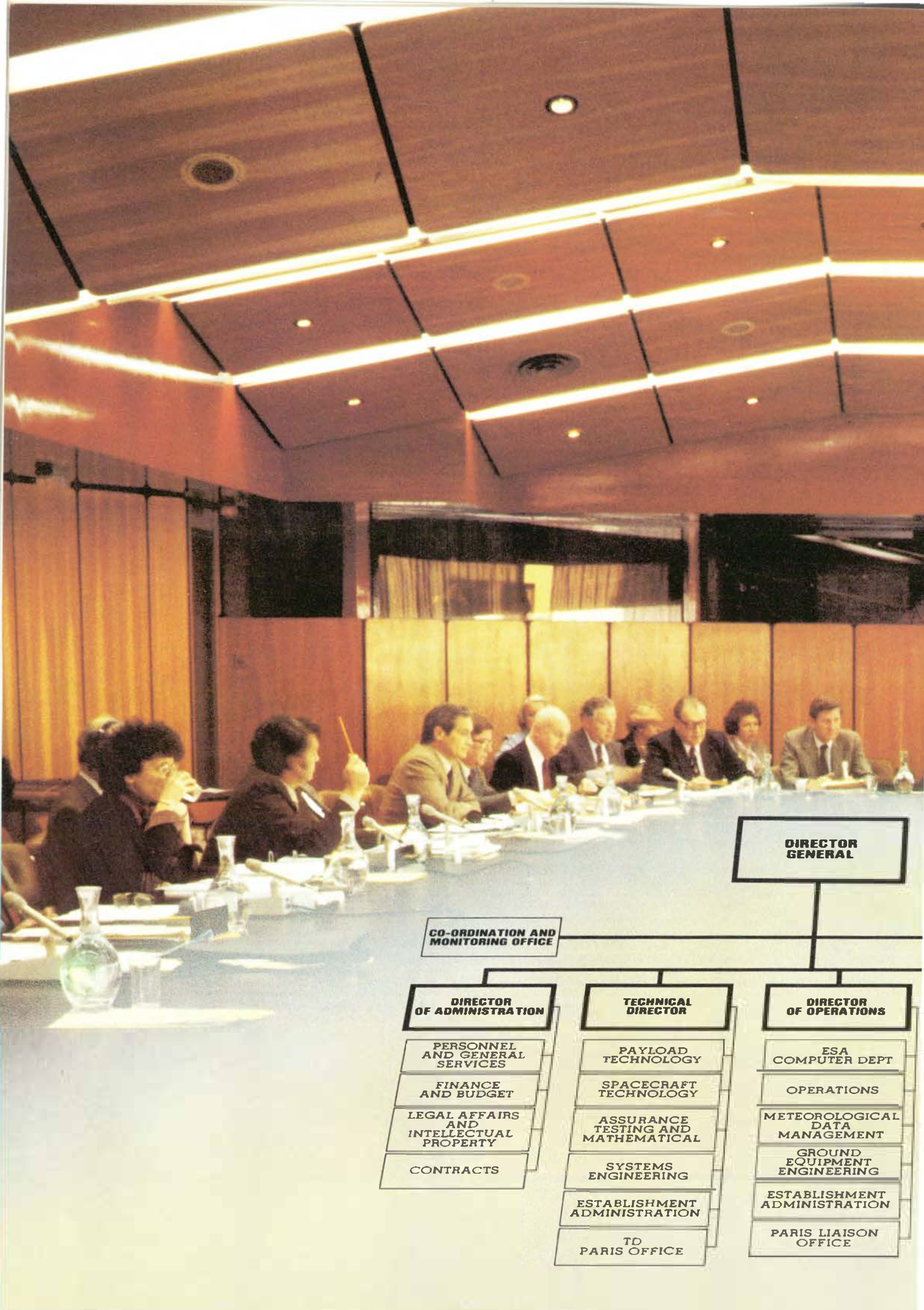
The Agency's policy-making body is the ESA Council, composed of representatives of the Member States. The Council takes decisions on the policy to be followed by the Agency, and on scientific, technical, administrative, and financial matters, each state having one vote (but none in the case of an optional programme in which it is not participating). The level of the Agency's resources for its mandatory activities is determined for a period of five years in advance by a unanimous decision of all Member States. Other decisions are taken on a simple, or two-thirds, majority vote.
The Convention established a Science Programme Committee, to which are referred matters relating to the mandatory science programme; the Committee is authorised to take decisions relating to that programme. The Council may also establish such other subordinate bodies as may be necessary for the purposes of the Agency. Delegations from the Member States sit on all such committees and programme boards.
The chief executive and legal representative of the Agency is the Director General, who is appointed by the Council for a defined period. He is assisted by six directors who are responsible for the following directorates: Administration, Applications Programmes, Spacecraft Operations, Scientific Programmes, Space Transportation Systems, and the Technical Directorate.

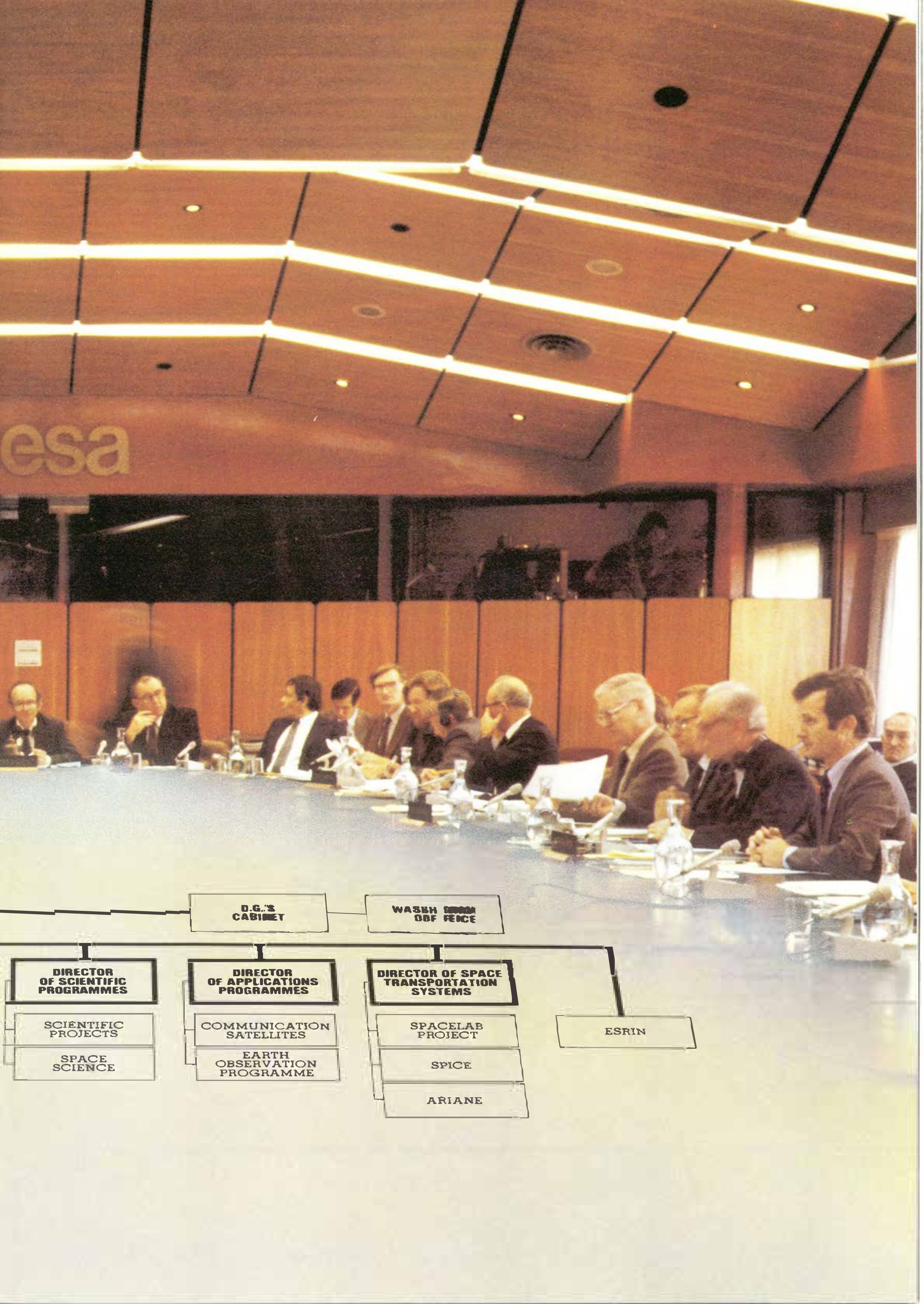
International Relations
Member States
Belgium - Denmark - France - Germany
Ireland - Italy - Netherlands - Spain
Sweden - Switzerland - United Kingdom

African States - Australia
Brazil - Finland - Greece - India
Indonesia - Japan - Morocco
Popular Republic of China
Soviet Union - United States

UNO
(ITU - WMO - IMCO - ICAO - FAO)
European Communities
Council of Europe
WEU
Interim Eutelsat
Inmarsat
EBU - COSPAR - IAF

States with special agreements
Austria - Canada - Norway


DIRECTOR GENERAL
CO-ORDINATION AND MONITORING OFFICE
DIRECTOR OF ADMINISTRATION
PERSONNEL AND GENERAL SERVICES
FINANCE AND BUDGET
LEGAL AFFAIRS AND INTELLECTUAL PROPERTY
CONTRACTS
TECHNICAL DIRECTOR
PAYLOAD TECHNOLOGY
SPACECRAFT TECHNOLOGY
ASSURANCE TESTING AND MATHEMATICAL
SYSTEMS ENGINEERING
ESTABLISHMENT ADMINISTRATION
TD PARIS OFFICE
DIRECTOR OF OPERATIONS
ESA COMPUTER DEPT
OPERATIONS
METEOROLOGICAL DATA MANAGEMENT
GROUND EQUIPMENT ENGINEERING
ESTABLISHMENT ADMINISTRATION
PARIS LIAISON OFFICE



esa
D.G.'S CABINET
DIRECTOR OF SCIENTIFIC PROGRAMMES
SCIENTIFIC PROJECTS
SPACE SCIENCE
DIRECTOR OF APPLICATIONS PROGRAMMES
COMMUNICATION SATELLITES
EARTH OBSERVATION PROGRAMME
DIRECTOR OF SPACE TRANSPORTATION SYSTEMS
SPACELAB PROJECT
SPICE
ARIANE
ESRIN

esa in figures

ESA Budget
(in millions of accounting units - MAU
1 AU = $ 1.4

PROGRAMMES	1979 (actual)	1980 (actual)	1981 (proposed)
General Budget (including Earthnet, CSG/Kourou, part of Exosat launcher)	74	86	89
Scientific programmes (including extension of Cos-B)	79	89	96
Meteosat 1 & 2 (including exploitation)	23	18	17
Sirio-2 (including exploitation)	6	8	12
Remote Sensing - preparatory programme	1	3	3
OTS	14	7	6
ECS (including phase 3 bis)	36	60	88
Marecs A & B	27	36	52
L-Sat phase B	1	5	9
Other telecommunications programmes	5	5	12
Spacelab (development, follow-on development and first payload)	122	107	60
(follow-on production)		26 *	55 *
Ariane (development, followon development and user support)	175	144	104
Marecs C (Inmarsat)	2 *	6 *	
TOTAL	565	600 **	603 ***

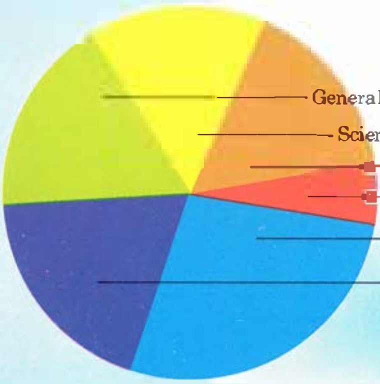
* Financed by third parties.
** Of which 569 MAU financed by contributions.
*** Of which 548 MAU financed by contributions

Cost-to-completion of the principal on-going programmes
(mid-1980 price levels; 1981 rates of exchange)

PROGRAMME	MAU
Exosat	159 *
Space telescope	90
International Solar Polar Mission	106
Sled	6
Giotto	97
Hipparcos	155
Telecom phase 2 - OTS	261
Telecom phase 3 - ECS 1 & 2	180
Telecom phase 3 bis - ECS 3, 4, 5	272 **
Marecs A & B	257
Meteosat 1 & 2	215
Sirio-2	29
Spacelab	738
First Spacelab Payload	37
Ariane	886
Ariane promotion series, user support	81

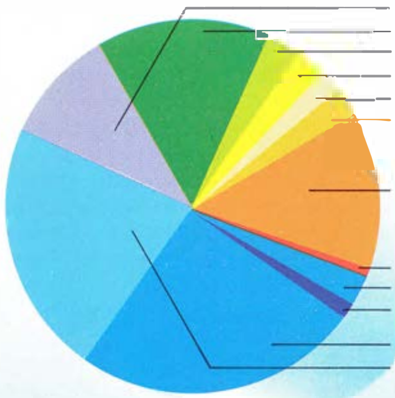
* Including General Budget contribution to launch costs.
** Total cost without counting Eutelsat receipts.

ESA budget 1981
approximately 603 MAU (850 M$)
(in percentages)



* Including CSG/Kourou and part of Ariane launcher.
** Including user support.

ESA budget 1981
Income from Member States and other sources



Contributions of Member States to the principal ESA programmes in 1981
(in percentages)

Member States	General Budget	Science	Meteosat Exploitation	Sirio-2	OTS	ECS	ECS Phase 3 bis	Marecs A	Marecs B	Spacelab	Ariane Development
Belgium	4.71	4.49	4.06	3.30	5.17	3.27	3.19	0.95	0.14	5.07	1.92
Denmark	2.63	2.51	2.41	—	2.90	0.33	0.74	—	—	1.81	0.40
France	22.45	21.40	23.70	7.50	24.69	25.93	26.52	11.92	5.74	12.07	79.34
Germany	26.82	25.57	25.66	9.00	25.00	30.68	30.42	19.08	13.29	64.78	5.31
Ireland	0.54	0.54	—	—	—	—	—	—	—	—	—
Italy	5.51	12.46	15.07	72.39	14.38	14.78	13.85	2.20	1.28	1.00	5.31
Netherlands	6.29	6.00	—	—	2.50	0.94	1.77	4.63	1.49	2.53	0.34
Spain	5.29	5.04	—	0.50	—	0.17	0.53	0.95	0.34	3.38	4.18
Sweden	4.16	4.25	—	1.50	4.91	1.62	3.97	2.96	6.61	—	0.63
Switzerland	4.19	3.99	3.48	3.50	4.59	2.13	0.55	—	—	1.00	0.08
United Kingdom	14.42	13.75	20.60	1.83	15.86	20.15	18.46	55.81	69.89	7.60	2.49
Other Participants											
Austria	0.68	—	—	0.48	—	—	—	—	—	0.76	—
Canada	2.23	—	—	—	—	—	—	—	—	—	—
Norway	0.08	—	—	—	—	—	—	1.50	1.22	—	—
Other income	—	—	5.02	—	—	—	—	—	—	—	—

Establishments and their staff

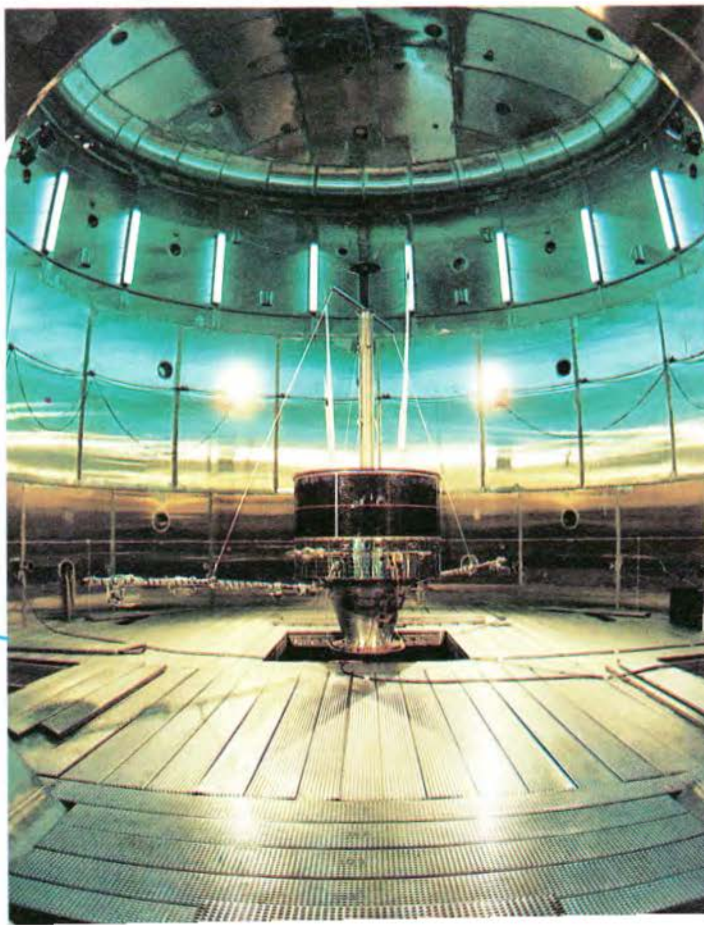
ESA's total staff at the end of 1980 amounted to some 1420 persons, drawn from the Member States and located at the Headquarters and the various Establishments.

- The ESA Headquarters is situated in Paris and has a staff of some 280;
- ESTEC (European Space Research and Technology Centre) is located at Noordwijk in the Netherlands and has a staff of about 790. It is responsible with the Programme Directors, who are in charge of the various projects, for study, design, development and testing of spacecraft in collaboration with industry and the scientific community. ESTEC is also responsible for applied research in space technology.
- ESOC (European Space Operations Centre) is located at Darmstadt in Germany, and has a staff of about 230. It is in charge of all satellite operations and of the corresponding ground facilities and communications networks. The ESOC controlled network includes a central control centre in Darmstadt and telemetry, tracking and control facilities at Michelstadt (Germany), Redu (Belgium), Villafranca (Spain), Kourou (French Guiana) and Carnarvon (Australia). In addition to these sites, the Agency uses the following national ground stations: Malindi (Kenya), Fucino (Italy), Kiruna (Sweden) and Maspalomas (Canary Islands/Spain).
- ESRIN (previously European Space Research Institute) is located in Frascati, near Rome, Italy, and has a staff of 60. Two programmes are on site: IRS (Information Retrieval Service), responsible for the operation of the most powerful automated documentation retrieval system in Europe, with a file of more than 18 million bibliographic references; and Earthnet, which collects, preprocesses and distributes images and data from remote-sensing satellites.

Several technical teams are located in national establishments for the conduct of specific programmes: about 40 people are working in the Earth Observation Programme Department at Toulouse (France); some 10 work with SPICE (Spacelab Payload Integration and Coordination in Europe) at Porz-Wahn (Germany); others are at the Ariane launch site at Kourou (French Guiana). The Agency also has a liaison office in Washington.

Odenwald - Antenna

ESTEC's dynamic test chamber, with Geos



ESA headquarters, Paris

Finance

The Agency is financed by the Member States who contribute to the budgets for its mandatory activities (i.e. the general budget and the scientific programme budget) on the basis of their average national income calculated over the past three years.
Additionally, many of the Agency's major programmes are optional and Member States contribute to these to the extent that they are interested. They may be joined in these programmes by other states who may select the level of their participation and are permitted to vote in Council on the programmes to which they contribute. Examples of such participation in action are that of Austria in the Spacelab programme, Canada in the Remote Sensing preparatory programme, and Norway in the Marecs programme.
States participate in ESA programmes on an understanding of "fair return". This means that they expect to receive for their national industries contracts of a value roughly proportional to their original contributions.
The concept of "fair return" for Member States is but a part of the Agency's overall industrial policy of which the keystone is to foster the development of a competitive European space industry. The Agency does this by encouraging existing industry in the Member States, with whom it places industrial contracts, and by putting its contracts out to free competitive bidding.
The implementation of ESA's industrial policy is extremely significant to the development of Europe's space industry. There is little private financing of space exploration or exploitation in Europe. All space ventures so far have been the concern of governments or government-controlled companies and two-thirds of Europe's space investment is at present handled by ESA.
The Agency works on a principle of "no profit, no loss" and thus does not handle the commercial exploitation of the programmes whose design and development it has financed. When a clear and continuing future need is seen for the products of its research and design, exploitation of the project is entrusted by ESA to a selected industrial entity, as is the case with the Ariane launcher whose production is being handed to Arianespace, a private company founded by European industry.

Industrial spin-off from initial ESA contracts can be of great importance to the companies to whom these contracts are awarded. It enables them to develop advanced technology and to forge teams capable of carrying out highly specialised tasks. Such capabilities not only qualify the companies concerned to undertake follow-on development for ESA or other agencies (as in the case of the NASA * order of a second Spacelab), but also qualify them to seek further contracts on the open market. ESA Member States' space industry currently provides work for some 20,000 employees.
In real terms, ESA's scientific budget has remained virtually constant for the past decade. The Agency has nevertheless been able to make a substantial and significant contribution to space research. But exploration of the near-Earth environment with relatively inexpensive missions is now coming to an end. The missions of the future, planetary and deep space missions, as well as those to investigate specific problems of the Earth's environment in depth, are likely to prove quite expensive. Where they are not within ESA's budget constraints, the Agency will need to undertake such missions in cooperation with other agencies (NASA for example).
Such cooperation was already envisaged in the Agency's Convention in which it was stated that, by a unanimous decision of the Council, the Agency might cooperate with other international organisations and institutions and with governments, organisations and institutions of non-Member States. Such cooperation can give European scientists wider scope for advanced scientific research, and may also serve to make Europe's achievements and capabilities in space better known to wider potential markets.

* US National Aeronautics and Space Administration.

ESRIN building

Operations room, ESOC

today's science programme

In the closing years of the past decade the European Space Agency has had four scientific satellites in orbit and operating with notable success.
Two astronomy satellites, Cos-B and IUE, have been investigating the sky in the gamma (Cos-B) and ultraviolet wavelengths (IUE). Cos-B, launched in 1975, was the Agency's eighth scientific satellite to be placed in orbit. It provided such valuable data that its mission was extended to continue until 1981. The IUE spacecraft was launched in 1978; it is a Joint Venture of ESA, NASA and the SRC (Science Research Council of the United Kingdom). Its use has been so much in demand that its mission, too, has been extended.
The Agency's Sun/Earth satellites, Geos and ISEE are being used to monitor the plasma and magnetic fields emitted by the Sun and to study the response of Earth's surroundings to changes in these emissions. The present Geos satellite, Geos 2, was launched in 1978. ISEE 2 is the ESA spacecraft in a team of three craft which work together on a joint mission to investigate the magnetosphere, the other two craft belonging to NASA. ISEE 1 and 2 were launched together in 1977, followed by ISEE 3 in 1978.
ESA is currently developing four further scientific spacecraft which have been approved by its Science Programme Committee. They are Exosat, which will study X-ray sources; an ESA satellite for the joint International Solar Polar Mission to be launched into deep space by NASA; an astrometry satellite called Hipparcos which will study the distance, position and proper motions of some 100,000 stars; and a spacecraft named Giotto which will study Halley's Comet, depicted by the medieval Italian painter Giotto di Bondone, and which will make its next appearance relatively close to the Earth in 1986.
Finally ESA is participating in NASA's advanced space telescope to which the Agency is to contribute certain pieces of equipment in return for a proportion of the viewing time for European astronomers.

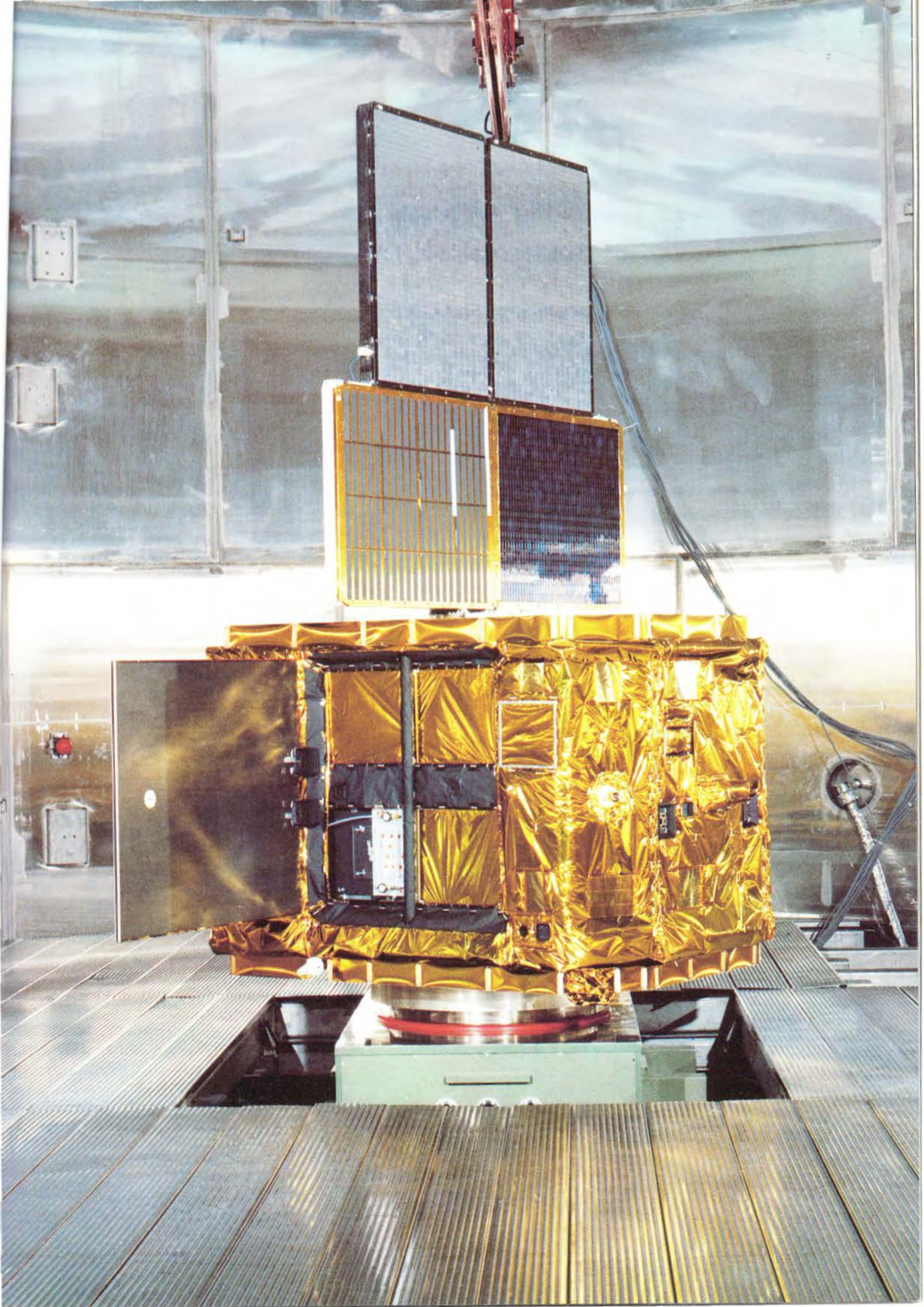
Cos-B

The ESA Cos-B satellite was launched in 1975 to study the sources of extra-terrestrial gamma radiation. Its mission has been so successfully accomplished that it has been extended, from an initial termination date in 1977, to continue through until 1981.
The search for gamma rays is no simple one since these radiations, produced by nuclear reactions with energies of some million electron volts, have very short wavelengths and cannot be handled by elegant optical or ultraviolet techniques. They are identified rather by the reactions of the material through which they pass, and risk being heavily contaminated by other sources of spurious radiation. The success of Cos-B stems from the fact that it has been able to reject the interfering background radiations to produce the first catalogues of the celestial sphere seen in gamma rays.
Most of the observed gamma radiation appears to originate in our own galaxy, the greater part of it coming from the Milky Way, of which Cos-B data provide the first detailed gamma-ray survey. The satellite has also detected 29 point-like sources of gamma radiation, most of which have not yet been identified by other techniques since they seem to emit a negligible amount of X-radiation. Three of them have, however, been identified: two are the Crab and Vela pulsars which had already been discovered at other wavelengths. These pulsars flash their radiation in a way which makes them resemble a lighthouse in the sky. The third source appears to be a quasar (a quasi-stellar object) outside our own galaxy.

Cos-B

project approval	1970
start of development	1972
prime contractor	Messerschmitt-Bölkow-Blohm
launch date	1975
launcher	Thor Delta
mass	280kg
end of mission	1981

Exosat during dynamic testing



IUE

The International Ultraviolet Explorer (IUE) satellite was launched in 1978 into a geosynchronous orbit at 36,000 km above the Earth. Its mission is to provide a space observatory facility for ultraviolet spectrometry of celestial objects.
The satellite is a joint project of ESA, NASA and SRC. ESA contributed the deployable solar cell array in the spacecraft, and constructed and operates the European ground station at Villafranca near Madrid, where users come to observe in a similar fashion to that of ground-based observatories. In the first two years of its operation some 250 scientists from 16 different countries have participated in proposals accepted by ESA while yet others have taken part in projects accepted by the SRC. So many applications for its use during 1980-81 have been received that not all could be accommodated and the mission of the satellite has had to be extended.
Ground based telescopes with a spectrograph placed behind them enable astronomers to study light from distant stars by resolving it into spectral lines at different wavelengths. Many of the more interesting wavelengths, however, cannot penetrate the Earth's atmosphere but are absorbed by it. Hence the interest of a space observatory which has opened up a whole new range of possibilities.
The IUE satellite carries a 45 cm telescope which is used exclusively for ultraviolet spectrometry and two spectrographs to obtain high-resolution, ultraviolet spectra of stars and to observe, at low resolution, faint stars, galaxies and quasars. It can observe planets and comets and can show variable spectra of celestial objects. Other scientific aims are to study the gas streams around some binary systems and to define the way in which starlight is modified by interstellar dust and gas.

IUE
(International Ultraviolet Explorer)

project approval	1973
start of development	1973
launcher	Delta 2914
launch date	1978
launch mass	670 kg
in orbit mass	430 kg
end of mission	mid 1980s

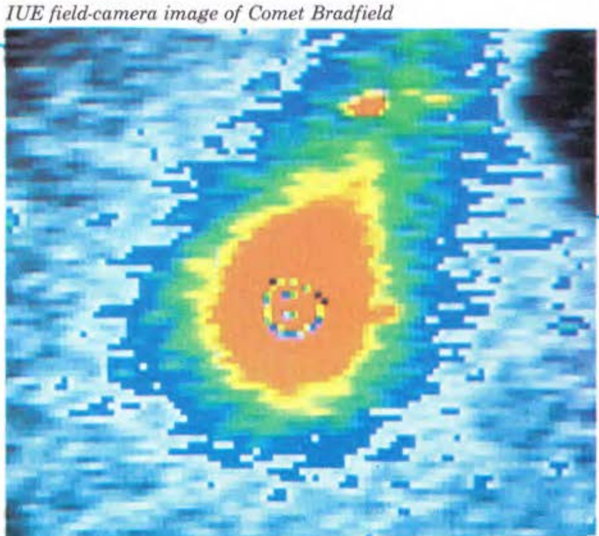
Geos

The scientific mission of the two Geos satellites has been to increase understanding of the Earth's near environment. They were specially equipped to measure electric fields in the Earth's magnetosphere, for much of which no reliable measurements existed before this mission.
Geos 1 was launched in 1977 and despite the fact that it did not reach its planned orbit, was able to make substantial contributions to the International Magnetosphere Study. It was reactivated in late 1978 and early 1979 but further attempts to reactivate the satellite in January 1980 were unfruitful and its mission was declared terminated. Processing of the large amounts of data from the satellite is now sufficiently advanced for detailed surveys and in-depth studies of particular events to be available.
Geos 2 was launched in 1978 with a lifetime due to terminate in June 1980. Its mission was extended in 1980 and, after a period of hibernation, the satellite was reactivated for a fixed term in 1981. This satellite has proved very useful as the reference spacecraft for the International Magnetosphere Study. It has collected magnetic attitude data of good quality and the observations carried out near the geomagnetic equator have proved particularly interesting. The information collected by this satellite has been widely used in correlations with ground-based data and also with data from other satellites. It has made a significant contribution towards identifying the composition and movement of the plasma around the Earth's magnetosphere.

Geos 1 and 2

project approval	1969
start of development	1973
prime contractor	British Aerospace Dynamics Group
launch dates	1977 Geos 1 1978 Geos 2
launcher	Thor Delta
launch mass	575kg
in orbit mass	275kg
end of mission	1979 Geos 1 1981 Geos 2

IUE field-camera image of Comet Bradfield



Geos spin test

ISEE

The three ISEE (International Sun-Earth Explorer) satellites were launched as a fully integrated mission to study the dynamic properties of the magnetosphere. ISEE 1 and 3 were built by NASA and ISEE 2 by ESA. The first two spacecraft were launched together in 1977 and work as a team, circulating through the magnetosphere at a known and controllable distance apart, carrying carefully matched payloads. Comparison of the observations made from the two platforms enables the speed and direction of features to be identified, and the spatial and temporal variations to be distinguished. Since this is not usually possible from a single platform, ISEE is making the first comprehensive survey of magnetospheric dynamics.

The third spacecraft, ISEE 3, was launched in 1978 and positioned between the Sun and the Earth, at the sunward libration point 1.5 million km away from the Earth. There the satellite gyrates around the Sun's disc as seen from the Earth, in what is known as the halo orbit. Its task is to monitor solar wind features on their way to the magnetosphere, since events occurring in the latter are believed to result from varying conditions in interplanetary space. ISEE 3 also carries instruments capable of analysing high energy particles, an important study in its own right.

With its highly sophisticated and sensitive instruments and three-craft collaboration, the ISEE mission is able to study the cause and effect of magnetospheric processes in finer detail than has ever been achieved before.

ISEE
(International Sun-Earth Explorer)

project approval	1973
start of development	1974
prime contractor	Dornier
launch date	1977
launcher	Thor Delta
in orbit mass	160kg
end of mission	1981

Exosat

The Exosat spacecraft's scientific mission is, broadly speaking, to measure the position, structural features and spectral and temporal characteristics of cosmic X-ray sources. It will use two methods of observation in this study: that of occultation, using the moon as the occulting body, to determine the position and diameter of celestial bodies by observing the time and speed of their disappearance behind the moon; and the arbitrary pointing mode to study the temporal and spectral variability of sources over long, uninterrupted intervals of time.

Occultation is a classic astronomical technique but is limited, in the case of terrestrial observations, to those parts of the sky occupied by the moon's disc as it revolves around the Earth, which are only about 8% of the whole. The advantage of the Exosat spacecraft is that it will be placed in a highly elongated orbit, at right angles to the moon's orbital plane, which will extend the possibility of observed occultations over 20% of the sky.

In this programme ESA, for the first time, is financing and managing the scientific payload in order to provide data for European observers other than those concerned in the development programme.

The Exosat spacecraft is scheduled to be launched by Ariane, in 1982. It will follow a highly eccentric orbit, with an apogee of 300,000 km and a perigee of 300 km, which will permit long, uninterrupted contact with the ground station near Madrid, and will maximise the possible number of occultations.

Exosat
(X-ray Orbiting Satellite)

project approval	1973
start of development	1978
prime contractor	Messerschmitt-Bölkow - Blohm
launch date	1982
launcher	Ariane
mass	500kg
life time	2 years

ISEE 2 vibration test

Hipparcos

The Hipparcos astrometry satellite was selected in 1980 by the Science Programme Committee. One of the principal objectives of this project is to measure with unprecedented accuracy the position and displacement velocity of some 100,000 stars. It will provide a tenfold improvement in the precision of existing observations of several astronomical parameters, enabling an accurate, coherent, whole-sky stellar reference frame to be compiled. Such a reference frame is needed inter alia for the study of the motions of planetary and solar system bodies and for geodynamics.

The basic principle of the Hipparcos observation is to scan the entire sky continuously and systematically with a telescope capable of measuring accurately the angles between widely separated stars. The attitude of the spacecraft about its centre of gravity is controlled to enable it to scan the whole celestial sphere in a regular movement. Its observing programme is to be managed from the ground. Numerous astronomers have shown an interest in this project and have proposed research programmes making use of its data. Until now the relative positions and movements of stars have been measured with large telescopes and with very long baseline interferometry; this has been done with high precision, but the accuracy of the absolute position of any one star depends on the accuracy of the primary reference frame for its immediate vicinity. It is in this respect that the information collected by Hipparcos, documenting the five astrometric parameters of a very large number of stars distributed more or less uniformly over the whole sky, will be of such great value.

Hipparcos	
project approval	1980
start of development	1983
launch date	1986
launcher	Ariane
launch mass	840 kg
in orbit mass	480kg
life time	2.5 years

Giotto

The European Giotto spacecraft will investigate Halley's Comet when it reappears in 1986; there will not be a further chance to study this comet before 2061 as it follows a 76-year orbit.

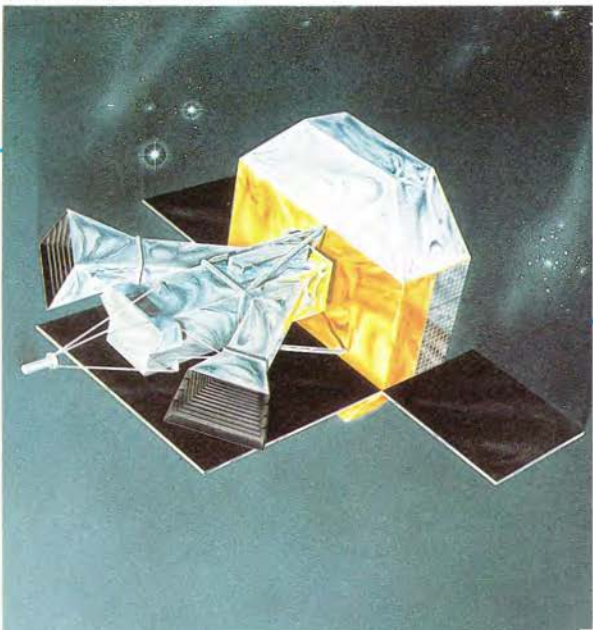
Very few of the 630 comets which have been recorded are suitable for study by spacecraft. Halley's Comet is one of the few; it has been known for a very long time, records date back to 239 B.C. The first naturalistic description of the comet could be said to be the painting of it as the Star of Bethlehem in a fresco in the Arena Chapel of Padua. This was painted, after the comet's appearance in 1301, by the famous Italian painter Giotto di Bondone from whom the ESA mission takes its name.

Little is known at present about comets; what we can see from the Earth is actually a very thin atmosphere of neutral and ionised gas molecules and tiny dust particles which reflect the sunlight. It is thought that in the centre there is a solid nucleus, too small to be visible from Earth, perhaps a few kilometres in diameter and consisting of a mixture of snows and ices of condensed gases with some solid particles, a kind of "dirty snowball". Under the heat of solar radiation the nucleus releases large quantities of gas and dust which are swept into a long, curved tail, streaming out behind it.

The spacecraft will fly through the comet's coma at a speed of 70 km per second; it will be protected by a bumper shield from the impact of dust particles which will strike it at a speed 50 times greater than that of a bullet leaving a gun. The particles will become larger as the spacecraft approaches the Comet's nucleus and its eventual survival cannot be guaranteed. Its equipment will include a camera able to take colour photographs of the surface of the nucleus and it will collect basic information on the comet's atmosphere.

Giotto	
project approval	1980
start of development	1982
launch date	1985
launcher	Ariane
launch mass	750 kg
in orbit mass	480kg
end of mission	1986 encounter with Comet Halley

Hipparcos, artist's impression



Model of Giotto

ISPM

The joint ESA/NASA International Solar Polar Mission (ISPM) aims to explore deep space and to observe the Sun over the full range of heliographic latitudes. This mission will make the first in-situ measurements of the interplanetary medium well outside the thin disc near the ecliptic plane in which all the planets lie and to which all previous spacecraft have been confined.

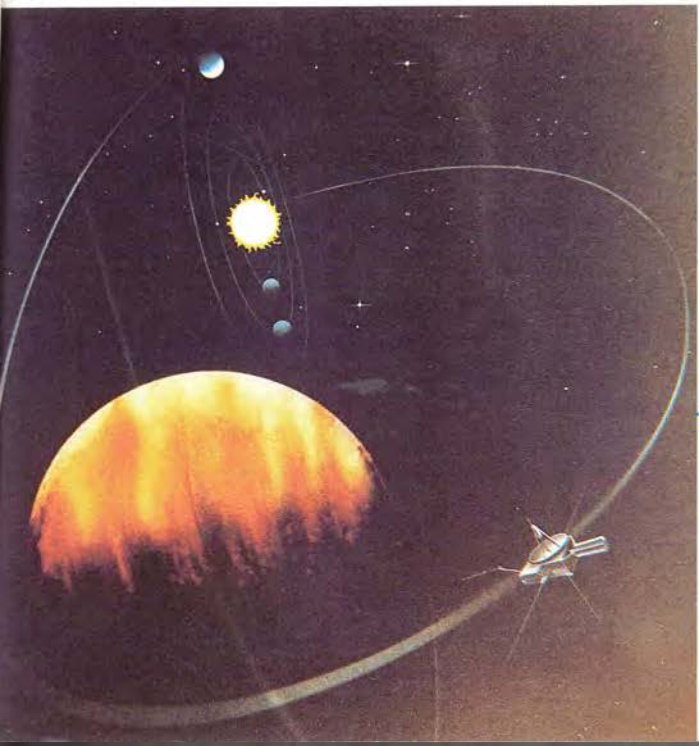
The mission will employ a pair of spacecraft, one European, one American, which are due to be launched in 1985. The spacecraft will follow similar trajectories from Earth to the Planet Jupiter where they will be deflected by the planet's gravitational field into elliptical trajectories approximately at right angles to the ecliptic plane. One spacecraft will then pass over the northern hemisphere of the Sun while the other passes over the southern hemisphere. Both will reach near polar solar latitudes where they are expected to fly over the Sun's poles at a distance of approximately 255 million km. They will then recross the ecliptic plane and traverse the opposite hemisphere of the Sun. The mission, which will be concluded after the second polar pass, will last five years.

Instruments on board the spacecraft will study and analyse the properties of the solar wind, composed of charged particles which are continuously propagated by the Sun. Others, such as the coronograph on one of the spacecraft, will perform solar observations which, combined with terrestrial observations, will allow a stereoscopic study of various transient phenomena in the Sun's atmosphere to be made. It is the first time that ESA has been involved in the development of a spacecraft for a mission into deep space.

ISPM
(International Solar Polar Mission)

project approval	1978
start of development	1980
prime contractor	Dornier
launch date	1985
launcher	Space Shuttle
mass	350kg
life time	4 to 5 years

ISPM's orbit around Jupiter



Space telescope

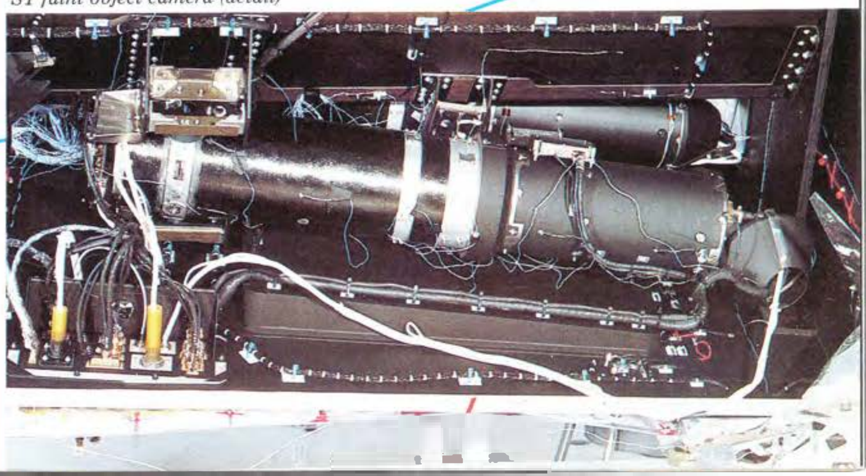
The NASA space telescope, in which ESA is participating, is the most ambitious project to he under taken at present in space astronomy and is likely to dominate research in this field for the rest of the century. The programme aims to place a high-resolution, 2.4 m telescope in orbit at an altitude of 500 km (by Space Shuttle), in 1985. The Shuttle will periodically retrieve the telescope, which is designed to operate for at least 15 years, for servicing on Earth.

The unique capabilities of the space telescope will extend the sensitivity, resolving power and spectral range of astronomical observations far beyond those obtainable from ground-based telescopes. It will be able to register objects 100 times fainter than those observable from the ground; it will also have access to the vacuum ultraviolet region, unobservable from Earth, and to the visible and infrared regions.

Its mission will include a precise determination of distances of galaxies, measuring the rate of deceleration of the Hubble expansion of the universe, testing the basic reality of universal expansion, and establishing the history of star formation and nuclear processing of matter. By extending the absolute distance scale ten times further out than is currently possible, the space telescope will enable scientists to tackle the great cosmological problem of defining and tracking beyond time the expansion of the universe, to throw light on its ultimate fate.

ESA's participation in the space telescope programme will earn for European astronomers the right to 15% of the total observing time. ESA will provide the Faint Object Camera, Solar Arrays and deployment mechanisms, and will support the activities of the Scientific Centre which will be established to guide and perform the scientific programme of the Space Telescope in its operational phase.

ST faint object camera (detail)



earth observation

Satellites are being used increasingly as observation platforms. They can observe atmospheric phenomena to assist in the production of meteorological forecasts; they can study the Earth's land surfaces and oceans by means of remote sensing; or they can study geophysical characteristics such as the Earth's magnetic and gravitational fields, important indicators of processes inside the solid earth. ESA currently supports both meteorological and remote-sensing satellite missions.

Meteosat

Meteosat 1 was launched in November 1977 and successfully carried out its mission for two years before a partial failure in November 1979. Since that time attempts to bring it back to full operational status have not succeeded, but the satellite has continued to support the data collection mission.

Meteosat was launched into geostationary orbit over the Gulf of Guinea, at a longitude of 0°. It embraced Europe, Africa and parts of South America within its field of vision. An almost continuous monitoring of meteorological conditions for these regions was possible on the basis of the images which it produced.

Meteosat 1 and 2

project approval	1972
start of development	1973
prime contractor	Aérospatiale
launch date	1977 Meteosat 1 1981 Meteosat 2
launcher	Thor Delta (1) Ariane (2)
launch mass	700kg
in orbit mass	290kg
end of mission	1980 (1)
-contractual	1984 (2)

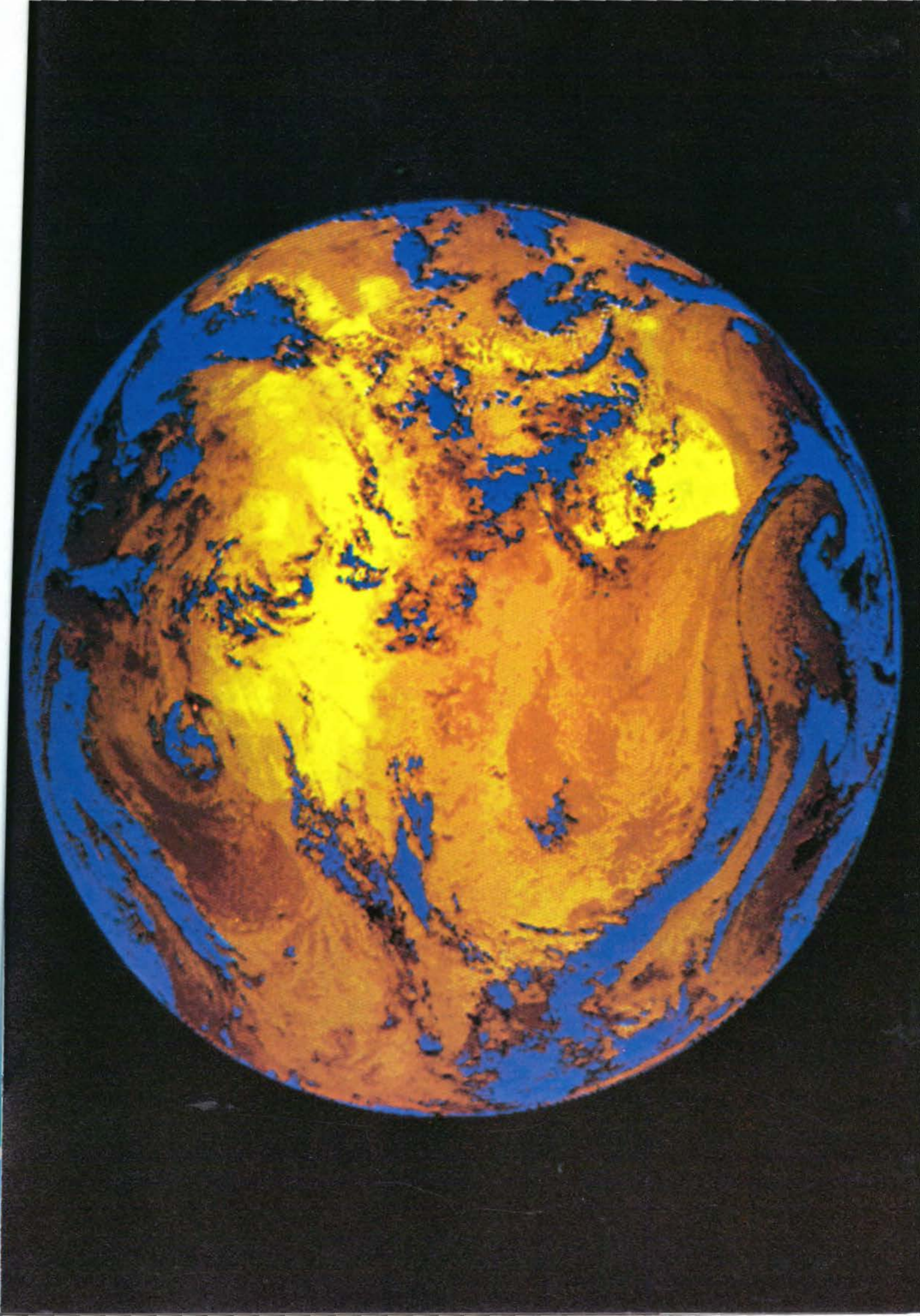
The satellite observed the Earth's disc within its range of vision, taking 30 minutes to scan the whole range. It measured the Earth's radiance and imaged the cloud cover by means of a radiometer operating in three spectral bands which correspond to the visible, the thermal infrared and the water vapour spectra. Such a monitoring system is ideally suited to provide a basis for short-period weather forecasting, for which the data obtained were primarily used. The satellite could also monitor meteorological centres of disturbance such as cloud clusters and vorticity centres, mountain waves, tropical storms and hurricanes.

Distribution of the data which it collects is a vital part of the satellite's mission. The raw image data are relayed to Earth, to the ground station in Odenwald in Germany, from whence they are transferred to ESA's nearby European Space Operations Centre at Darmstadt for processing. The processed data are relayed back to the satellite for distribution to users, to whom they are available within an hour of acquisition. Meteosat also relays images from the western Atlantic and the Americas, taken by a U.S. satellite, which are sent on to it from the ground station at Lannion in France.

The users have a choice of two kinds of station to receive the data: sophisticated Primary Data User Stations which can take full advantage of the digital data stream, and lower-cost Secondary Data User Stations which primarily use the images as photographs. There were some six PDUSs and 200 SDUSs taking the data at the time of the partial failure of Meteosat 1.

It also collects measurements from a number of data collection platforms on land, on ships or buoys at sea, or carried on planes. The ground-based stations are not infrequently in inhospitable locations, to which there is no ready access for regular monitoring. The stations are automatically controlled to relay their data, either at regular intervals (usually hourly or three-hourly) or else when interrogated by the satellite, or lastly on a basis of "alert", i.e. when their measurements exceed certain thresholds. Such "alert" messages would be immediately processed and made available to the platform's owners since their purpose is as a hazard warning. The majority of the stations, however, are of the self-timed variety.

Meteosat image of the Earth



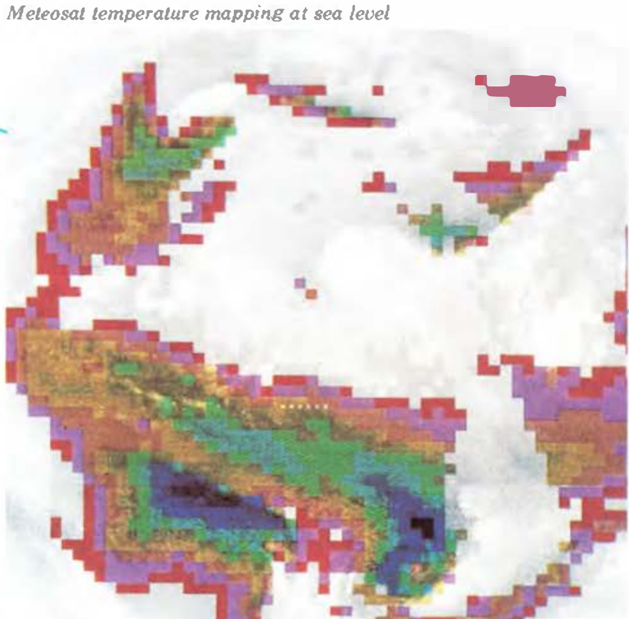
Apart from its value to European national weather forecasters, Meteosat has been able to play a useful role in global meteorological programmes, set up by the World Meteorological Organisation. It has contributed on a permanent basis to World Weather Watch, and participated throughout its duration to the experimental international undertaking of the Global Atmospheric Research Programme, organised by the WMO and the International Council of Scientific Unions. The global weather experiment lasted for one year, from the begining of December of 1978 to the end of November 1979. During this period an unprecedented number of observing systems provided a stream of data for the use of atmospheric and oceanographic research groups. Among these systems was a chain of five geostationary satellites, positioned over the equator and spanning the entire globe (with the exception of the polar regions). Meteosat was one of them and thus was able to make a significant contribution to the experiment.

Meteosat 2, a successor to Meteosat 1, has been prepared for launching on the third Ariane development flight in 1981. The satellite successfully completed its last test in May 1980 and work on the preparation and improvement of the mission's ground segment is underway.

There is considerable potential for more effective use of the Meteosat data and for the improvement of short-term forecasts as well as climatological studies. Some users are now introducing video display systems linked to computers; these will exploit the available material more extensively and can dramatically improve the information that the forecaster will be able to extract from the image data.

Flight model of Meteosat 2

Meteosat temperature mapping at sea level



Sirio 2

In 1977 Italy showed an interest in using the spare flight model of its successful Sirio 1 satellite on a broader European basis. After examining its catalogue of needs and in cooperation with the World Meteorological Organisation, ESA proposed using the satellite for a dual mission. This proposal was accepted by the Agency's council in December 1978. Development was started in 1979 and the satellite is due to be launched in 1982 by Ariane.
Sirio 2 will be used for meteorological data dissemination on the continent of Africa. Meteorological data are normally transmitted by standard telecommunications means. These are often deficient in Africa but the presence of the satellite will enable meteorological stations there to communicate direct with simple, robust, inexpensive transmitter/receivers. Three prototype ground stations are already under development for demonstration purposes. After the end of Sirio's lifetime its function could be incorporated into the operational follow-up of the present Meteosat.
The satellite's other mission will be the Laser Synchronisation from Stationary Orbit (Lasso) experiment. The scientific aim of this mission is to facilitate the extremely accurate synchronisation of high precision atomic clocks, large distances apart, to allow the precise correlation of phenomena on the same frequency or time scale.
Clocks in different locations will trigger a laser beam to the satellite at a presumed identical moment. Sirio 2 will time-tag the arrivals of the pulses and transmit the differences to the ground for evaluation, adjustment allowing for distances from the clocks to the satellite, and subsequent synchronisation (within an accuracy of one billionth of a second) of the clocks. The distance can be calculated accurately thanks to optical reflectors on the satellite which reflect back the laser pulse, enabling the emitting station to calculate the distance it has travelled.

Sirio 2	
project approval	1978
start of development	1979
prime contractor	Compagnia Nazionale Satelliti di Telecomunicazioni
launch date	[illegible]
launcher	Ariane
launch mass	420kg
in orbit mass	230kg
life time	2 years

Sirio 2 in ESTEC vacuum chamber

Applications and research planned for the next decade call for an extremely high degree of accuracy in clock synchronisation. Lasso should be able to provide this during the two years' utilisation predicted for Sirio 2. The satellite will be stationed first over the Atlantic, to allow the possibility of intercontinental clock comparison links with the Americas, and will then move to a location over Africa.

Remote-sensing programmes

The missions of remote-sensing satellites cover a wide variety of application objectives, e.g. crop inventory and yield forecasts, management of forestry and water resources, soil and arable land use, exploitation of mineral resources, shore and coastal areas surveillance, ocean processes and ice monitoring. Such applications are of interest not only to the industrialised countries but also to developing countries which in many cases have no fundamental information available on the state of their natural resources.
The Agency and its "Remote Sensing" Working Group studied the aims of a European programme and in 1977 defined a number of elements directed along the following three lines:
- a network of data collection stations "Earthnet"
- a European remote-sensing payload flown on the first Spacelab mission
- the preparation of future European remote-sensing satellite projects.

Earthnet

Earthnet is a mandatory ESA programme in which all the Agency's members participate. The programme, to set up a network of ground stations for the collection, processing and distribution of data from the American remote-sensing satellites Landsat 1, 2 and 3, the Heat Capacity Mapping Mission (HCMM), Nimbus-7 and Seasat, was approved by the European Ministers in February 1977.

The Earthnet system, which became operational in 1978, includes four receiving stations and two synthetic aperture radar (SAR) processing centres. The receiving stations are located at Fucino in Italy (Landsat data), Kiruna in Sweden (Landsat data), Lannion in France (HCMM and Nimbus-7 data), and Maspalomas in the Canary Islands, which came into service in August 1980 and receives data from Nimbus-7. The two processing centres are at RAE, Farnborough (UK), and DFVLR, Oberpfaffenhofen (Germany).

Seasat functioned from June to October 1978 only, during which time its data were received by the station at Oakhanger, U.K. Data from these satellites are managed at the Earthnet Programme Office at Frascati, which organises their distribution throughout Europe.

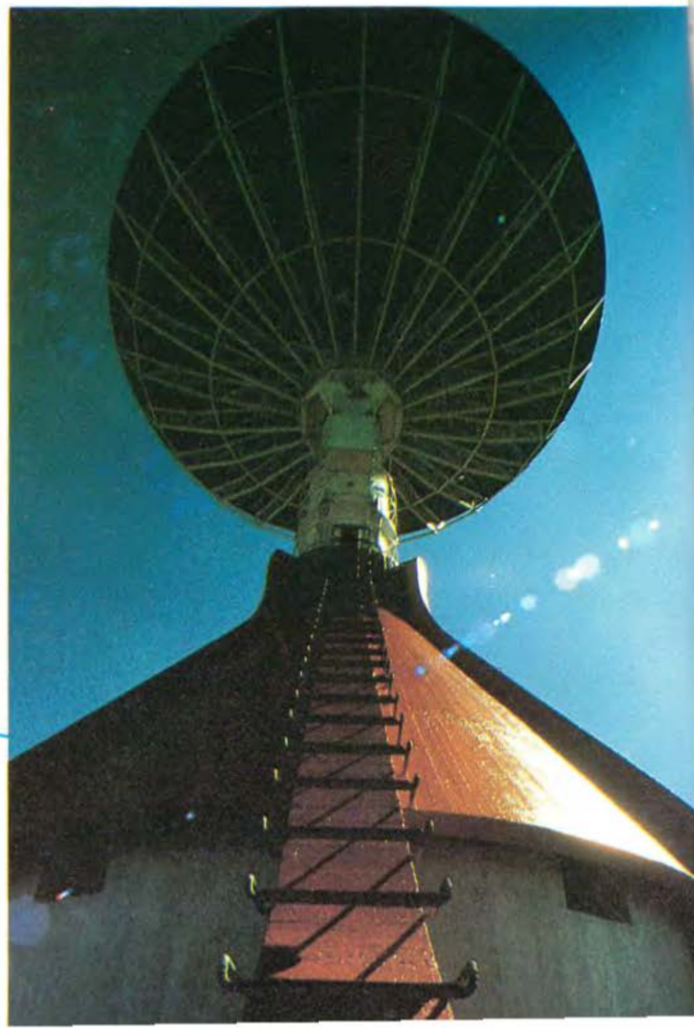
Earthnet is preparing to receive also Landsat-D data. Furthermore, it forms a fundamental element in the definition of the specification for the ground network which will be associated with future European remote-sensing satellites.

Spacelab utilisation

Two European experiments in the remote sensing of Earth resources will be flown on the first Spacelab mission in 1983. The first of these two experiments should provide an assessment of the possibilities of using pictures taken by a very high-resolution metric camera (10 - 20 m) covering a ground area of 188.5 × 188.5 km. This camera will mainly be used for mapping (scale 1/100,000) but also for a numher of thematic applications such as geology and all disciplines related to land use.

The second experiment is an attempt to develop a microwave remote sensor in Europe. The instrument will have several operating modes which will enable it, whatever the cloud cover, to measure the temperature of the oceans, to study the ocean swell and take high-resolution pictures of the Earth's surface. The use of these two instruments on Spacelab provides a unique opportunity for in situ experimental research before developing future European remote-sensing satellites.

Landsat data acquisition antenna



Landsat image of Alps and northern Italy

Future remote-sensing satellite missions

ESA is currently engaged in the preparation of a proposal for a European remote-sensing programme, which includes technological activities, system studies and instrument definition. This programme, subject to approval by the ESA Council, would consist of two remote-sensing satellites known as European Remote-Sensing Satellites (ERS 1 and ERS 2) to be launched by Ariane into circular sun-synchronous orbits in 1986 and 1988 respectively. The selected repetition rates for the orbits are 3 days for ERS 1 and 17 days for ERS 2. Payloads considered for these two missions generally consist of a combination of optical imaging and all-weather microwave instruments. The two satellites would use the multi-mission platform currently under development in connection with the French project SPOT.

ERS 1 would be allocated to coastal zone/ocean exploration and exploitation and to ice monitoring. Five major instruments are currently candidates for this mission: they include one optical instrument (Ocean Colour Monitor-OCM) and four microwave instruments (Synthetic Aperture Radar - SAR, Imaging Microwave Radiometer - IMR, Radar Altimeter - RA and Radar Scatterometer - RS). Final payload composition will be made in 1981 leading to a programme proposal to ESA Member States during 1981.

This mission would provide a major contribution to the scientific understanding of ocean/coastal zone and ice processes and would benefit a number of commercial applications (offshore activities, ship routing, ice surveillance, aid to fisheries etc.). Coordination with non-ESA missions (e.g. U.S.A., Japan) will be considered to improve data repetition rate and Earth's coverage.

ERS 2 would be allocated to land applications and the payload would include a Synthetic Aperture Radar and a high resolution Optical Imaging Instrument operating in the visible and infrared parts of the spectrum.

In preparation for these two missions, the Agency has undertaken a two-year support technology programme to define and to pre-develop the key elements of the optical and microwave sensors needed for these future satellites.

It is expected that these various missions will also make a significant contribution to the World Climate Research Programme as established by the World Meteorological Organisation in 1980. In recent years, growing concern over the increasing vulnerability of mankind to climatic change and variability has been heightened by awareness of the possibility of man-made changes. The impact of such changes on global food production and water resources has major economic implications. ERS 1, in particular, will contribute to a better understanding of ocean/atmosphere interaction processes.

Landsat image of Netherlands

communication satellites

It has become commonplace, over the past few years, to pick up the telephone and dial a number elsewhere in Europe, or even halfway across the world. We expect the ensuing conversation to be perfectly audible; indeed, it is often as clear as if we were simply calling someone in the next street, or even clearer. Telephone and telex are now accepted as normal ways of doing business, part of the standard equipment of our daily life.

This has caused a veritable explosion in Europe's telecommunications requirements, as a result of which ESA has undertaken to set up a system of satellite links designed to meet the needs of the near future. The Agency aims to make available to the European PTTs and, through them, the broadcasting organisations a satellite system capable of carrying, from 1982, a large share of intra-European telephone and telex traffic, and of relaying Eurovision programmes. More specialised services, such as data transmission, electronic mail, teleconferencing and off-shore oil rig communications are also foreseen.

According to the traffic forecasts made by European PTTs in the Interim Eutelsat Organisation, the operational satellite system needs to carry the equivalent of some 5000 telephone circuits in 1983, rising to about 12,000 circuits in 1987. The basic requirement for television is the permanent allocation of two wide-band repeaters capable of high-quality transmission.

OTS
(Orbital Test Satellite)

project approval	1971
start of development	1974
prime contractor	British Aerospace Dynamics Group
launch date	1978
launcher	Thor Delta
launch mass	900kg
in orbit mass	440kg
end of mission	1981 (projected)

OTS

European telecommunications satellite activities started in 1971 with an evaluation of a European regional system. The Orbital Test Satellite was designed taking into account needs defined by the European Conference of Posts and Telecommunications (CEPT) and the European Broadcasting Union (EBU); satellite development started in 1974. The OTS was launched in 1978. Its primary aims were to demonstrate the performance and reliability of the equipment; to fulfil, experimentally, the objectives which would be required of a subsequent operational mission; and to provide an experimental traffic capacity of 3000 telephone circuits and two television programmes.

The experimental programme has three main objectives: to prepare the way for the ECS operational system; to foster European capability in the design of communications satellites; and to study possible new uses of the communications system. The coordination is entrusted to Interim Eutelsat.

The experiments involve many national administrations which have brought their earth stations into the network used for the test programme. As part of the extensive propagation experiments, eight small earth stations owned by various national PTT Administrations, educational bodies and ESA have been transmitting and receiving test signals through the test satellite, and more than thirty small receive-only earth stations have been measuring beacon signals from the spacecraft on a regular basis.

In addition to purely Western European experiments, a number of demonstrations to the international community have been made outside the European region. They include experimental television transmissions to Cairo and Rabat, and a regular television transmission from France to Tunisia.

The OTS and its equipment have proved satisfactory and the spacecraft has enough fuel to maintain itself at the correct geostationary position, with the proper orientation, for a total mission of at least five years. It is expected that during the remaining period the data from the satellite, and the uses to which it can be put, will continue to provide a clear demonstration of Europe's advanced capabilities in the field of space communications.


SKOPAS
MONROVIA

Experiments with OTS

A number of experiments are being carried out with the OTS in order to provide experience with satellite techniques for new applications.

Television: Although it is not designed for television broadcasting, OTS nevertheless offers interesting possibilities in this area. Transmissions of television programmes through its high-gain spot-beam antenna enable a useful signal to be received under most conditions with an antenna of 3 m diameter and a sensitive receiver.

STELLA: In the data transmission field, two experiments are currently in progress. The first one is called STELLA (Satellite Experiment Linking Laboratories). It concerns the transmission of large volumes of data at high speed from the European Centre for Nuclear Research (CERN), Geneva, to national high-energy physics laboratories in the United Kingdom, Germany, Italy and France. The main objective is to investigate and explore electronic data processing techniques associated with high speed/high quality data links connecting large data sources with distant computer centres.

SPINE: The second experiment, called SPINE (Space Informatics Network Experiment), has developed into a European project with participation of national and international organisations. Spine has as its main objective the use of satellite links for a broad spectrum of specialised services. It is not therefore designed around a single application but is rather intended to serve as a test bench for different types of services, which can be broadly categorised as:

a) Digital transmissions of Earth observation image information;

b) Computer communications applications;

c) Data-base oriented applications.

OTS satellite antenna

ECS

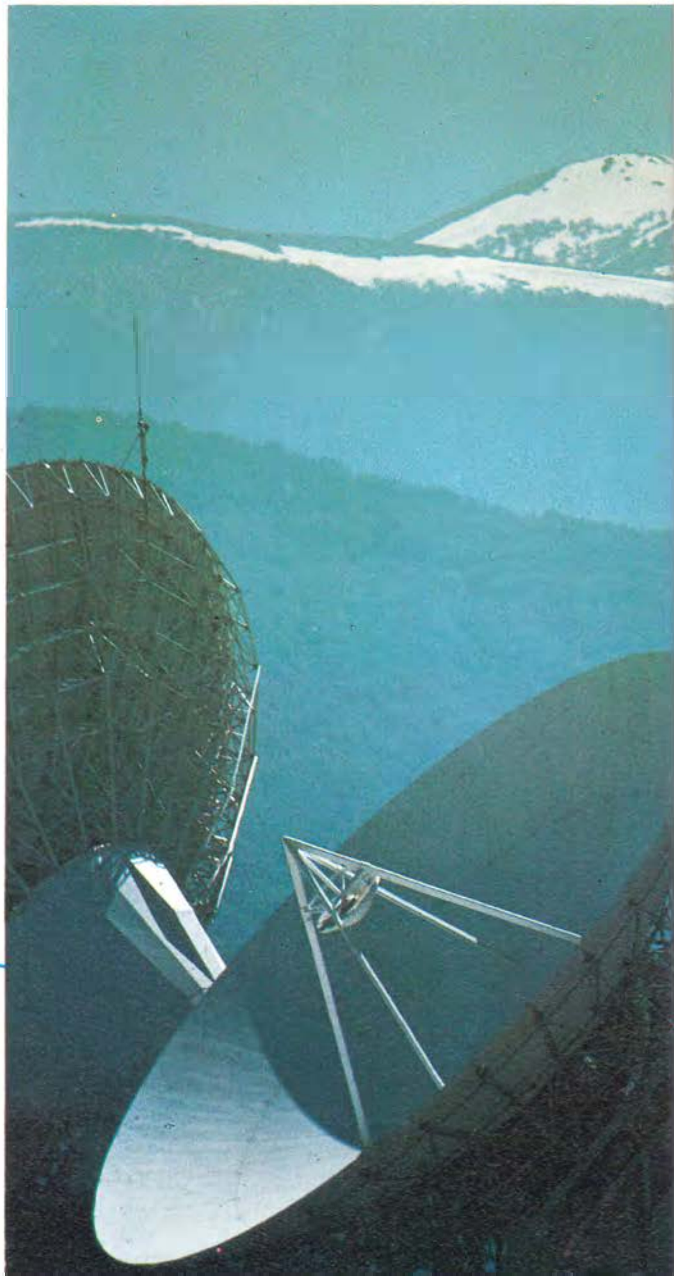
OTS served as the basis for the design of the ECS spacecraft. The ECS satellite thus similarly consists of a communications module (payload) comprising repeater and antenna, and a service module (the platform).

Prime contractor for the design, development and supply of the spacecraft is BAeDG leading an industrial consortium which groups firms from 10 European countries (Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom).

ECS
(European Communications Satellites)

project approval	1978
start of development	1979
prime contractor	British Aerospace Dynamics Group
launch dates	1982 onwards
launcher	Ariane
launch mass	1000kg
in orbit mass	550kg
life time	7 years

OTS antenna at Fucino



ESA foresees construction of five ECS satellites to meet the needs of the system over a ten-year period. The first of the series will be launched by Ariane in 1982.
The ECS system will provide international trunk telephone circuits to complement the terrestrial network between the countries of CEPT members. It will also offer a means of exchanging television programmes between member organisations of the EBU. This mission was formalised in a ten-year agreement to come into operation as soon as two satellites are in orbit (probably in 1982); it was signed in 1979 by ESA and Interim Eutelsat. Interim Eutelsat is a provisional European organisation created by several administrations or telecommunication recognised entities of the CEPT, in order to establish European satellite telecommunications systems.
The system may also be used to provide other services such as additional television relay data transmissions or communications to off-shore oil or gas rigs, or high speed data transmissions between small earth terminals. Such use is compatible with the design of the satellite and the provision of the primary telephone and television services.
The earth segment of the ECS system will consist initially of 15 stations and the space segment will comprise two ECS satellites in orbit, one operational and located at 10° E in a geostationary orbit and the other in reserve, as well as the necessary ground facilities for satellite control.
The earth stations will be equipped with an antenna of approximately 15 m diameter. Two of these stations, Fucino and Bercenay-en-Othe, are already in existence and have been used in the OTS programme.

Marecs

Long-distance radio links between ships and shore stations are still far from satisfactory. It is surprising but true that even today 93% of all messages to ships at sea are sent in morse code and only 7% by radiotelephone. Also, because of radio-wave propagation anomalies, the quality of communications can be very bad and it is sometimes impossible to establish the link.
A geostationary maritime satellite communications system whose service has characteristics similar to those of the fixed service (with respect to quality, rapidity, automatic operation etc.) is the most effective way of overcoming the drawbacks of radiotelephony.
It was with this aim in mind that the ESA Member States, acting on a United Kingdom proposal, decided to undertake in 1973 a maritime satellite programme.
Development of the satellite was entrusted by ESA to the British Aerospace Dynamics Group as prime contractor; Marconi Space and Defence Systems was responsible for the communications payload.

Marecs A and B
(Maritime European Communications Satellites)

project approval	1973
start of development	1974
prime contractor	British Aerospace Dynamics Group
launch dates	1981-1982
launcher	Ariane
launch mass	1000 kg
in orbit mass	560 kg
life time	7 years

The initial Marots programme underwent progressive changes and was then transformed into the Marecs programme in 1978. The original concept, confined to an experimental phase, evolved in favour of an operational system using a more advanced technical design for the spacecraft, derived directly from the ECS spacecraft.
The interest of this new system stemmed largely from the possibility of making it the basis for a worldwide maritime satellite programme. The discussions started in 1978 on this subject in a Joint Venture, grouping 18 countries interested in participating in a world maritime satellite system and ended successfully with the award of a contract from Inmarsat in November, 1980.
Inmarsat is an international organisation comprising some 25 Member States which came into being in summer 1979. It is responsible for defining, procuring and managing the worldwide maritime communications satellites system. The system now being implemented by Inmarsat will make use of the two Marecs satellites, Intelsat V satellites equipped with maritime payloads, and a Marisat satellite which is already in orbit.
The Marecs spacecraft comprises two main components, a service module — identical to that of ECS — providing all the essential support functions, and a communications module containing the payload. This is a platform housing the repeaters, surmounted by an antenna kept pointed towards the Earth. Two rotating wings with three panels each, fixed to the sides of the spacecraft, constitute the solar array. The nominal lifetime of the satellite is 7 years.
Operating in the 4 to 6 GHz and in the 1.5/1.6 GHz frequency bands (C and L bands), Marecs will provide a high-quality reliable and real-time operational maritime communications service. It will provide duplex telephone and telex links between ships at sea and shore stations, and will be able to relay ship-to-shore search and rescue messages. Each Marecs satellite will be able to handle up to 40 high quality telephone circuits.
The satellites will be launched by Ariane in 1981 and 1982 into a geostationary transfer orbit and will be positioned to provide coverage of the Atlantic and Pacific Oceans.

L-Sat

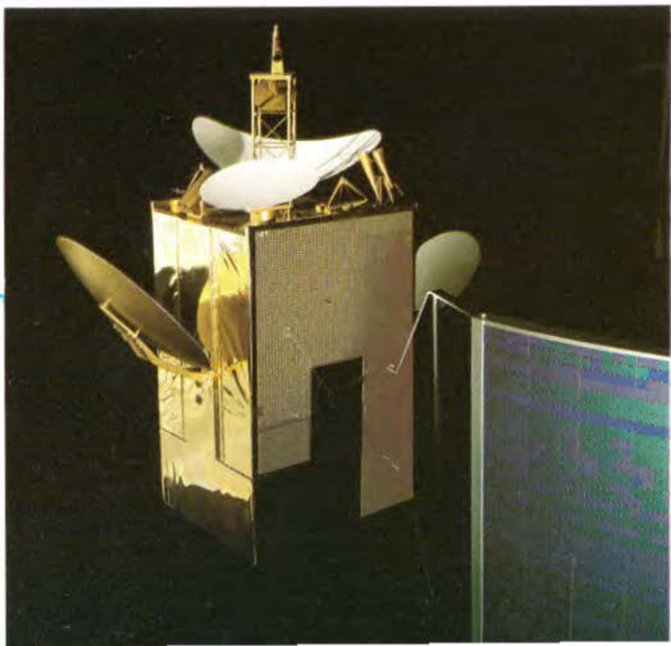
ESA has been investigating the potential development of a new class of communications satellite, which would cover the market for television broadcasting where a larger satellite type becomes mandatory. The programme is currently in the definition phase; development should start in 1981, leading to a launch in 1985.
A broad investigation in 1979 of the future market had proved the merit of proceeding with the development of a class of larger multipurpose satellites, called L-Sat, with mission objectives matching the full range of future applications.
The L-Sat programme has two major objectives:
- development and demonstration in orbit of a large multipurpose platform able to satisfy the range of foreseen future mission requirements on a competitive basis;
- development of communications payload hardware related to future mission needs and in-orbit demonstration of new types of communications systems to stimulate the introduction of new satellite-based services and techniques.

L-Sat
(Large Satellite)

preliminary project approval	1979
prime contractor	British Aerospace Dynamics Group
launch date	1985
launcher	Ariane or Space Shuttle
launch mass	2100 kg (Ariane)
in orbit mass	1130 kg
lifetime	5 years mission life 10 years design life

Marecs during testing

Model of L-Sat



The programme is based on the principle of a design-to-cost approach, in order to develop a commercially competitive product for subsequent exploitation by European industry in the international market.
The satellite is designed for compatibility with both the Ariane launcher and the American Space Shuttle. There is a basic flexibility of design which will enable the satellite to meet a wide range of objectives and to accommodate a variety of future missions.
L-Sat will carry a demonstration payload consisting of the four following elements:

- a two-channel TV payload suitable for high power direct-to-home broadcasting; one channel would be employed for pre-operational services in Italy while the other channel would be steerable to support experiments and demonstration over the whole of Europe;
- specialised or business services employing advanced concepts and covering the whole European zone, operating with small terminals on private or public premises with antenna diameters of 3 metres or less. This would prefigure a future operational European system and prove the key technologies and systems needed;
- a payload to develop techniques to use the 20/30 GHz bands, for services demanding greater bandwidth, is under study. Primary missions would be video-conference and communications system trials;
- a 20/30 GHz beacon to obtain the necessary data concerning propagation conditions, for the design of future satellite systems. This would cover the whole of Europe and support the range of required measurements.

Development for the future

The activities described above, in conjunction with others being conducted in parallel at national level within several of the ESA Member States, are expected to satisfy communications needs within Europe, and to maintain European industry in a competitive position in the world space market, until the end of this decade. In addition, because of rapid expansion in the types and extent of services being requested by the users of satellite communications, ESA is involved now in planning for the communications satellite systems which will be needed in the 1990s. A comprehensive research and development programme is under way, to define and develop both the system concepts and the necessary technology for the larger and more diverse space segments envisaged for the next decade.

Television control room

ariane

The Member States of ESRO, now the European Space Agency, decided in July 1973 to develop the Ariane Launcher to give Europe an independent launching capability for its own applications and scientific satellites, and also to enable it to secure a share of the large launcher market forecast for the 1980s. Something like 200 geostationary satellites are expected to be launched during that decade. Most will be for space applications and a high proportion of these for communications. It is estimated that the European launcher could obtain a share of this market amounting to somewhere between 30 and 50 launches.

Ten European Member States, (Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom), have been participating in the launcher development programme. They have been joined by Ireland for the production programme. France is the major contributor, providing over 60% of the total budget. More than 50 firms in the 10 countries are taking part in the construction of the launcher, for which the prime contractor for the development phase is the Centre National d'Etudes Spatiales (CNES) and the system integrator is Aérospatiale. Along with Spacelab, Ariane has been ESA's major project of the 1970s, and the lion's share of the Agency's budget from 1974 to 1981 was devoted to the launcher. The production programme of the Ariane 1 launcher has already started as well as a follow-on development programme leading to the uprated versions of the launcher, Ariane 2 and Ariane 3.

Ariane

project approval	1973
start of development	1974
prime contractor	Centre National d'Etudes Spatiales
test launches	1979-1981
operational launches	1981 onwards

The design of Ariane is based on technology already known and proved in Europe. Ariane's first and second stages are equipped with engines using storable propellants which had already reached an advanced state of development when the new launcher was undertaken. Expertise in the cryogenic propulsion, liquid hydrogen and oxygen, used for the third stage also existed in France and Germany.

Ariane 1

Ariane is a three-stage launcher designed for a wide variety of missions ranging from low-orbit missions to deep-space exploration. The launcher was more particularly designed for placing geostationary satellites in transfer orbit.

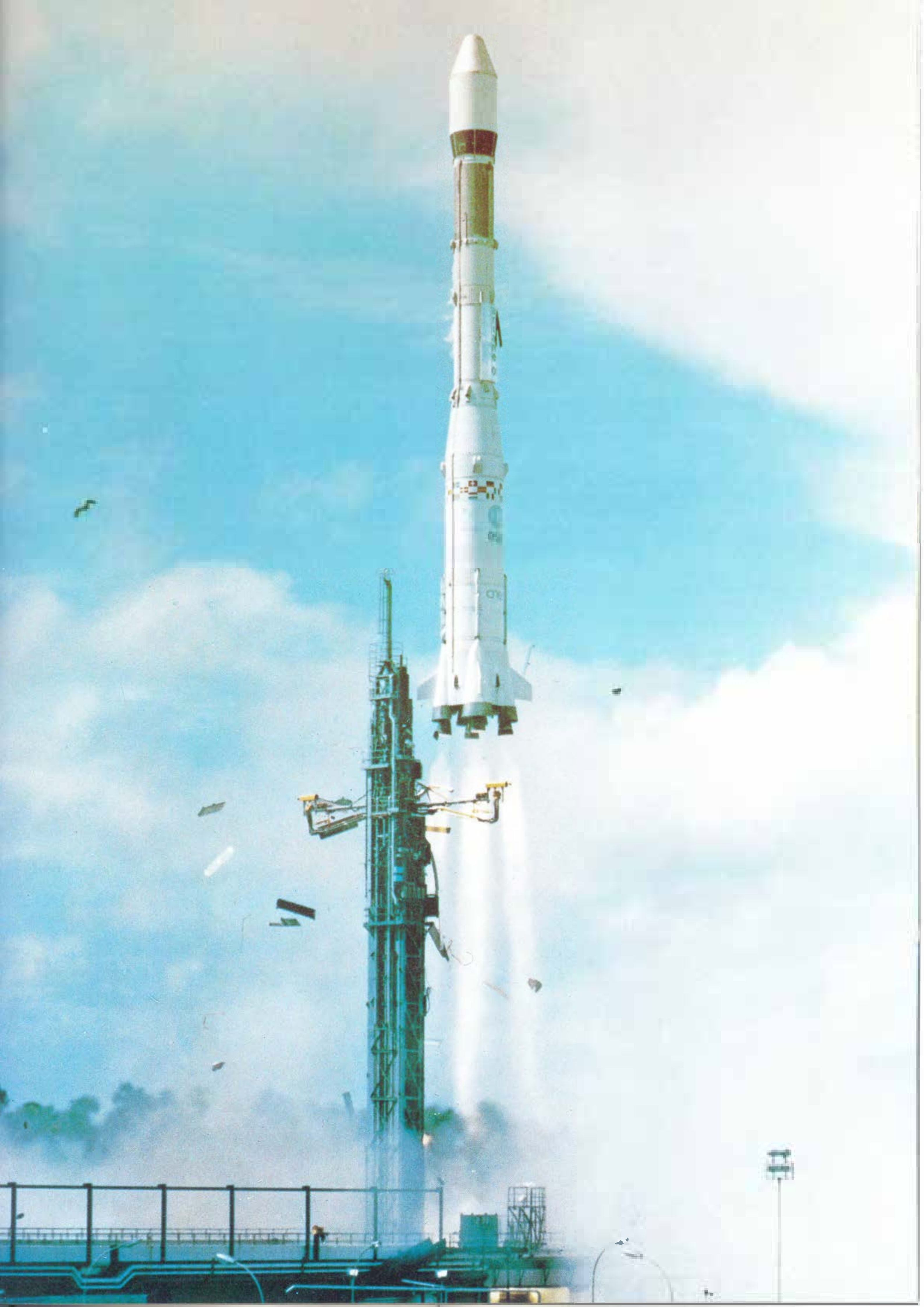
With Ariane 1, the following masses can be placed in orbit:

- 1700 kg into geostationary transfer orbit (perigee 200 km and apogee 35,800 km).

Launching a 1000 kg satellite into geostationary orbit at 35,800 km above the equator involves placing in transfer orbit a total weight of about 1700 kg. This includes an apogee boost motor which effects the final transfer to geostationary orbit. The geostationary orbit is used in particular for communications and meteorological satellites.

- 4800 kg into low circular Earth orbit (altitude 200 km): scientific satellites.
- 2500 kg into a sun-synchronous Earth orbit: in this quasipolar type of orbit the satellite passes at the same local time above the same point on Earth; it is used mainly for Earth observation missions.
- Lower masses into hyperbolic trajectories: interplanetary missions.

The launcher fairing, in which the satellite is carried, consists of two half shells of aluminium with a boat-tail section of laminated material which is radio transparent. Its useful volume of more than 40 m³ allows a large satellite of the Intelsat V type to be launched, or two medium-sized satellites mounted one above the other in the Ariane Dual Launch System, SYLDA.



The SYLDA structure has been developed to accommodate medium-sized satellites to be launched from the early 1980s onwards. The ability to carry two payloads simultaneously will considerably increase the vehicle's ability to compete in the world launcher market. The SYLDA consists of a bearing structure and three ejection devices, one for each satellite and one for the structure itself. The total weight of the SYLDA is some 160 kg.
The fairing itself weighs 826 kg and is 8.65 m high and 3.2m in diameter. It protects the payload during the ascent through the atmosphere and is jettisoned during the second stage of the launcher's flight, at an altitude of some 120 km.
The ascent of the launcher is effected by its three-stage propulsion systems. The first stage is equipped with four Viking engines which develop a thrust of 245 tonnes at lift-off and during the first 145 seconds of flight. The four turbopump engines are mounted symmetrically on the thrust frame and can be swivelled in pairs about two orthogonal axes to provide three-axis control. They are fed from two steel tanks containing 147.5 tonnes of propellants. Four tail fins improve the aerodynamic stability.
The second stage has one Viking engine and two propellant tanks, pressurised with gaseous helium. The engine develops a 70 tonnes thrust in vacuo for a flight period of 138 seconds.
The third stage is the first cryogenic stage to be developed in Europe. It is equipped with an HM7 engine which develops a thrust of 6 tonnes in vacuo, for about 10 minutes of flight. The engine is fed from two tanks containing the propellants, liquid hydrogen and liquid oxygen. The hydrogen and oxygen tanks are pressurised in flight by gaseous hydrogen and helium respectively. They are clad with an external thermal protective layer of Klegecell to prevent heating of the propellants. Separation of the three stages of the launcher is effected by means of retro-rockets mounted on the lower stage and acceleration rockets mounted on the upper stage.
The equipment bay, mounted on the third stage of the launcher, houses the vehicle's electronic equipment, supports the payload and provides the attachment points for the fairing. In it is the computer, round which is grouped all the electrical equipment needed for the launcher's mission and for performing the following functions: sequencing, guidance, flight control, tracking, safety and telemetry.
The launcher itself has a total height of 47.4 m and weighs 210,000 kg; 90% of this weight consists of the propellant.
The total flight of the Ariane launcher takes a bare 15 minutes, from the time it leaves the launch site in Kourou until the satellite is released into orbit.

Fairing

The launch range

The Ariane launch site has been set up within the perimeter of the Guiana Space Centre at Kourou in French Guiana. The Centre provides the necessary support for preparation and launch of space vehicles, several hundreds of which have been launched from there since 1968 when it was established. Its near-equatorial location (5.23° North) is extremely favourable for launching all types of geostationary satellites: an eastward launch from there benefits from a natural lift and can place in orbit a payload 17% heavier than an equivalent launcher could have done from the Kennedy Space Centre.

The Ariane Launch Base, designed to perform 4 to 5 launches per year, comprises: the launch site itself, with the specific facilities required for final assembly, check out and launch operations; the payload preparation complex which provides satellite preparation facilities for users; the additional support facilities in the Guiana Space Centre and the down range stations located in Natal, Brazil (ESA), and Ascension Island (NASA) to track the complete trajectory of the launcher's thrust phase.

ESA owns the Ariane launch site and the payload preparation complex and contributes to the operating and investment costs of the Guiana Space Centre, whose facilities are available to the Agency under an agreement concluded with the French government in 1976.

Development programme

To achieve its qualification, the Ariane launcher is scheduled to make a series of four test flights before being used for operational launches. These test flights come as the culmination of a long series of tests of all stages and subsystems of the launcher, which have been carried out on test stands in Europe.

The first test launch was carried out at Kourou on 24 December 1979 and was completely successful. The propulsion performances of each of the three stages on this first test launch turned out to be greater than pre-flight estimates.

The second test launch was made at Kourou on 23 May 1980. The lift-off was normal but pressure fluctuations, which developed in one of the engines of the first stage, caused the failure of the propulsion system and the self-destruct device to be brought into operation. Manufacturing tolerances in the fuel injection system, which was the source of the trouble, were adjusted in the light of post-flight tests. The third and fourth test launches are scheduled for 1981, to be followed straight away by the first of the operational launches.

The Apex (Ariane passenger experiments) programme covers the launch of payloads, free-of-charge, on the last three development flights of Ariane. The following satellites were selected for the test flights: Firewheel, a German scientific satellite, and Oscar 9, a radio amateurs' communications satellite, for the second test launch (L02); Meteosat 2, an ESA meteorological satellite, and Apple (Ariane Passenger Payload Experiment), an Indian experimental communications satellite, for the third test launch (L03); Marecs A, a European maritime communications satellite, for the fourth test launch (L04).

Antenna at Kourou

Production programme

ESA initiated the production of a first promotional series of six operational Ariane launchers in 1978. Production of further launchers was entrusted in 1980, by the participating States, to Arianespace, a private-law company founded to manufacture, finance, market and launch the Ariane launchers. Its shareholders are 36 leading European space firms participating in the programme, along with 11 European banks and CNES (which holds 34% of the shares).
The launchers will be used initially to place the following satellites in orbit: Marecs B (an ESA maritime communications satellite) and Sirio 2 (ESA meteorological satellite) which will be carried in a dual launch using the SYLDA system; Exosat (ESA scientific satellite); ECS 1 to 4 (ESA communications satellites); three Intelsat-V communications satellites; Telecom-1A and 1B (French communications satellites); SPOT (French remote-sensing satellite); TDF (French television satellite); a German TV-Sat; and Giotto (ESA scientific satellite).

Follow-on development and further studies

In June 1980 the ESA council adopted an Ariane follow-on development programme, which should lead specifically to the design and construction of Ariane 2 and Ariane 3. These more powerful launchers are intended to meet the growing demand for satellites of greater mass and the increasing cost-consciousness of users. They will facilitate dual launches of satellites and will reduce the cost per kilogram in orbit of the launch by about 25%.
Ariane 2 will be capable of placing a payload of more than 2000 kg in geosynchronous transfer orbit. It will have an uprated third stage with a 25% increase in tank capacity; there will also be an increased thrust in the first and second stages. Ariane 3 will be rather more powerful, incorporating the same improvements as those in Ariane 2 plus two additional boosters to the first stage. It will be able to place loads of 2420 kg in transfer orbit. A larger fairing will be introduced to increase the payload volume which can be carried within it.
A further economy in the cost of the launch could be achieved by recovery of the launcher's first stage. The possibility of controlling the free fall of this stage of the launcher by means of parachutes is

2nd stage engine of L 03

Ariane L 04

Control room at Kourou

currently being studied. Re-use of the first stage could represent an economy of 10 to 15% in overall costs.
Since a demand for even greater payloads is expected from 1985 onwards, studies are being undertaken now with a view to the design of uprated versions of the launcher, Ariane 4 and 5.
Ariane 4 would virtually double the performance of the present launcher, being able to lift 3500 kg into transfer orbit. It would differ from Ariane 3 in that the first stage boosters would be increased from two to four; the consequently greater load-carrying capacity would reduce the cost per kilogram in orbit to only 55% of that of Ariane 1.
This launcher could be made available in 1985. Its operation will necessitate the construction of a second launch site at Kourou and this is to be undertaken in the intervening period. Work on this new launch site is scheduled to start in summer 1981 and should be completed in late 1984. The site will be used for the Ariane 2, Ariane 3 and Ariane 4 launchers: it will increase the total number of launches possible from the Kourou launch base to a rate of one per month. Development of this second site will have the added advantage of providing a reserve launch facility for Ariane at Kourou.

Ariane 5 would be a two-stage vehicle, capable of placing up to 10,000 kg in low, circular orbit (200 km altitude), or 5500 kg in transfer orbit. Ariane 5 would have the same first stage as Ariane 4 with a second cryogenic stage carrying 40 tonnes of liquid hydrogen and oxygen, and powered by a new engine with a thrust of 60 tonnes. This launcher could be ready for use from 1990 onwards, and would further reduce launch costs per kilogram to 40% of the original cost.

spacelab

A joint programme to design, develop and operate a manned space laboratory was undertaken in 1973 with the signing of an intergovernmental agreement between Member States participating in the programme and the United States of America, and the ESRO/NASA Memorandum of Understanding. This programme was to become the biggest cooperative venture between ESA and NASA. For Europe it is of particular significance since it heralds the entry of the European scientific and technological communities into the realms of manned space flight.

Under the terms of the Memorandum of Understanding, Europe is entirely responsible for the design and development of the Spacelab; NASA is to provide the launcher, the orbiter of the Space Shuttle, which will carry the laboratory in orbit for each mission and bring it back to Earth again once a mission is terminated. NASA undertook, furthermore, to purchase a second Spacelab and additional equipment as required for the Spacelab programme. In January 1980 NASA signed a contract with ESA for the purchase of the second Spacelab; the contract was extended in May to include a second Spacelab Instrument Pointing System.

On the European side, ESA is fulfilling its obligations in the development of this major programme which will open new fields for basic and applied scientific research in space. Nine Member States (Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Switzerland and the United Kingdom) and one state with associate member status - Austria, are pooling their technical, financial and intellectual resources in the interests of the programme.

Germany is the main contributor to this programme, providing over 50% of the budget, and prime contractor is the German firm of VFW-ERNO of Bremen. Some 40 companies in Europe have been involved in construction of the Spacelab; at the height of the development phase an industrial workforce of about 2000 was employed on the programme. Their efforts reached fruition in November 1980 when the first Spacelab Engineering Model was delivered to NASA; the first Flight Unit is scheduled for delivery in 1981.

The Spacelab and the Shuttle

The Spacelab is composed of two elements, a pressurised module and an unpressurised pallet. The module provides the working environment for the payload specialists who will man the laboratory in orbit in space, while the pallet consists of a platform on which instruments are mounted.

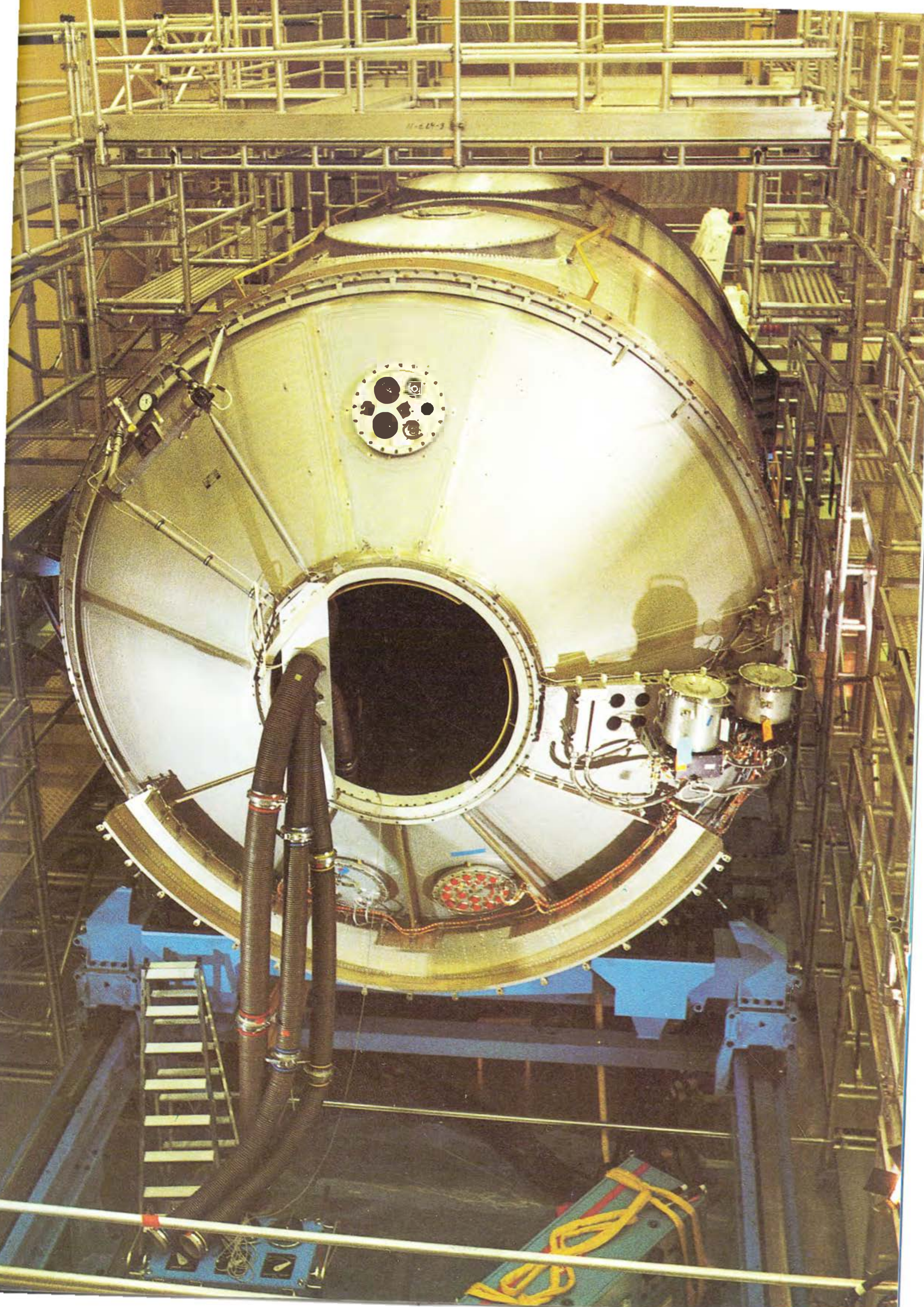
The pressurised module is a cylindrical element made of aluminium alloy. It can have one or two segments, according to mission requirements; each segment is 4 m in diameter and 2.7 m long. When the two segments are used together the module can carry a payload of up to 4.6 tonnes and provides a usable working volume of 22 cubic metres for experiments. One of the two segments is known as the core module because it houses the essential subsystems — monitoring equipment, electrical supplies, computers and thermal regulation.

Unlike the experiment module, the pallet is not pressurised and is, indeed, directly exposed to the space vacuum. This structure consists of one to five segments and can carry approximately 9000 kg of instruments. (It is worth recalling that the scientific payload of ESRO's first satellite weighed only 20.4 kg). The payload could include telescopes and antennae or radars, which may either function automatically, or be controlled from the module, the orbiter or the ground. The Spacelab module and pallet can be used in conjunction for a mission, or either one of them may be used separately. Hence the unit's considerable flexibility as a research medium.

The Spacelab is carried throughout its mission in the orbiter of the Space Shuttle. It is linked to the orbiter by a tunnel, 1 m in diameter, which allows the payload specialists to return to the Shuttle and share the astronauts' living accommodation and enables two of the Shuttle crew to enter the Spacelab.

The main element of the Space Shuttle is the orbiter. This combines the qualities of a rocket, a spacecraft and a glider: it is capable of the vertical take-off of the first, of orbiting in space like the second, and of landing on a runway like the third. For lift-off the orbiter is attached to a tank, considerably larger than itself, which contains 2 million litres of liquid hydrogen and oxygen for refuelling its engines. Two solid propellant boosters are fixed to the sides of this tank and will operate during the first two minutes of flight. They will then be jettisoned and recovered for re-use. The tank itself will also be jettisoned, once the propellants are exhausted, and will burn up on re-entry into the atmosphere.

Spacelab engineering model



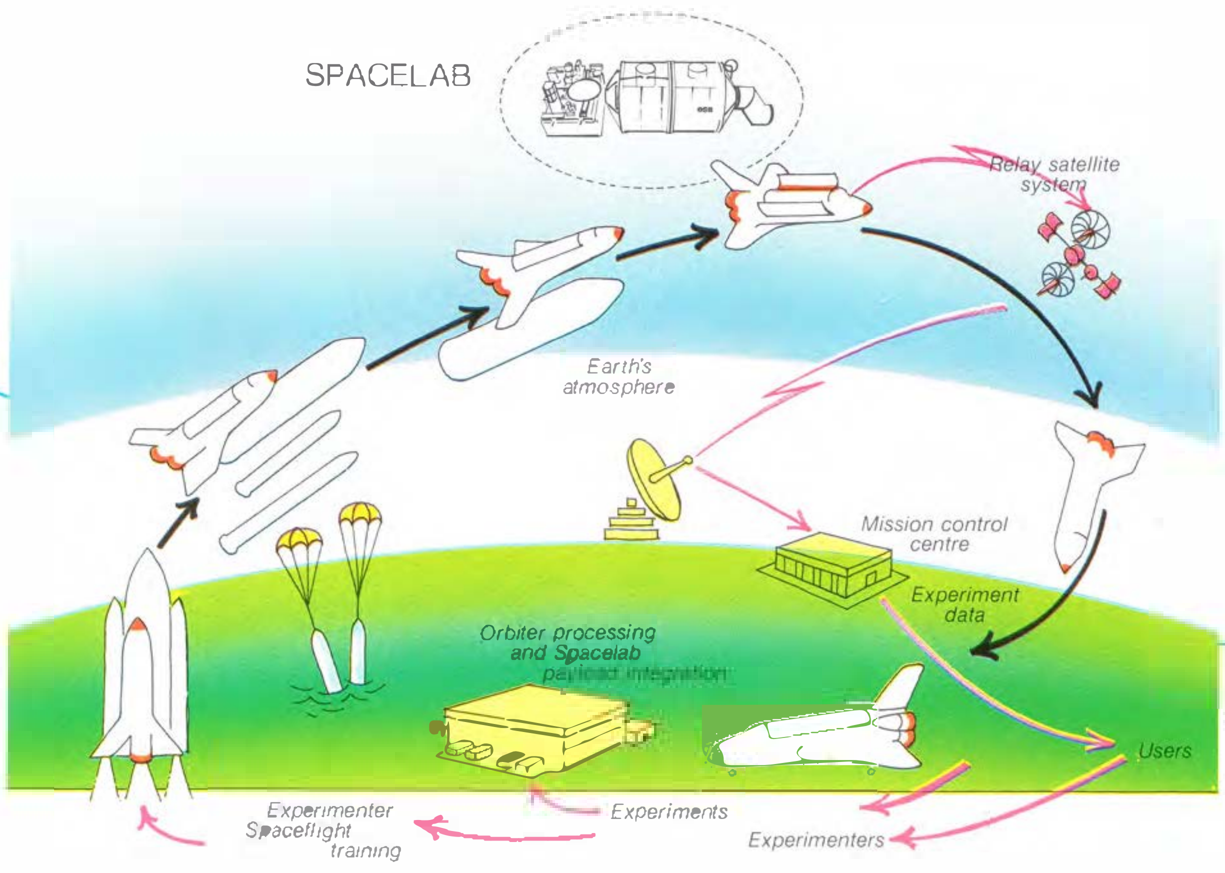
The Shuttle and Spacelab will orbit at an altitude of between 200 and 900 km (inclination 28° to 104°). Missions will initially be of one week's duration and the whole craft will be manned by a team of up to seven. This team will consist of a crew comprising the commander and pilot, and one or two mission specialists who will be responsible for liaison between the Spacelab and the Shuttle and who will also be able to devote some of their time to helping with the experiments in the Spacelab; and up to four payload specialists who will manage the research procedures of the Spacelab experiments. The teams may work in shifts, thus enabling the Spacelab to function continuously throughout the duration of its mission.
Each mission will be controlled from two ground centres, one for the Shuttle and the other for the operation of the Spacelab and experiments. Communication between the Shuttle and ground will be via a tracking and data relay satellite system. Data acquired during missions can thus be available on the ground in real time, but can also be stored on board for distribution at the end of the mission. When the mission is concluded the Spacelab systems are switched off, the cargo bay doors of the orbiter are closed and the descent to Earth begins.

Spacelab	
project approval	[illegible]
start of development	1974
prime contractor	VFW-ERNO
launch date	1983 onwards
launcher	Space Shuttle
life time	repeated missions

Spacelab's contribution to research

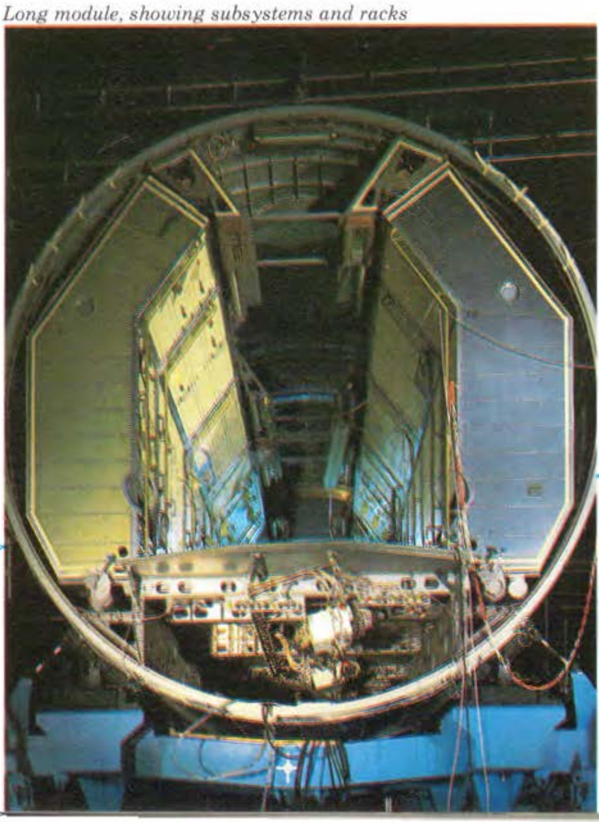
Spacelab will provide facilities for experiments in basic and applied scientific research, taking advantage of a situation of almost zero gravity and absence of atmosphere. It will favour research in astronomy, atmospheric physics, plasma physics, materials and life sciences, Earth and ocean physics, and astrophysics.
The observation platform, open to a cloudless sky free of our Earth's atmosphere, will considerably widen astronomers' possible field of investigation, thanks to its battery of instruments and telescopes functioning simultaneously in different wavebands. Spacelab will also be used for observation of the Earth and could contribute to the study of climatology, on which so much of the world's economic activity depends. Instruments such as plasma probes and mass spectrometers will investigate the Earth's environment and gather information on the origin of our universe.
Observations of the Earth's surface, using instruments similar to cameras but considerably more complex — in particular a remote-sensing metric camera and a microwave facility, will help to identify hidden resources. The data obtained can be used in crop surveys, soil classification, management of the world's natural resources, detection of

Spacelab and Shuttle mission



river and coastal pollution and many other fields which could promote protection of the environment and a fuller exploitation of our resources.
In this laboratory it will be possible to carry out scientific investigations in biology and human medicine. The effects of weightlessness on various organisms, such as cell tissues and plants, can be studied. It will be possible to separate biological substances to obtain pure cell preparations for use in transplants, to prepare concentrated antibodies for the treatment of certain illnesses, and to purify vaccines. The effects of motion on the human mechanisms of equilibrium will also be studied.
Matter itself will be the subject of a major research effort. In the absence of gravity, substances behave differently and present novel properties, which it is hoped to turn to good account. Efforts might be directed at manufacturing techniques for alloys that cannot be obtained on Earth because of gravity. Such manipulations could lead to the introduction of new material processing techniques.
The recoverability of the Spacelab payload is of considerable importance in extending the range of experiments for which the facilities are appropriate. Experiments and samples will return to Earth for further study on the ground; the payload specialists will be able to modify experiments in mid-flight after observing the first results; larger instruments can be carried on Spacelab than on traditional spacecraft, thus extending the range of potential experiments; and equipment can be reused in subsequent flights. It is envisaged that a pool of instruments should be established which could be made available to Spacelab researchers, thus reducing yet further the costs of individual projects.

Long module, showing subsystems and racks



The First Spacelab Mission

The first ESA/NASA joint Spacelab mission is scheduled to take place in mid-1983. It is conceived primarily as a testing mission to check the performance and flight conditions of the Shuttle/Spacelab system and to demonstrate the scientific possibilities offered by Spacelab. For this first mission a wide range of experiments has been selected; many of them may be the forerunners of later, more ambitious projects. Research into the stratosphere and the upper atmosphere will play a predominant part in this flight. Many other fields, however, will also be studied: plasma and solar physics, materials processing, astronomy, biology, medicine, and also technological subjects such as thermodynamics and lubrication.
Finally 37 individual experiments have been approved, 13 of them by NASA and 24 by ESA. A very large number of experiments were proposed for this mission but weight was a limiting factor. Each Agency will be able to fly 1392 kg of scientific equipment on the Spacelab; this constraint has meant that some of the experiments initially identified for inclusion in the first mission have had to be deferred to later flights.

Space Shuttle

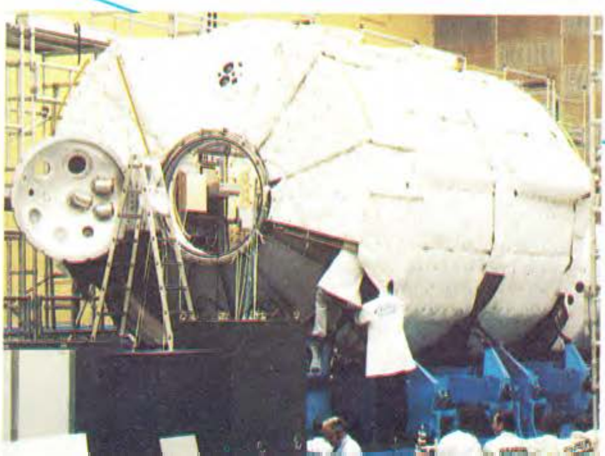
On this first mission, which will last for one week, the Spacelab will consist of the long pressurised module and a single pallet. Two payload specialists, one American and one European, will be chosen to conduct the experiments. ESA has selected three candidates from whom the European choice is to be made. All three are undergoing intensive training since the two candidates who do not fly in the first mission will provide support from the ground.
The European candidates are:
- Ulf Merbold, physicist, born at Greiz, Germany, in 1941;
- Claude Nicollier, astronomer and pilot, born at Vevey, Switzerland, in 1944;
- Wubbo Ockels, physicist, born at Almelo, Netherlands, in 1946.

All three are citizens of ESA Member States and they were selected from among 2000 candidates. The two American specialists selected for training by NASA are:
- Michael Lampton, physicist, born at Williamsport, U.S.A., in 1941;
- Byron Lichtenberg, scientist, born at Stroudsburg, U.S.A., in 1948.

Space Sled

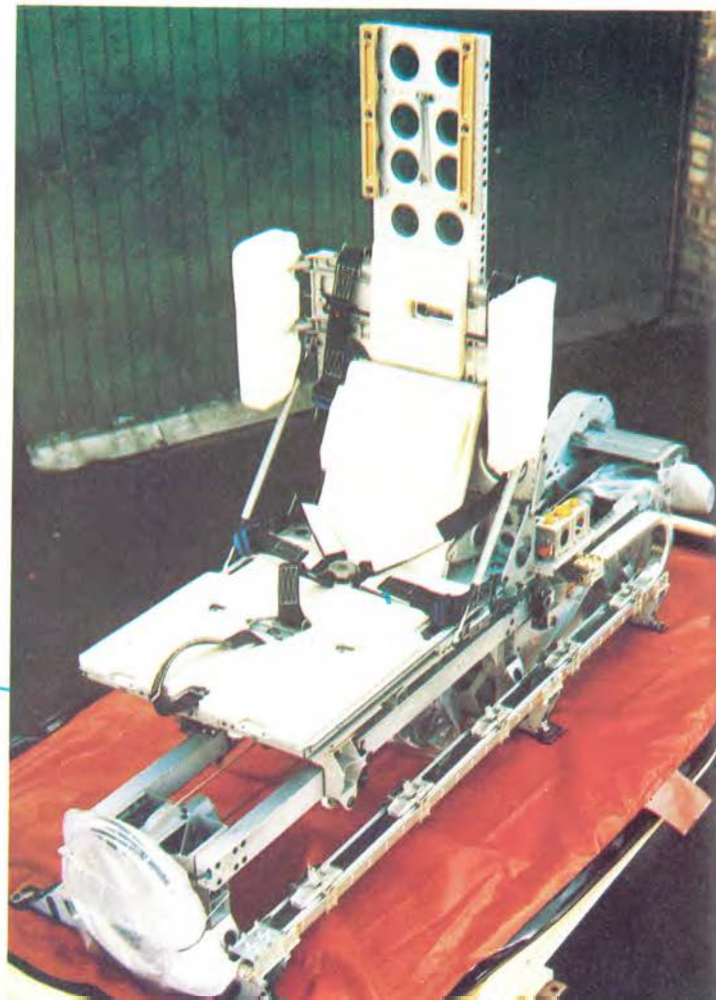
The ESA Space Sled will promote scientific investigation of the effects of space environment on the human organism. It is designed to be incorporated in the Spacelab module and consists of a seat carried on a rail track which will be mounted on the floor of the module. The seat can be swivelled in three directions facing forwards, sideways or upwards, and will move backwards and forwards along the length of the cabin.
The Sled will accelerate at controlled rates, enabling the effects of movement on crew members and/or animals to be studied. Man senses his orientation and direction of motion through several organs, the main ones being the balance (vestibular) organs in the inner ear, sight, hearing and touch. The brain interprets these sensory signals and when they do not correlate sickness may result. Movements in microgravity conditions can cause similar symptoms.
The research should extend our basic knowledge of the vestibular function, and increase understanding of how the human body functions in weightless conditions.
It is also hoped that the studies carried out by means of the Space Sled will contribute to solving the problem of space sickness from which many astronauts suffer, especially during the first few days of a space mission.

ESA payload specialists - medical training



Engineering model with thermal shroud

Space Sled

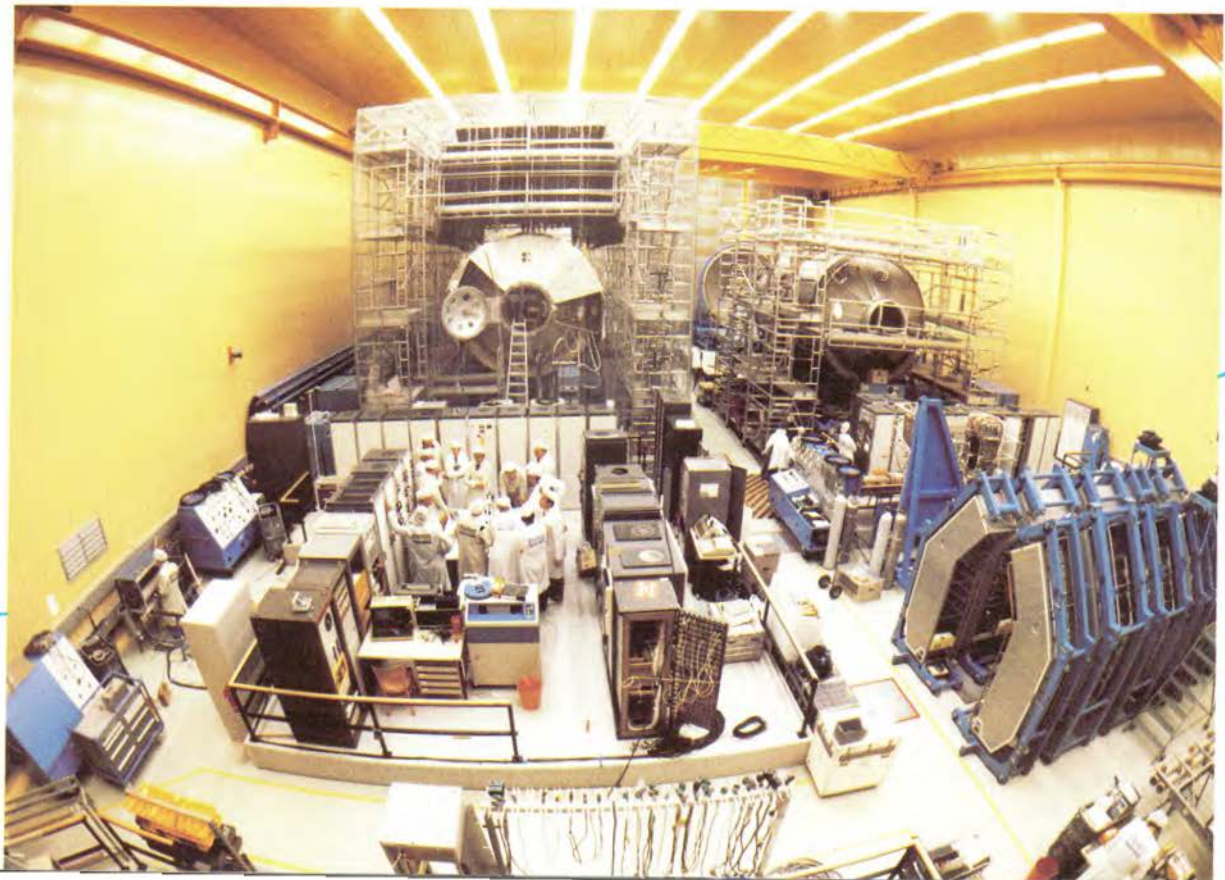


Future perspectives

Prospects for improvement of the Spacelab in the future hinge on increasing the supply of on-board electric power. If a greater power supply could be made available, it would not only enable a wider variety of missions to be undertaken, but would also allow the Spacelab to remain in orbit for considerably longer periods, of up to about three weeks in duration.
Spacelab's immediate programme for the 1980s is based on week-long missions. Its schedule is tied to that of the NASA Space Shuttle which is due to make some 200 flights during the decade of which about 60 will be allotted to Spacelab.
On a longer time scale various possible developments can be envisaged. If results of experiments carried out on the first Spacelab mission are truly promising and show that new materials can in fact be manufactured in space at reasonable cost, this could lead to the development of regular production facilities in space by the end of this century. There it might be possible to produce extremely pure metals with novel properties, to process composite materials offering increased resistance to high temperatures, and to make crystals of a quality never before obtained, for use in the electronics industry and for optical lenses.
Two kinds of space systems for the future are now being considered by NASA. The first of these is an unmanned space platform, which would be visited and tended by the Space Shuttle. It would consist of a large power system to which would be attached a series of platforms of pallet-like elements. A range of payload instruments would be mounted on the platforms. The Spacelab pallet could provide a basis for this system.

The second system is more ambitious and envisages a permanent manned operations centre in space. Such a centre could be used for performing operations in space, and would likewise be serviced by the Space Shuttle. Its operations might include the assembly in space of large elements brought to the centre by successive Shuttle flights, the repair in orbit of satellites also brought alongside by the Shuttle, and the refuelling of orbit transfer vehicles. The centre could consist of a series of pressurised modules in which a crew of up to 8 people could live and work. The modules might well be derivatives of the pressurised module of Spacelab.
Both these systems could be possible candidates for the further ESA/NASA cooperation envisaged in the original intergovernmental agreement. Such cooperation would be valuable to Europe in that it would develop know-how and provide home industries with desirable technological spin-off. Thus participation in today's manned Spacelab flights might pave the way to Europe's presence in space tomorrow.
The scientists of tomorrow have been considered too in ESA's Spacelab programme. Future European Spacelab missions may provide educational facilities in two ways: firstly films could be made of experiments in space which cannot easily be demonstrated on Earth, such as the laws of inertia, for example, and these films would be distributed to schools and colleges. Secondly, schoolchildren and students will be invited to propose their own experiments for Spacelab missions, and to participate in reducing the data acquired on Spacelab flights.

Engineering model (left) and flight unit (right) at ERNO



advanced technology

The Agency's ability to carry out its programmes and the quality of those programmes will depend heavily on the advances in technology and the degree of confidence which can be placed in any new undertaking. Therefore, the Agency puts strong emphasis on furthering the most important areas of space technology so that critical technologies are ready when needed, the more ambitious missions can be undertaken with confidence, and development risks can be more clearly identified and reduced before new projects are undertaken.

The technology programme supports all of the Agency's programmes with the following specific objectives:

- to ensure that the technology required by the Agency's programme is available on time,
- to maintain a high level of competence in space technology in Europe.

The Agency closely coordinates its programme with Member States' national technological research and development activities to ensure that the overall European efforts for new space technology developments are optimised and compatible.

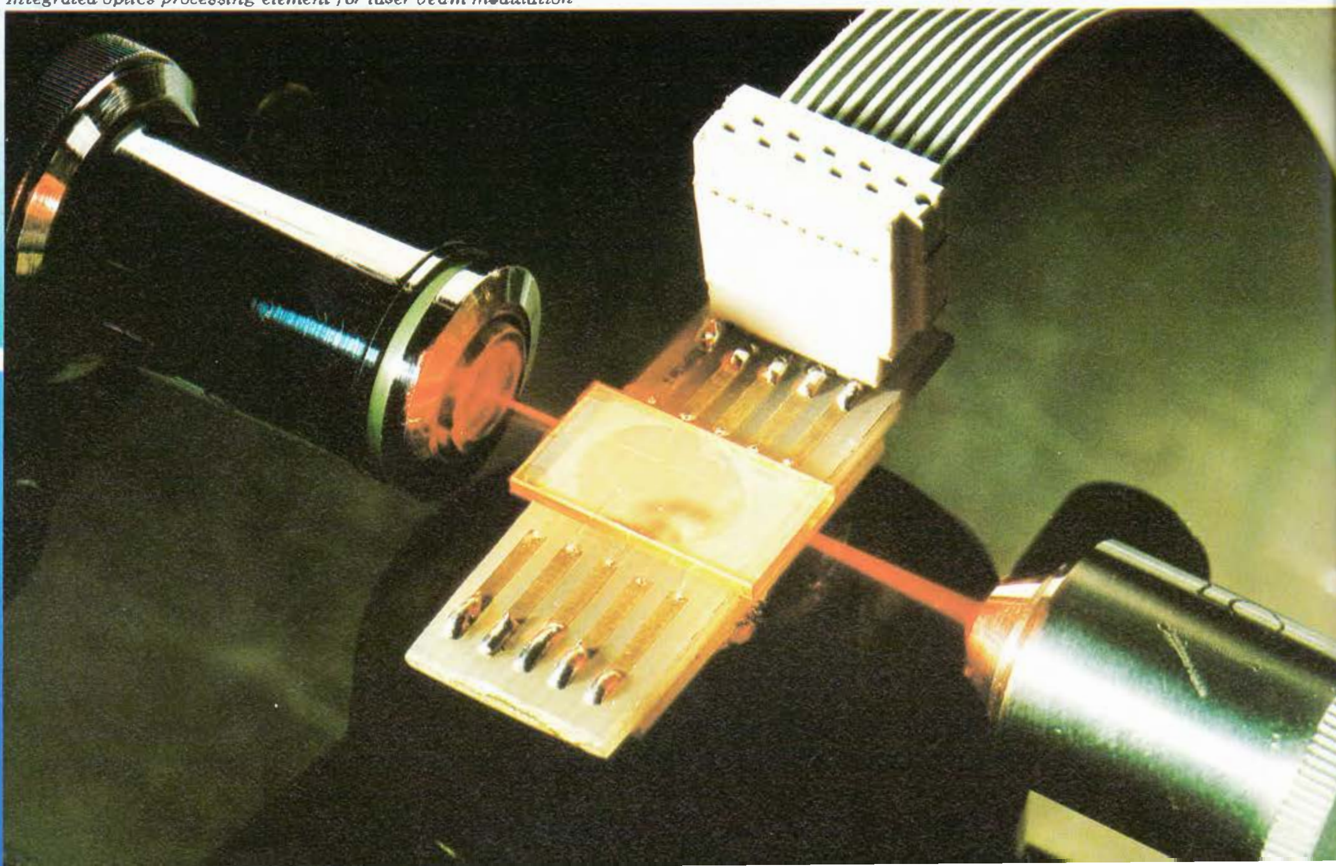
The Agency's programme comprises the following activities:

The Basic Technology Research Programme (Basic TRP)

advances the state of the art in the main common domains of space technology on the basis of anticipated mission requirements from the Agency's future programmes to the point of demonstrating feasibility through a "working system", i.e. it undertakes the technology pre-developments, normally through the development and evaluation of a breadboard model. The Basic TRP addresses medium and long-term mission needs and its overall results apply to all the Agency's future programmes.

The Basic TRP is focused on a few major technology themes and, for reasons of efficiency, is partially implemented in the form of multidisciplinary technology projects. It provides the essential knowledge on technological feasibility, risks and constraints, prior to the completion of the Agency's project feasibility studies and initial commitments to new ESA projects. In this way it helps to reduce costs both for the Agency and within industry. It further provides continuity in specialised fields of activity and strengthens specific competence in industry.

Integrated optics processing element for laser beam modulation



The Support Technology Programme (STP) is associated directly with the major programmes of the Agency and is allied to identified, near and medium-term projects or programme requirements. In general, it advances the technology from the "working system" to the point of demonstrated "flight worthiness", through the development and testing of an engineering model or the conduct of very specific technology developments. Preparatory STPs exist for the Telecom and Earth Observation Programmes, and are envisaged for the Science and Microgravity and the Spacelab Programmes, as well as for certain of the Agency's more common or special infrastructure technology developments. The STPs significantly reduce the risks for the remaining equipment flight qualification, which will normally be undertaken during a project development phase. The STP consists of the following elements:

Earth observation - development of the complex spacecraft technology, including payloads, and its instrumentation requirements as well as the advanced ground facilities and data handling systems needed for global and specific Earth observation missions.

Telecommunications - emphasis is on the development of the new payload technology and operating methods for the expected transition to the next generations of spacecraft which will incorporate advanced technologies such as intersatellite links, multiple beams, on-board switching, the utilisation of higher frequencies, and large unfoldable and deployable antennae.

Science and microgravity - concentrates on the new technologies associated with major new science projects, including deep-space missions. Development in the microgravity field is planned for a number of instruments and critical mission support equipment for life and materials sciences missions.

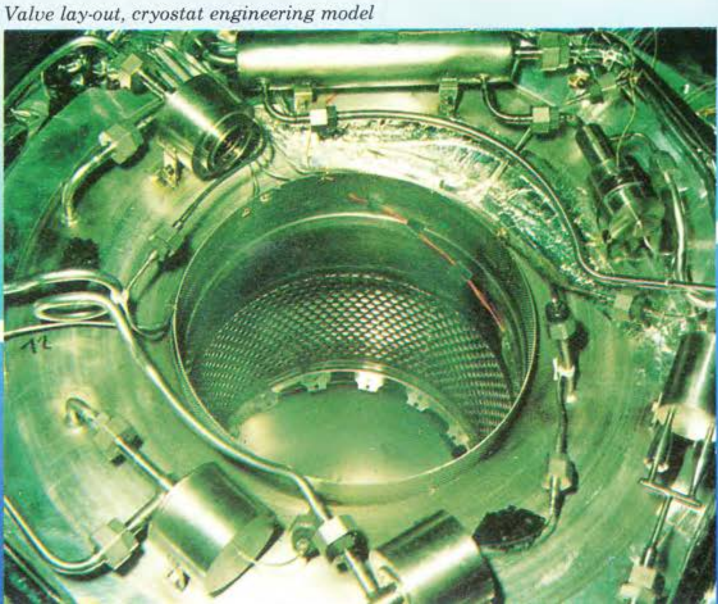
Spacelab - efforts are devoted to supporting Spacelab utilisation and advanced systems for free-flying pallets and modules, and possibly to preparing the ground for larger space operations.

Special technology developments - cover items essential for several programmes which form part of the technical infrastructure of the Agency. Technology is included for large synchronous platforms supporting multiple missions, and the necessary associated techniques with emphasis on rendezvous and docking. Further, critical technologies needed for the Agency's future telematics network, i.e. its space-to-ground data management infrastructure, for advanced modular propulsion systems and for space energy systems are supported here.

The Agency's technology programme is executed with the help of many industrial companies and research institutes throughout Europe. It continuously challenges the frontiers of mankind's engineering know-how and produces new solutions to previously insoluble problems, thus allowing breakthroughs in new space missions and providing impetus for new terrestrial applications.

CRHESUS, cryostat breadboard model

Valve lay-out, cryostat engineering model



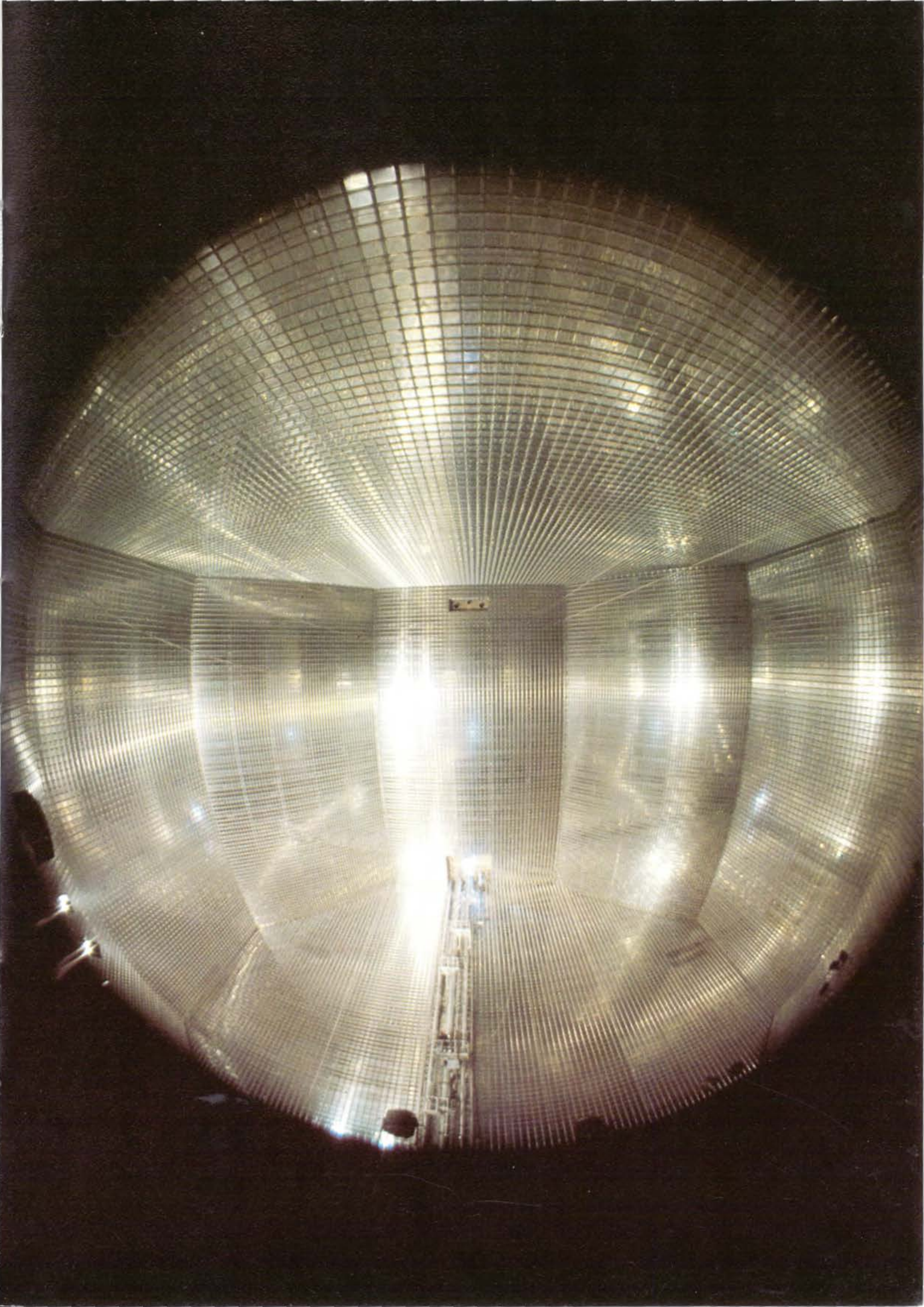
tomorrow's science programme

ESA's science programme is a basic mandatory activity in which all the Member States participate. It provides a central, unifying element which binds together the diverse interests of the various States in the service of the Agency in which are vested Europe's hopes for a future in space. It is a recognition of the importance of fundamental research in the foundation of that future.
The science programme was the only contender for government space funding during the early years of ESRO's existence. During the 1970s, however, the need for applications programmes became more pressing and ESA Members began to devote a larger share of their budgets to the latter. As a result of an agreement in 1971, a ceiling was imposed on ESRO-ESA's expenditure on the scientific programme. The latter has continued to receive some 15% of the total budget, which has provided a virtually constant income throughout the decade of the equivalent of some 80 MAU/year at present-day values. This accounts for the need to enlist outside cooperation for increasing numbers of scientific programmes; cooperation with NASA has in fact been a feature of two out of every three programmes in the past decade.
At the dawn of the 1980s Europe is on the threshold of a new era in space. The Ariane launcher will give Europe the means of placing its own spacecraft in orbit. The construction of Spacelab provides a space research facility of broad scope and multi-disciplinary appeal. Given the necessary financial resources, Europe's scientific community can look forward to exploiting these new facilities to support the investigations which could keep them in the forefront of space research.
ESA plays a key role in directing European efforts in space science. By the selection and evaluation of scientific programmes, and by managing those selected through the design and development phases, the Agency determines the course of much of Europe's space science effort. The selection procedure of the scientific programme is therefore of major importance.

A new programme planning cycle is started roughly once in every two years, when a Call for Mission Proposals is sent out to the European scientific community. The replies received are evaluated by the Agency's scientific advisory groups, for example the Astronomy Working Group, the Solar System Working Group, etc., and by the senior scientific advisory body to the Director General, the Science Advisory Committee.
Some 8 or 9 proposals will be selected at this stage for an initial assessment which covers their scientific, technical and programme content and establishes costs on a preliminary basis. The proposals are then screened again by the scientific advisory bodies who choose 3 or 4 of them to be put forward for rigorous in-depth feasibility studies, known as Phase A studies. When these studies are completed, a final selection procedure will eliminate all but the most suitable projects, of which one or more will be approved by the Science Programme Committee for development.
The following survey gives a brief description of the mission proposals under evaluation at the beginning of 1981.

Biorack

Biorack is a multipurpose Spacelab research facility for use particularly in the study of cell and molecular biology. It will contain several incubators, reference centrifuges, and auxiliary equipment such as a freezer, a glove box, microscopes and cameras. This equipment will fit into a single Spacelab rack and the individual components will be interchangeable to allow maximum flexibility for researchers. The experiments to be carried out with the Biorack equipment will be prepared on the ground; in orbit they will be managed by the Spacelab payload crew, or semi-automatically.
The Biorack will facilitate experiments in space and will thus enhance the interest of the Spacelab facility for life scientists. Within the pressurised module it will be possible to study terrestrial organisms in the space environment (microgravity, cosmic radiation, absence of circadian rhythms, etc.). Such studies, which have been initiated over the past two decades in American spacecraft, and the Soviet Cosmos and Salyut series, may now be pursued in Spacelab.



X-ray timing, transients and spectroscopy satellite

The X-ray timing, transients and spectroscopy mission aims to make a detailed study of the spectroscopic and temporal behaviour of selected X-ray sources over a wide energy range and to monitor the X-ray sky for transient and burst phenomena. Studies of X-ray variability can throw light on the generation and release of energy in compact objects such as neutron stars, black holes, quasars and the nuclei of active galaxies.

Notable progress has been made in X-ray astronomy in recent years. It is a field of major significance since most of the observational data obtained by this means are of direct relevance to the most important questions in contemporary astrophysics. Existing data in this field are, however, incomplete or inadequate and no other scientific mission has been approved with similar instrumentation and comparable sensitivity.

The X-ray satellite involved could be launched by Ariane and would be placed in a low-altitude circular equatorial orbit.

POLO (Polar Orbiting Lunar Observatory)

The POLO project aims to provide a space observatory to study the physical and chemical properties of the moon, and to carry out a complete global survey of the lunar surface. Previous lunar missions have produced a wealth of data about the moon, but have also posed a large number of key questions which can only be answered with further research of the kind proposed for the POLO mission.

The POLO mission would be undertaken by two spacecraft which would be launched together to move into polar orbit around the moon. The first would orbit at low altitude and carry the scientific payload; the second would orbit at high altitude to relay data from the other orbiter when it was on the far side of the moon, the only way to provide gravity mapping of the reverse lunar surface. The mission would last for about one year.

The POLO mission could be expected to throw light on the origin and evolution of the solar system since the moon's crust contains the earliest complete record of primeval events in the solar system. It could lead to greater knowledge of the Earth-Moon relationship and might even determine whether Darwin's theory of fission was correct.

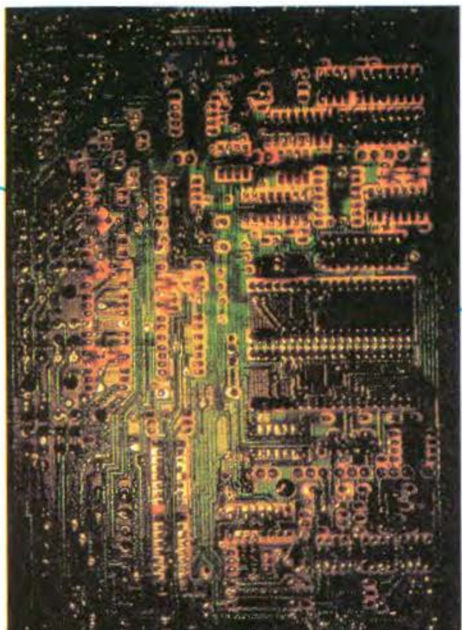
ISO (Infrared Space Observatory)

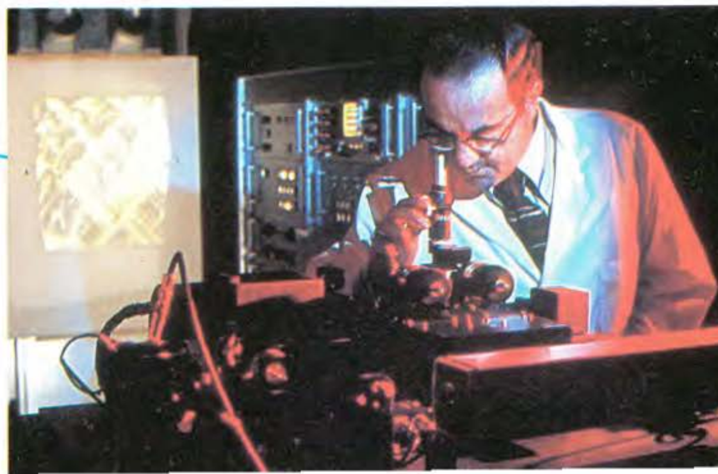
This proposal is for a space observatory dedicated to infrared astronomy. The telescope would be carried in a spacecraft launched by Ariane. Its planned lifetime of 1.5 years would enable it to tackle a wide range of astrophysical problems, with unequalled sensitivity.

The satellite would carry a 60 cm diameter telescope, cooled by liquid helium contained in a cryostat. The telescope and accompanying scientific instruments would be capable of extremely sensitive observation since they would not be limited by the severe restrictions on wavelength range and sensitivity imposed by the atmosphere, which adversely affect ground-based systems and those carried by aircraft or balloon.

Cooling of the telescope and other instruments is fundamental to the success of the project. Operating an observatory at cryogenic temperatures will involve considerable new technology for Europe.

The infrared space observatory could undertake deep surveys in the near infrared for primeval galaxies, and could study the star formation regions in our own galaxy. It could be used for mapping the galaxies, of which it is expected to detect at least 40,000.





GRIST
(Grazing Incidence Solar Telescope)

Although the sun is the nearest star to Earth it has not so far been examined in the X-ray to extreme ultraviolet region of the spectrum. Most of the Sun's high intensity line emissions lie in this region; this has led to interest in the development of a solar telescope capable of high resolution spatial and spectral measurements in the above wavebands.
GRIST would be a large telescope, 6 m in length and 2.4 m in diameter; it would use special grazing incidence optical techniques to reflect the incoming energy at shallow angles from precisely formed optical surfaces. The telescope would be mounted on the instrument pointing system (IPS) of Spacelab and would be controlled and monitored by one of the spacecraft's payload specialists.
The GRIST measurements could provide a major breakthrough in the understanding of many solar phenomena, including the heating mechanism of the chromosphere and the corona, and the origin and acceleration mechanism of the solar wind.
GRIST could be carried on the Spacelab along with NASA's SOT telescope since the two complement each other well.

New frontiers for research

New fields of research are being opened to European scientists by the development of ESA's Spacelab. In the microgravity-oriented sciences, interest has been shown by some 150 research institutes which have already proposed to ESA about 260 experiments to take advantage of the new opportunities. In an environment where weight plays no role, liquids and gases move and mix in a manner quite different to that on Earth. Hot air, for instance, no longer rises; liquids float free of containers and coat differently the surface of solids. Their presence in other substances may alter the nature of those substances. As Vladimir Lyakhov remarked on his return from 175 days in space: "Weightlessness may spring a surprise on us in the future" (Spaceflight, January 1981).

Microgravity Research Programme

ESA is proposing a programme to foster research into fundamental questions concerning phenomena and underlying mechanisms in conditions of an almost complete absence of gravity. It also aims to identify the part which gravity plays at all levels of life, from simple organisms to highly complex ones, including man.
This programme will encourage scientific cooperation between research teams who have hitherto tended to work independently. It will enable them to tackle entirely new questions offering as yet unknown possibilities. Themes which are of common interest to them include transport processes and mechanisms in fluids, transport and stabilisation of particles in metals and non-metallic systems, wetting of solids, transport processes and mechanisms at cellular level, and the effects of gravity on the development of multicellular organisms and in their orientation processes.
The programme would make use of hardware existing in Europe or to be developed for future missions, and will ensure repeated flight opportunities.
This programme could build up gradually during the 1980s to a level capable of satisfying the lively interest of the scientific community. It can be expected to attract a far higher number of qualified researchers over the coming years.

"As long as there have been humans we have searched for our place in the Cosmos... We find that we live on an insignificant planet of a humdrum star lost in a galaxy tucked away in some forgotten corner of a universe in which there are far more galaxies than people. We make our world significant by the courage of our questions and by the depth of our answers."

(Carl Sagan quoted in *Time*)

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