EUROPE IN SPACE

A survey prepared by the European Space Research Organisation (ESRO)

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FOREWORD

Europe's first ten years of co-operative space activity have stimulated an impressive growth of industrial effort in this new field of technology.

The setting up of industrial consortia to undertake space study and development contracts has forged new links of practical co-operation between European countries. Special high-precision skills and techniques have been developed and new expertise has been gained. Joint ESRONASA *programmes have been undertaken.*

This is an appropriate time to take stock of Europe's space capability in industry, in the scientific field and in the « official » sector of national organisations. We hope that this survey will be useful not only to those who know relatively little about European space activity but also to those who, in following closely our progress in this field, may have wished for a single comprehensive publication on the subject.

A. HOCKER

March 1974 *Director General, ESRO*

The information on which this publication is based was obtained principally from the organisations and companies mentioned therein.

INTRODUCTION

Cooperation on space projects began in Europe ten years ago. Having pooled part of their resources, the European countries decided in the early 1960s to set up two organisations, one to develop satellites, the other launchers. This was how the European Space Research Organisation (ESRO) and the European Space Vehicle Launcher Development Organisation (ELDO) came into being in 1964. Certain European countries which had undertaken to develop their own national satellites before ESRO and ELDO were created continued these projects in parallel.

The skills acquired by these countries helped ESRO and ELDO in the early stages. Now it is the other way round: European programmes are on a scale far exceeding that of national programmes, and will in future provide experience and guidance for the latter.

A decade after it began, space activity in Europe has taken a new turn. Having confined itself up to then to the development of scientific satellites, in December 1973 ESRO issued its first two contracts for the construction of application satellites in the fields of meteorology and telecommunications, in line with a long-term programme formulated in December 1971.

To this first long-term programme was added in July 1973 an even more ambitious programme that will double ESRO's budget in less than three years. The European countries decided to develop a new manned space laboratory to be carried into orbit by America's Space Shuttle in 1980, to build a heavy launcher—Ariane, capable of placing 800 kg satellites in geostationary orbit— and a further applications satellite, the Marots maritime satellite. It was decided at the same time to combine ESRO and ELDO activities under a single organisation—the European Space Agency (ESA)—and that this agency should coordinate more closely national and multinational space activities.

Thus an immense task lies ahead of Europe in the coming decade; yet the European countries could hardly have set themselves such ambitious goals had they not spent ten years sharpening their skills and paving the way. From 1962 to 1972 Europe built 28 satellites and a number of launchers (Black Arrow in the UK, Diamant in France, and Europa 1 and 2 through ELDO) and set up several ranges and various technical centres. European industry has become familiar with space technology thanks to prime contractorships awarded by European organisations or national agencies, and it now has the expertise needed to move on to the next stage.

It is the aim of this Survey to make known Europe's past, present and future space activities. In reviewing these, we have elected to present existing hardware and future projects by area of activity (satellites, launchers, sounding rockets, etc.) as well as by country. It was felt also that it would be of interest to describe satellite, launcher or sounding rocket programmes as much in terms of achievements by industry as in terms of the role of conception and coordination played by national or European organisations. We have therefore attempted, after giving background histories and descriptions of the various national and European programmes, to make a factual assessment of the skills and expertise acquired by Europe's industry over the years irrespective of programmes or nationality.

This historic and dynamic rather than descriptive and static presentation, which has been extended to include the activities of the scientific laboratories, has led us to devote considerable space to the future. Having earmarked only a small part of their gross national product for space at first, the European countries will in the coming years increase their efforts significantly and engage more and more in international collaborative ventures first and foremost with the United States, but also with Canada, India, Japan, the Soviet Union and Latin America.

In order to be able to collect as much information as possible about the space programmes of ESRO member countries in Europe, we sent long questionnaires to ministries and organisations responsible for space matters and to many industrial concerns throughout Europe. We should like to take this opportinuty to extend our thanks to them for undertaking this tedious task on our behalf, as well as for their valuable assistance, without which this Survey could not have been prepared.

Although our aim was to collect extensive information from a wide variety of sources, this Survey does not claim to be exhaustive. We hope, however, that it is sufficiently comprehensive and informative to stimulate suggestions for improvements or modifications. We also hope it will be of some use to all those who wish to have a better insight into the conquest of space and the difficulties it poses, and to become better acquainted with Europe's efforts in this field.

I - THE AIMS OF EUROPE

For 10 years the conquest of space was marked by a close contest between the United States and the Soviet Union which culminated in an unprecedented exploit—man's first landing on the moon.

When they initiated their first space programmes, it was not the intention of the European countries to try to rival the two major space powers, nor to seek political prestige from their achievements. Their aim was to take part in the difficult exploration of an unknown environment in order to uncover some of its secrets and riches and to see whether this new knowledge and the skills which industry would acquire in the process could be turned to the advantage of society as a whole.

Thus from 1964 to 1972 the European countries decided to abandon the idea of manned space flights for the time being and devoted limited funds to the conquest of space, i.e. a total of 2 300 million accounting units * for all national and European satellite and launcher programmes. Yet this limited effort proved sufficient to enable Europe to set itself more ambitious goals. The second phase, up to 1980, will consist mainly in improved coordination and broader and more diversified projects of a complexity comparable to that of certain American and Soviet programmes. These include application satellites, the Ariane heavy launcher and, above all, a first manned space laboratory (Spacelab). The corresponding budget, excluding national programmes, will be close on 2 000 million accounting units for the period 1974-1980.

1963 to 1973

When the European countries spelled out their initial space projects shortly after the first artificial satellite was launched in 1958, their objectives were clearly defined but limited. From the scientific point of view, Europe wanted to participate in exploration of the earth's environment and to gain a better understanding of the sun's influence on it. It also wanted to acquire the technical and industrial expertise needed to undertake this exploration and reap the benefits of future space applications. From the political standpoint, although some European countries were anxious to maintain their independence in this field, they nevertheless concentrated some of their activities within two organisations—ESRO for the development of satellites and ELDO for the development of launch vehicles.

Europe then « went to school » in America. It sent engineers and technicians to the United States, which with good grace agreed to share its newly acquired knowledge and to lauch the first scientific satellites built by the United Kingdom and later by Italy, France and Federal Germany. With modest resources at its disposal, ESRO undertook at the same time to acquaint all its member countries with space technology. To sounding rocket launching campaigns was added the development of ESRO's first scientific satellites, which were placed in orbit by US rockets.

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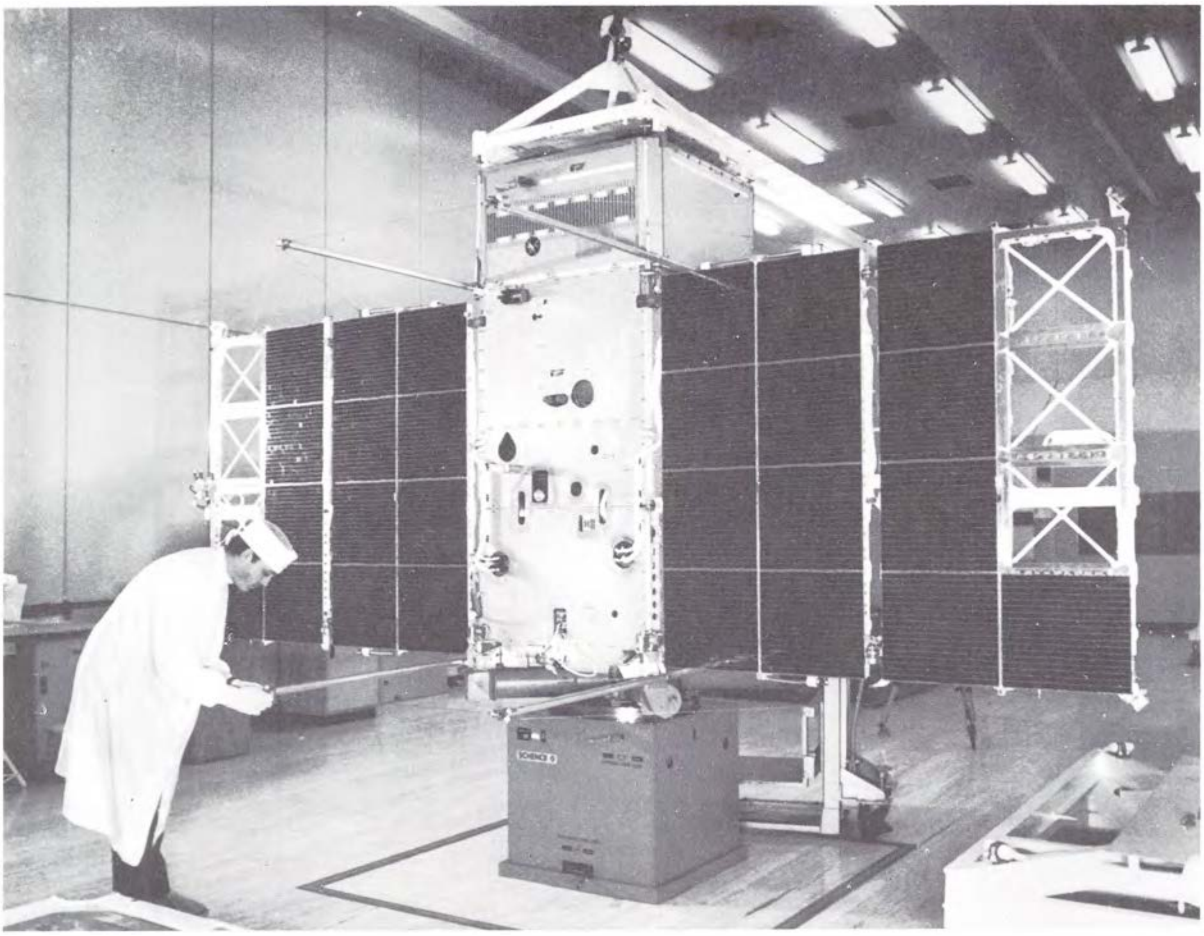
* One Accounting Unit (AU) = 1.26 US dollars in 1974.



TD-1A, ESRO's *first astronomical satellite, launched in 1972.*

Up to 1968-69 these first satellites, European or national, were fairly simple and served above all to explore the ionosphere and the magnetosphere — two areas little known at the time. This initial phase also enabled Europe to acquire the infrastructure needed for space exploration: satellite integration and test centres, networks of telemetry and telecommand stations, earth-based monitoring facilities, sounding rocket and satellite launcher firing-ranges.

The 28 satellites built by the European countries and ESRO since 1962 and the numerous launchings made of sounding rockets and balloons have provided researchers and scientists with useful opportunities for experiments and industry with contracts with which to gain expertise in various advanced techniques (metallurgy, lubricants, energy sources and converters, communications systems, stabilisation systems, etc.). Most of the satellites functioned longer than expected, and after the inevitable teething problems, the ground infrastructure gave entire satisfaction.

In the realm of launchers, however, Europe's efforts proved less encouraging. France developed the Diamant rocket, which functioned correctly right from its first launching in 1965 but which after six successful launches registered two consecutive failures in 1971 and 1973. The United Kingdom finally abandoned the Black Arrow rocket in 1971 after it had successfully orbited the first British satellite, while the Europa rocket developed by ELDO was also abandoned after several in-flight failures.

EUROPEAN SATELLITES

SATELLITE WEIGHT (EXPECTED) AND REAL LIFETIME	COUNTRY	LAUNCH DATE ROCKET LAUNCHING BASE	ORBIT PERIGEE APOGEE INCLINATION	SCIENTIFIC OR APPLICATION MISSION
UK-1 (Ariel-1) 60 kg 2.5 years	United Kingdom	26-4-1962 Delta Wallops Island	387 km 1 206 km 53.9°	Ionospheric and solar studies
UK-2 (Ariel-2) 75 kg 7 months	United Kingdom	27-3-1964 Scout Wallops Island	288 km 1 349 km 51.6°	Study of the galactic noises, of the atmospheric ozone and of the micrometeorites
San Marco-1 114 kg 3 months	Italy	15-12-1964 Scout Wallops Island	205 km 816 km 37.8°	Study of the upper atmosphere and of the ionosphere
A-1 41 kg 2 days	France	26-11-1965 Diamant-A Hammaguir	525 km 1 758 km 34.2°	Technology
F-1 60 kg (3 mois) 33 months	France	6-12-1965 Scout Vandenberg	780 km 780 km 75.8°	Ionospheric studies
D-1A (Diapason) 19 kg 6 years	France	17-2-1966 Diamant-A Hammaguir	506 km 2 740 km 34°	Geodesy
D-1C (Diadème-1) 23 kg 2 years	France	8-2-1967 Diamant-A Hammaguir	572 km 1 353 km 40°	Geodesy
D-1D (Diadème-2) 23 kg 50 days	France	15-2-1967 Diamant-A Hammaguir	592 km 1 885 km 39.5°	Geodesy
San Marco-2 128 days	Italy	26-4-1967 Scout San Marco platform	216 km 297 km 2.9°	Study of the upper atmosphere and of the ionosphere
UK-3 (Ariel-3) 90 kg (1 year) 2.5 years	United Kingdom	5-5-1967 Scout Vandenberg	489 km 595 km 80.2°	Study of the upper atmosphere and of the ionosphere
ESRO-II (Iris) 75 kg (6 months) 36 months	ESRO	17-5-1968 Scout Vandenberg	332 km 1 094 km 97.2°	Study of solar x-rays and cosmic and galactic particles
ESRO-IA (Aurorae) 86 kg (6 months) 21 months	ESRO	3-10-1968 Scout Vandenberg	253 km 1 534 km 93.8°	Study of the ionosphere and auroral phenomena
HEOS-1 108 kg (2 years) partially active on 30-6-1973	ESRO	5-12-1968 Thor-Delta Wallops Island	424 km 223 428 km 28.3°	Study of interplanetary space and solar particles
ESRO-1B (Boréas) 86 kg (6 months) 52 days	ESRO	1-10-1969 Scout Vandenberg	306 km 393 km 85°	Study of the ionosphere and auroral phenomena
GRS-A (Azur) 71 kg (1 year) 8 months	Germany	8-11-1969 Scout Vandenberg	382 km 3 128 km 103°	Study of the magnetosphere and of earth-sun relations
Skynet-1 28 kg	United Kingdom	21-11-1969 Delta Wallops Island	34 496 km 36 467 km 2.4°	Military communications satellite
Mika and Wika (DIAL) 52 and 63 kg Mika: 1 hour Wika: (18 days) 71 days	France/ Germany	10-3-1970 Diamant-B Kourou	328 km 1 629 km 5°	Mika: French technological capsule Wika: German scientific capsule for ionospheric studies

SATELLITE WEIGHT (EXPECTED) AND REAL LIFETIME	COUNTRY	LAUNCH DATE ROCKET LAUNCHING BASE	ORBIT PERIGEE APOGEE INCLINATION	SCIENTIFIC OR APPLICATION MISSION
Intasat 24.5 kg (2 years)	Spain	July 1974 Delta Vandenberg	1 000 km 1 100 km 100°	Ionospheric study
ANS 136 kg (6 months)	Netherlands	August 1974 Scout Vandenberg	500 km 500 km 97.3°	Study of cosmic X-ray sources and stellar UV radiation
Helios-A 355 kg (18 months)	Germany	Sept. 1974 Titan-III E - Centaur Kennedy Space Flight Center	ecliptic orbit (perihelion: 0.3 UA aphelion: 1 UA)	Probe for solar observation and study of interplanetary space
Starlette 47 kg	France	Sept. 1974 Diamant-BP4 Kourou		Geodesy
SRET-2 21.5 kg	France	Oct. 1974 Vostok	450 km 39 000 km 65°	Technology
D-5A and D-5B 36 and 76 kg (7 months) and (5-6 years)	France	Dec. 1974 Diamant-BP 4 Kourou		Technology hydrazine (micro-thruster and micro-accelerometer)
Sirio 220.5 kg (2 years)	Italy	1st half 1975 Thor-Delta Kennedy Space Flight Center	geostationary orbit	Experimental communication satellite
COS-B 280 kg (2 years)	ESRO	Feb. 1975 Thor-Delta Vandenberg	350 km 100 000 km 25°	Study of cosmic and galactic rays
D-2B 120 kg (8 months)	France	April-May 1975 Diamant-BP4 Kourou	500 km 700 km 37°	Study of stellar radiation and extended sources
Symphonie 237 kg (5 years)	France/ Germany	1975 Thor-Delta	geostationary orbit	Experimental communications satellite
GEOS 180 kg (2 years)	ESRO	mid-1976 Thor-Delta	geostationary orbit	Magnetospheric studies
Helios-B 355 kg (18 months)	Germany	1976 Titan-III E - Centaur Kennedy Space Flight Center	ecliptic orbit (perihelion: 0.3 UA aphelion: 1 UA)	Probe for solar observation and study of interplanetary space
Meteosat ≃ 315 kg (3 years)	ESRO	end 1976 Delta Kennedy Space Flight Center	geostationary orbit	Meteorology
IUE	ESRO/NASA United Kingdom	Dec. 1976 Delta Kennedy Space Flight Center	geostationary orbit	Study of stellar and galactic radiation
OTS 324 kg	ESRO	beginning 1977 Delta Kennedy Space Flight Center	geostationary orbit	Communications satellite

SATELLITE WEIGHT (EXPECTED) AND REAL LIFETIME	COUNTRY	LAUNCH DATE ROCKET LAUNCHING BASE	ORBIT PERIGEE APOGEE INCLINATION	SCIENTIFIC OR APPLICATION MISSION
IME 155 kg	ESRO/NASA	1977 Thor-Delta	300 km ≃ 140 000 km	Magnetic exploration
Marots	ESRO	mid-1977 Delta Kennedy Space Flight Center	geostationary orbit	Maritime satellite
Exosat 250 kg (2 years)	ESRO	1979 Thor-Delta	300 km 200 000 km	Study of the location of radiation of galactic and extragalactic X-ray sources

Geographical location of launching bases:

Hammaguir : Algeria
Kennedy Space Flight Center: United States
Kourou : French Guiana, equatorial base
San Marco platform : floating base off the coast of Kenya, equatorial base
Vandenberg : United States
Wallops Island : United States
Woomera : Australia
N.B. The not-yet-launched satellites mentioned in this table are all approved and financed.

1973 to 1980

Satisfactory as far as satellites are concerned but less so in the case of launchers, these results were naturally taken into account in defining the objectives and content of the second generation of European programmes. However, other considerations also played a part in formulating the new programmes.

Having hesitated for about ten years to concentrate the major part of their space activities under a single European organisation, the member countries of ESRO finally decided to back heavily the horse of European cooperation. This was a decision taken not in an unreasoning wave of enthusiasm but after much careful thought and a lot of arguing about what a better-integrated European programme should look like and how to go about organising and running it.

Europe was fully aware that if it was not to lag too far behind the United States and the Soviet Union it had to broaden the scope of its space activities and expand the scale of its projects. Having surveyed the progress of space exploration in the United States and the Soviet Union first, then in Japan and Canada, Europe elected to give further breadth to collaborative programmes, the scale of which now considerably exceeds that of most national projects. At the same time, the European countries were anxious to coordinate launcher and satellite programmes more effectively and wanted to see national and European projects dovetailed under a single space authority, the European Space Agency (ESA).

The large scale of the new programmes reflects the diversity of objectives set for the next decade:

1. Scientific goals

The aim is to extend our knowledge of the universe—first to the entire solar system and, beyond that, to outer space. Satellites will continue to study the near earth environment: GEOS, for example, will study variations occurring in the physical conditions prevailing in a given region of the ionosphere or magnetosphere, while IME (International Magnetospheric Explorer)—a joint ESRO/NASA programme—will endeavour to correlate the variations in two different regions. Other satellites will tackle the exploration of outer space. By means of instruments placed on board American and Soviet interplanetary probes, European laboratories will take part in the exploration of the solar system and the outer planets. For the first time, moreover, Europe will launch two probes towards the sun (the Helios project).

For Europe, however, 1970-1980 will be primarily a decade of space astronomy. National and European scientific satellites alike are now beginning to observe the stars and the galaxies on wavelengths ranging from the ultraviolet to X- and gamma radiation: these astronomical satellites are Britain's UK-5, France's D-2B, the Netherlands' ANS and ESRO's TD-1A, COS-B and Exosat.

	FRANCE	GERMANY	ITALY	NETHERLANDS	SPAIN	UNITED KINGDOM	ESRO
Study of the ionosphere	FR-1	Aeros	San Marco-1 San Marco-2		Intasat	UK-1 UK-3	ESRO-I ESRO-IV
Study of the upper atmosphere			San Marco-3			UK-2	
Study of the sun and earth-sun relations	D-2A	Azur Wika Helios				UK-1	ESRO-II HEOS GEOS
Ultraviolet, X and gamma-ray astronomy	D-2B			ANS		UK-5	TD-1A COS-B IUE Exosat
Meteorology	Eole						Meteosat
Communications	Symphonie	Symphonie	Sirio			Skynet	OTS

2. Social objectives

As early as 1966 some European countries drew the attention of ESRO member countries to the operational flexibility of artificial satellites, which instead of being instruments for scientific research only were tending to become instruments for the benefit of society as a whole. Well in its stride in the United States, this relentless evolution will have taken place in Europe too by 1980 with the launchings of three experimental communications satellites (Symphonie, Sirio and OTS), a geostationary weather satellite (Meteosat) that will be part of the four-satellite worldwide network of the GARP (Global Atmospheric Research Programme) project, and the Marots maritime satellite. Europe has also begun initial studies on earth resources detection from space, on a satellite equipped with a side-looking radar and on television and data transmission satellites.

3. Industrial and technological objectives

To induce continuous technological growth and to arrive at a better-structured and more effective industrial organisation were two powerful motivations which explain the desire of virtually all the ESRO member countries to take part in expanded European programmes. The development of a first manned space laboratory represents a new challenge to Europe's industry. Similarly, the construction of application satellites—initially experimental, then operational—designed to operate without failure for five years, calls for higher reliability of onboard equipment than for scientific satellites. Also, the development of a heavy launcher employing a liquid oxygen and hydrogen stage represents a major advance in the realm of propulsion and a first step along the road to tomorrow's space carriers. These new programmes will therefore certainly bring about rapid industrial progress between now and 1980.

4. Political goals

What Europe hopes will be the outcome of its expanded and more flexibly run space programme (most of the projects are optional: countries elect whether or not to participate in them) is a more extensive integration of all its efforts and the ability to cooperate with non-European countries as well.

As is already the case with high-energy physics under the European Nuclear Research Organisation (CERN), space research has become an instrument for the construction of Europe. Because space remains an immense virgin territory for exploration, requiring powerful and costly research facilities, it was a natural field for the European countries to choose in 1973 to express clearly their renewed desire to undertake an ever closer cooperation, notwithstanding the tricky problems this entails.

The creation in 1974 of ESA, combining the activities of ESRO and ELDO, is material proof of this desire to achieve better coordinated and integrated efforts. Acting as a powerful magnet to European nations, the new programme can be expected to attract an ever larger part of the national programmes which ESA will have as one of its tasks to integrate. Like CERN, ESA will also no doubt attract other countries as well and reinforce its cooperation with non-member States like the Soviet Union, Canada, Japan, India and others.

But above all ESA emerges as a fully - fledged partner of NASA now that it is to be responsible for the construction of an orbital laboratory which will be carried by the American Space Shuttle and which will house both American and European experimenters and their equipment. This collaboration with the United States will stimulate Europe to perfect its already advanced management techniques. At the same time, the member countries of ESA have shown their desire to acquire some measure of independence in the field of heavy launchers so that they can place in orbit without outside constraints any satellites they choose and can make this capability available to other countries.

The creation of ESA after many hesitations and difficulties is both the outcome of these many motivations and an inescapable necessity if Europe wishes to exist as a space power in its own right and be able to place satellites at the service of its citizens and continue to develop its advanced technology.

II ORGANISATION OF ESRO AND ESA

The ESRO Convention came into force on 20 March 1964 when Belgium, the Federal Republic of Germany, France, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom had ratified the text of the Convention signed in June 1962. They were soon joined by Denmark. Barely a month before, on 29 February 1964, the ELDO Convention had come into force, after ratification by Belgium, Germany, France, Italy, the Netherlands and the United Kingdom.

Ten years later, the 10 member countries of ESRO are preparing to sign the Convention of the new single organisation which is to succeed ESRO and ELDO—the European Space Agency. The ESA Convention will come into force as soon as the instruments of ratification of the signatory countries, members of ESRO or ELDO—or both—have been filed.

The last ten years have been long and full of difficulties and pitfalls for Europe's space ambitions. Indeed one might almost say that a true « Europe in space » has only now come into being, so preliminary and preparatory seem the activities which preceded the birth of ESA by comparison with the current European programme.

All ESRO and ELDO activities were compulsory for all, except in the case of ESRO « special projects ». The Conventions of both organisations stipulated that member countries were required to participate financially in the different projects. However, the ESRO Convention already provided for cases where one or more member states might wish to undertake « outside the agreed programme but within the scope of the Organisation » a project for which a two-thirds majority of the members of the Organisation's Council could decide to grant ESRO assistance.

The decisions taken in 1973 concerning the new programmes—the Spacelab orbiting laboratory, the Ariane launcher, the Marots satellite—specifically recognised that ESRO member countries could have different views and wish to be committed to varying extents in the different programmes: member states finance projects in which they are interested, and the percentage of their participation is no longer fixed but may vary from one project to another. However, the Organisation does retain certain compulsory activities which are funded by its members proportionately to their gross national product (GNP).

The ESA Convention has taken this evolution into account and is based on it to a considerable extent. Above all, however, it is more ambitious, since ESA's competence will not only encompass but exceed that of the former ESRO and ELDO organisations. It now extends to launchers as well as satellites, and ESA will also be responsible for maintaining and developing cooperation between European states and for coordinating the European and national programmes.

Changing pattern of the framework

An analysis of ESRO's and ELDO's past difficulties showed the European countries that a more effective use of the funds devoted to space necessarily implied stricter coordination of all their projects. The European Space Agency will henceforth be the body through which national programmes will be submitted to all the member countries simultaneously and which will accordingly have a comprehensive general picture of the various programmes, national and European. This in turn will enable ESA to encourage European countries to collaborate and to concert their efforts.

Naturally this overriding concern did not exist in the early 1960s when ESRO and ELDO were created because few national space projects existed at the time and their scope was too limited to prompt the countries to collaborate spontaneously. This is no longer true today.

The experience of the last 10 years, moreover, makes it possible today to choose a framework for cooperation which has not only been tried out but is also sufficiently flexible to allow further modification. Manifestly, the structures and cooperation procedures chosen for ESRO are better suited than ELDO's to the accomplishment of a common task, and distinctly more effective.

For when ELDO was created it had been decided that its role would be primarily one of supervision rather than true project management. Individuai member countries had absolute responsibility for the stages or equipment they developed and they issued contracts directly to their own industry. ELDO had difficulty in exercising its right to supervise and in checking equipment costs and reliability. Not until 1967, when the decision to develop the Europa-2 was made, was the ELDO Secretariat given the right to award certain contracts directly to industrial concerns in its member countries, to supervise the execution of contracts issued indirectly, to set up a directorate of economic and financial affairs responsible for controlling costs and running the contracts department, to create individual managements for the Europa-1 and Europa-2 programmes, to restructure the technical departments on which both these managements would depend, to organise a planning department, and so on.

From the outset, the Convention under which ESRO was created was conceived altogether differently and authorised the Organisation to implement and run a truly cooperative space programme. Clause V of the Convention stipulated that the Organisation could (a) « design and construct soundingrockect payloads, satellites and space probes », (b) « procure launch vehicles and arrange for their launching », (c) « provide means for the reception, collation, reduction and analysis of data » and (d) « support research and development as required for its programme ».

To this end ESRO was authorised to set up the necessary installations: a space research and technology centre which would undertake and facilitate execution of the various programmes and promote technical research; a research laboratory to undertake the joint research projects considered necessary for the execution of the scientific experiments; a sounding rocket launching base; a telemetry, telecommand and tracking network; and a data processing centre.

ESRO's various facilities were created in this way. The European Space Research and Technology Centre (ESTEC) was set up at Noordwijk in the Netherlands, about 20 kilometres north-east of The Hague, and was equipped with laboratories and measurement and test equipment to assist in designing, developing and checking out satellites and sounding-rocket payloads. Begun in March 1965, ESTEC became operational in December 1967. An European Space Research Laboratory (ESLAB) was established near ESTEC. A sounding rocket firing range (ESRANGE) was built in northern Sweden, at Kiruna, to enable exhaustive studies of auroral phenomena to be made, and went into operation at the end of 1966. In 1965 it was decided to create another institute to be concerned primarily with theoretical research in physics and chemistry. This centre (ESRIN) was set up at Frascati in Italy.

ESRO's *control centre,* ESOC, *at Darmstadt.*

Other additions to the infrastructure were a Control Centre at Noordwijk, a Data Processing Centre (ESDAC) set up at Darmstadt (Germany), and a network of four telemetry, telecommand and tracking stations (ESTRACK). These stations were located at Redu (Belgium), Ny Alesund (Spitzbergen), Fairbanks (Alaska) and Port Stanley (Falkland Islands) for the purpose of tracking and monitoring the satellites which ESRO wanted to place on polar orbits.

These facilities evolved gradually over a period of ten years, and some changes were made to them in 1968 and 1971. Acting on the findings of a panel of experts (the Bannier Report) on how operation of the Organisation could be improved, the ESRO Council recommended a number of changes in 1967: a new European Space Operations Centre (ESOC) was set up at Darmstadt to regroup ESDAC and the Control Centre (transferred from Noordwijk), ESLAB was incorporated into ESTEC, and ESRIN was placed under the direct control of the Organisation's Director General.

At the end of 1971, at the same time as it voted a sizeable budget for a programme of applications satellites, the ESRO Council decided to terminate ESRIN's work after September 1973. The Space Documentation Service (SDS) has since been installed in the former facility at Frascati. The Council also decided that ESRO sounding-rocket launchings would continue from Kiruna until June 1972, at which date the ESRANGE property was handed back to Sweden. However, a special agreement concluded between Sweden, ESRO and certain ESRO member countries authorises the latter to use the bases at Kiruna (Sweden) and Andoya (Norway) for launching national sounding rockets. Under this agreement, Sweden and Norway undertook to maintain these bases in operational condition and to run them for an initial five-year period.

Functioning of the Organisation

ESRO's installations were not alone in experiencing changes over the past several years; ESRO's own internal organisation and the Convention were both amended slightly as well.

The Convention under which ESRO was created provided for a very simple internal structure: a Council, and a Director General and supporting staff. The Council is composed of representatives of the member states and meets at least twice a year. Each country has one vote on the Council, which elects its chairman for a one-year term of office (renewable twice in succession), determines annual programmes and work schedules by a simple majority and adopts the Organisation's annual budget an a two-thirds majority. Every three years the Council also determines by a unanimous decision the extent of the funds to be made available to the Organisation for the next three-year period and, provisionally, the funds for the three years after that. The Council appoints the Director General by a two-thirds majority for a specified period.

Following the reorganisation recommended in the Bannier Report, it was decided in 1968 that the Director General would henceforth be assisted not by three directors (for science, engineering and administration) but by four: a Director of Programmes and Planning, a Director of Administration, a Director of ESTEC and a Director of ESOC. The directorate of programmes and planning thus replaced the former science and engineering directorates and consisted of four divisions: a space missions division, a technical and industrial policy division, a forecasts and programmes division, and a space applications division. The administration directorate also consisted of four divisions: legal, contractual and international affairs, finance, personnel and general services, and scientific and educational information. ESTEC was divided into four departments: an administration and facilities department, a satellites and sounding rockets department, a development and technology department (in turn subdivided to cover quality control, telecommunications, energy conversion, stabilisation and control, applied mathematics, tests and structures); and a space science department. ESOC grouped together a computer department, data acquisition and processing departments and, until 1972, ESRANGE.

The ESA Convention

Subsequent to the new programmes voted by Organisation in 1971, the Council approved an amendment to the Convention in November 1972 which authorised ESRO to undertake its first application satellite programmes and which also entrusted it with the « a coordinating and concerting role in respect of all space programmes for peaceful purposes » formulated by it or by national agencies. It was agreed that the Organisation would be permitted to conclude individual arrangements enabling certain parts of its programme to be carried out by national agencies of the member countries, or in cooperation with them.

This amended Convention, whose ratification procedure was not undertaken by ESRO member countries because in December 1972 the creation of ESA was envisaged, provided the basis for the Convention of the new European Space Agency.

ESA is not intended to be merely a successor to ESRO and ELDO. Although it takes over the heritage left by ESRO, its aims are much wider. It is required « to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications:

1) by elaborating a long-term European space policy and concerting the Member States' policies with respect to other national and international organisations and institutions;
2) by elaborating and implementing a common European space programme;
3) by coordinating the common European space programme and the national programmes, and by integrating the latter progressively and as completely as possible into the common European space programme, in particular as regards the development and construction of application satellites;
4) by formulating and applying an appropriate and coherent industrial policy. »

Thus the Agency will have multiple activities. First, it will carry out a scientific programme and basic activities like technological research, documentation, education and the study of future projects and in addition it will have an information role aimed at harmonising national and international programmes. All the member countries will participate in these activities. Secondly, it will implement other satellite and launcher programmes in which the member states may choose to participate or not, according to their respective interests. Thirdly, it will make available to user agencies operational applications satellites they may wish to launch. Fourthly, it will endeavour to coordinate and integrate all space projects envisaged in Europe.

As was the case at ESRO, it will be up to the Council and the Director General assisted by his staff to carry out these difficult tasks successfully. However, the structures have been reinforced by the creation of Programme Boards.

The respective roles of the Council and the Director General will be the same as at ESRO. The Council will elect its chairman and vice-chairmen for a two-year period and, as at ESRO, each state represented will have one vote. The Council will approve the obligatory programme and other programmes, adopt ESA's annual work plans, adopt the annual overall budget by a two-thirds majority, and determine (by a unanimous decision of all member states towards the end of the third year of each five year period) the level of resources to be placed at the Agency's disposal for the new five-year period.

A Programme Board has been created for each programme, which will be the decision - making body on matters affecting it. All countries taking part in the programme will be represented on the Board.

The Director General of ESA will be appointed by the Council on a two thirds majority. His function will be to represent the Agency in all its activities, to take whatever measures are required to run it efficiently, and to see that its programmes are carried out, its policy applied and its objectives achieved.

Member states will take part in the Agency's obligatory activities and contribute to the common expenses in accordance with a scale established on the basis of average national income over a three-year period, and in the other activities on the same basis unless they decide otherwise.

In broadening ESRO's activities, ESA will endeavour to improve the competitiveness of Euro pean industry bv furthering space technololy and encouraging the rationalisation and development of industrial facilities adapted to the needs of the market. An Industrial Policy Committee will be given a watching brief to this end and will take care to see that contracts are apportioned geographically in accordance with the provisions contained in the annex to the new Convention dealing with industrial policy.

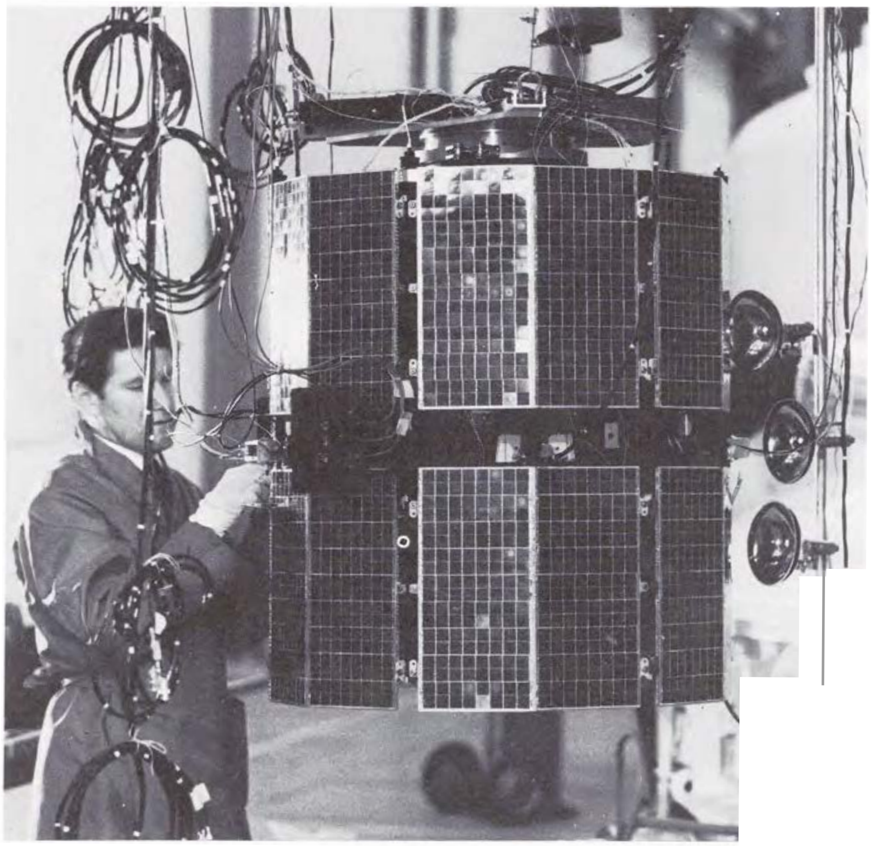
While favouring European industry as far as possible in the award of contracts, ESA will continue to cooperate with international organisations or with the governments and institutions of non-member states in order to widen the scope of its programmes. In taking over from ESRO, the Agency will manage several programmes being run on a cooperative basis with the United States: Spacelab and the IME and Aerosat satellites, the latter due to be built with Canadian participation also.

Clearly, ESA's role will be a very important one from the standpoint of Europe's space activities. The Agency will increasingly become the focal point on which the cooperative and national activities of its member states will hinge. This improved correlation should result in greater flexibility in the conduct of the various programmes and in greater efficiency in preparing for the programmes of the next decade, beyond the 1980s, when commercial and operational space activities will be under way in Europe.

III ESRO/ESA PROGRAMMES

With the budget of 306 million accounting units (MAU) granted to it for its first eight years of existence between 1964 and 1972, ESRO built seven scientific satellites, launched 184 sounding-rockets and installed a space technology centre at Noordwijk, a control centre at Darmstadt, a sounding rocket range at Kiruna and a network of telemetry, telecommand and tracking stations.

In December 1971 the ESRO Council decided that the Organisation should undertake an application satellite programme without further delay, even if it meant reducing slightly the scope of its scientific programme. It was agreed that for the 1974 1980 period the annual funding level for application satellites would not be less than 70 MAU at 1971 prices. A geostationary meteorological satellite, Meteosat, would be developed at a cost of 115 MAU at mid 1971 prices, a first experimental communications satellite, OTS (at a cost of 100 MAU at mid-1971 prices, subsequently increased to 115 MAU at mid-1972 prices for a more ambitious programme) and also an aeronautical satellite, Aerosat, in collaboration with the United States for which the limit placed on European expenditure was 100 MAU at mid-1971 prices. The funds devoted yearly to the scientific programme over the 1972 1974 period was to be at least 27 MAU.



ESRO's *first satellite,* ESRO II, *was launched in 1968.*

ESRO BUDGET BY PROGRAMMES (million accounting units)	1969	1970	1971	1972	1973	1974 (provisional)
Basic activities and scientific programmes (including TD-1A special project)	49.9	52.9	61.3	52.5	53.7	69.2
Applications programmes	1	1.9	11	21.4	41.6	66.3
Spacelab orbital laboratory				0.8	10	16.1
Ariane launcher					5.4	38.6
Total	50.9	54.8	72.3	74.7	110.7	190.2

In July 1973 the European governments gave further impetus to their space activities when it was decided to develop, between 1974 an 1980, a first manned orbiting laboratory (Spacelab) in collaboration with NASA for the sum of 308 MAU at mid-1973 prices and to build another application satellite (the Marots maritime satellite) for the sum of 75 MAU to be spent by the end of 1977 (both these figures include ESRO internal costs) and an European launcher (Ariane) evaluated at 380* MUC at January 1973 prices.

Thus ESRO's budget increased from 72.3 MUC in 1971 to 110.7 MUC in 1973 and is estimated at 190.2 MUC for 1974. From now until 1980 ESRO and its successor, ESA, are scheduled to develop four new scientific satellites—COS-B, GEOS, IME and Exosat—and to collaborate with NASA and the United Kingdom in developing an International Ultraviolet Exploration (IUE) satellite. By 1977 the member countries will have jointly built at least three application satellites (Meteosat, OTS and Marots) and by 1980 their first manned orbiting laboratory, Spacelab, should be aboard the American space shuttle and the first Ariane rocket launched.

Considering the present scope of the European programmes, it is hard to believe that up to 1972 ESRO had developed only three satellites for studying the ionosphere (ESRO-II, ESRO-I, ESRO-IV), two satellites with highly eccentric earth orbits (HEOS-1 and HEOS-A2) and an astronomy satellite (TD-1A) which, though the heaviest of all, still weighed no more than 472 kg.

1974 PERCENTAGE CONTRIBUTIONS BY MEMBER STATES TO ESRO PROGRAMMES

	GENERAL BUDGET AND SCIENTIFIC SATELLITE BUDGET	OTS TELECOM SATELLITE	AEROSAT	MAROTS MARITIME SATELLITE	METEOSAT	SPACELAB ORBITAL LABORATORY	ARIANE LAUNCHER
Belgium	3.67	3.91	3.67	0.97	4.06	4.20	5.00
Denmark	2.17	2.32	2.17		2.41	1.50	0.50
France	21.39	22.80	21.39	12.10	23.70	10.00	62.50
Germany	23.16	24.68	23.16	19.37	25.66	52.55	20.12
Italy	13.60	14.50	13.60	2.23	15.97	18.00	1.74
Netherlands	4.61	3.80	4.61	4.70		2.10	2.00
Spain	3.00		5.13	0.97		2.80	2.00
Sweden	4.53	4.83	4.53	3.00	5.02		1.00
Switzerland	3.14	3.34	3.14		3.48	1.00	1.20
United Kingdom	18.60	19.82	18.60	56.66	20.60	6.30	

* 2060 MF = 370.9 MAU (development) + 7 MAU (facilities) + 2.5 (ESRO internal costs).

It is also remarkable that the ESRO member countries should have agreed to this widening of programmes when it is remembered that it implied an annual expenditure which doubled from 1971 to 1973 and which will almost double again from 1973 to 1975. All member countries except one are taking part in the communication satellite programme and the Spacelab programme, and all but two in the Meteosat programme. Two countries have stayed out of the Marots programme but all are participing in the Ariane and Aerosat programmes.

The next new step for Europe is geostationary satellites. ESA's first earth-synchronous satellite will be the GEOS scientific satellite, due to be launched in mid-1976. It will be followed shortly afterwards by the Agency's first application satellite Meteosat, and later in 1976 by another geostationary scientific satellite in which ESA is participating, the International Ultraviolet Explorer. Then will come three more: OTS, Marots and Aerosat. By 1978 Europe will have built four geostationary satellites and collaborated with the United States in the development of another two.

With its first application satellite, ESA plans to develop families of satellites which use the same structure for different purposes. For instance, the decision in 1973 to develop the Marots maritime satellite was facilited by the fact that ESRO had already conducted preliminary design studies on the OTS experimental communications satellite and could use the same platform. In other words, the OTS satellite paved the way for the Marots satellite, and the same platform could well be used in the future for other missions.

These satellites are distinctly more complex than ESRO's first satellites. Foreshadowing future operational systems, the European experimental application satellites present a new technological challenge. Thus Europe is moving on to third-generation satellites.

The coming years should also herald closer international cooperation. European cooperation with other countries, hitherto timid, now extends to several scientific and application projects and to Spacelab. In the scientific field, Europe will collaborate with NASA in developing the IUE satellite, and will build an International Magnetospheric Explorer (IME) due to be launched together with a similar NASA satellite to make simultaneous magnetospheric plasma measurements. In addition, Europe will be cooperating with Canada and the United States on the Aerosat aeronautical satellite and for the experimental Canadian telecommunications satellite (CTS) ESA will be supplying certain items of equipment.

Thus space activity in Europe is experiencing a profound transformation which will be accompanied in the years to come by a no less important stage of evolution, namely the coordination of national and European programmes. Already, by virtue of an agreement concluded in 1971, the Meteosat satellite, which derives from a French study, is being developed by an ESRO project team located at the Toulouse Space Centre and into which personnel of the French space agency (CNES) have been integrated. Part of the functional support is provided by CNES free of charge, the remainder by ESTEC. This could well prove to be the first step towards closer ties between national and European space centres.

DISTRIBUTION OF ESRO PERSONNEL FROM 1971 TO 1973 BY BUDGET SECTOR

	1971	1972	1973
Scientific satellites	181	116	125
Space science	53	45	37
Application satellites	64	142	208
Sounding rockets	137	8	
ESRIN	75	60	
Basic activities (technology, instruction, documentation)	339	323	308
Non-fixed common costs	272	280	273
Support activities (workshops, testing, data acquisition and processing)	230	221	233
Total	1 351	1 195	1 184

Having launched an average of one scientific satellite each year from 1968 to 1974 within the framework of ESRO, the European countries are preparing to continue at the same tempo under the new Space Agency. From 1975 to 1979, four new scientific satellites will be orbited: COS-B, GEOS, IME (International Magnetospheric Explorer) and Exosat. In addition, the Agency will cooperate, together with the United Kingdom, in developing NASA's International Ultraviolet Explorer (IUE) satellite and subsequently in exploiting data received from it.

But whereas ESRO's first scientific satellites weighed an average of 90-100 kg (except for the TD-1A astronomical satellite which weighed 472 kg) and carried a playload of 20 30 kg (114 kg for TD-1A), these new satellites will weigh between 160 and 300 kg and carry payloads weighing between 30 and 120 kg.

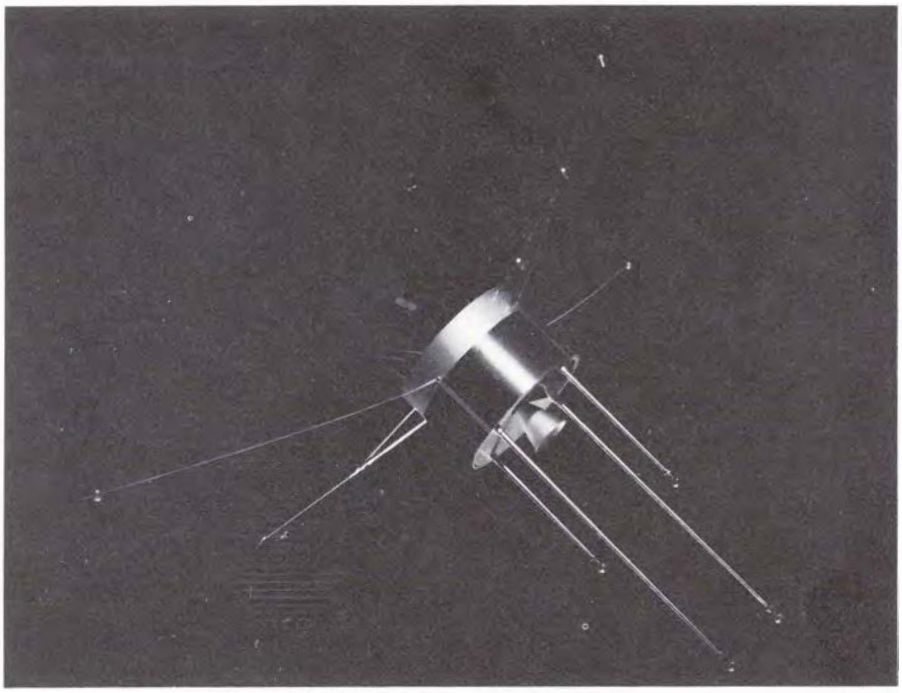
During the first years of its existence, ESRO had elected to explore the ionosphere and the magnetosphere with satellites in fairly low orbits (ESRO II, ESRO-I, ESRO-IV) and with satellites in eccentric orbits (HEOS-1 and HEOS A2). Two new satellites will be used to continue this exploration: the GEOS synchronous satellite, and the IME satellite which will be launched and will send back data simultaneously with another (NASA) satellite. The decision to build GEOS was taken in 1969 and the development contract was issued in May 1973. The decision to develop the IME was taken in April 1973.

In the realm of astronomy, observations of X-ray and gamma sources and of objects emitting ultraviolet light will be multiplied by means of COS B, Exosat and IUE. The decisions to build COS-B and Exosat were taken in 1970 and in April 1973 respectively. The development contract for COS-B was awarded in January 1972.

Exploration of the Magnetosphere: GEOS and IME

GEOS, due to be launched in 1976, and the pair of IME satellites, which will be placed in orbit in 1977, will continue the work of exploring the magnetosphere. Between 1960 and 1970 this exploration had resulted in the discovery of the radiation belts, the limits of the earth's magnetic field, the magnetopause, the shockwave and the magnetospheric tail. Other phenomena observed included the dynamics of this region, the oscillations of the magnetopause, the acceleration of trapped particles and the fight for supremacy between the sun's and the earth's magnetic fields. Still incompletely understood are the physical processes which lead to this configuration and dynamic state of the magnetosphere. For instance, what is the mechanism by which the solar wind pulls out the magnetosphere in a direction opposite to the sun? And what process is at the origin of magnetospheric storms?

The observation and measurement of simple parameters (energy spectra, particle fluxes and directions, field intensities) will now be succeeded by measurements of new parameters such



GEOS, ESRO's *first geostationary scientific satellite.*

as the rate at which oscillating motion of the magnetopause takes place, the extent of storm areas in the radiation belts and the rate at which these perturbations are propagated. These new measurements will require the satellites' orbits to be chosen with care.

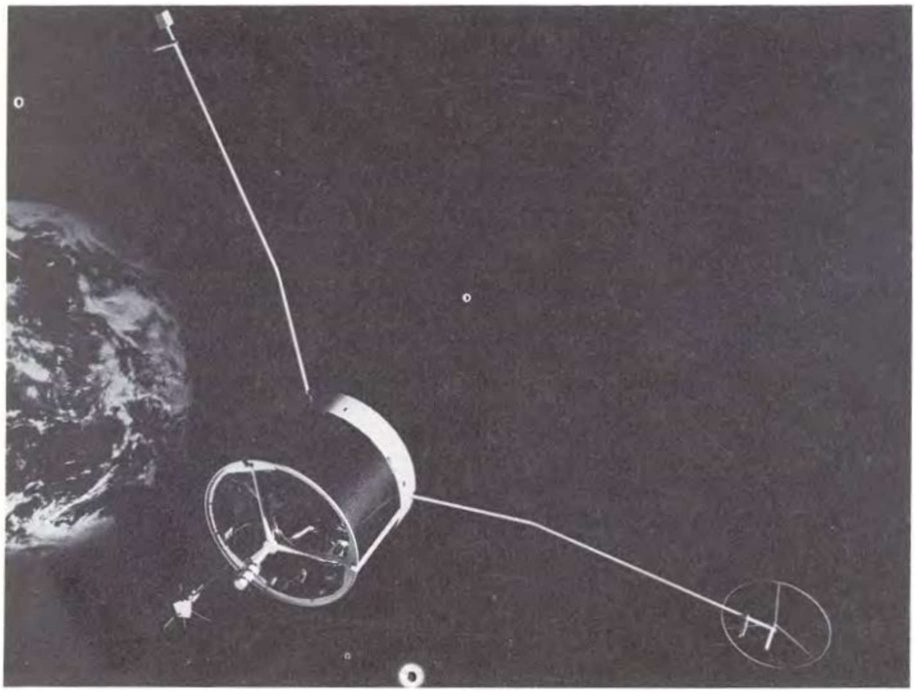
Whereas, as its name indicates, GEOS will be a geostationary satellite, the IME satellites will be placed in eccentric orbit. In fact GEOS will be the first geostationary scientific satellite ever to be launched, as well as being ESRO's first synchronous satellite. Its nine experiments will study temporal and spatial variations of the thermal plasma within the magnetosphere up to 300 keV, low - and medium - energy particles from 40 keV to 1.4 MeV, and electric fields up to 77 kHz and magnetic fields up to 5 kHz.

GEOS will be placed in an earth-synchronous orbit whose eccentricity will not exceed 2 % and whose inclination to the equator will be one degree. It will have a design life of two years, during which time it may shift between 40 degrees east longitude and 30 degrees west longitude. On this orbit it will be able to observe comfortably the behaviour of the particles and fields, particularly transient phenomena.

Plasma density will be measured by four different techniques. In two cases the electrostatic deflection technique will be used; active techniques—plasma relaxation and mutual impedance—will be employed for the other two. One of the active techniques is being tried for the first time. The instrument emits a 10^{-8} ampere electron beam. If this beam is emitted at right angles to the magnetic field and there is no electrical field in the plasma, it is deflected by the magnetic field and part of it returns to the source. If an electric field does exist in the plasma, the beam is returned with a spatial shift relative to the source, this shift being an indirect measure of the electric field and of the magnetic field gradient.

Three other experiments will study the various populations of the magnetospheric plasma's ionized particles and will determine their solar or polar origin. The amounts of low-energy and solar wind particles will be compared. Lastly, a triaxial magnetometer will measure the magnetic fields and observe perturbations, magnetic storms, etc. This instrument is carried on the end of a long boom, so that it is positioned at some distance from the satellite like the other three scientific instruments. It is planned to supplement the magnetospheric storm studies aboard the satellites with ground-based observations (using night photometers and cameras) and with measurements made from balloons and sounding rockets. It is hoped in particular to study the behaviour of the earth's magnetic field in zones which are in magnetic conjunction.

The experiments aboard the IME satellites will be fairly similar to the GEOS experiments. The IME satellites have been termed the Mother satellite and the Daughter satellite. The Mother satellite will be developed by NASA, the Daughter satellite by ESA. Launched by the same rocket, they will be placed in an eccentric orbit with a perigee of 300 km and an apogee of about 140 000 km, and will be separated by 100 to 5 000 km. In fact NASA is planning to launch a third satellite into a heliocentric orbit close to the libration point between the earth and the sun, about 1.5 million km from the earth.



ESRO's IME *satellite to be launched in 1977 to study the magnetosphere.*

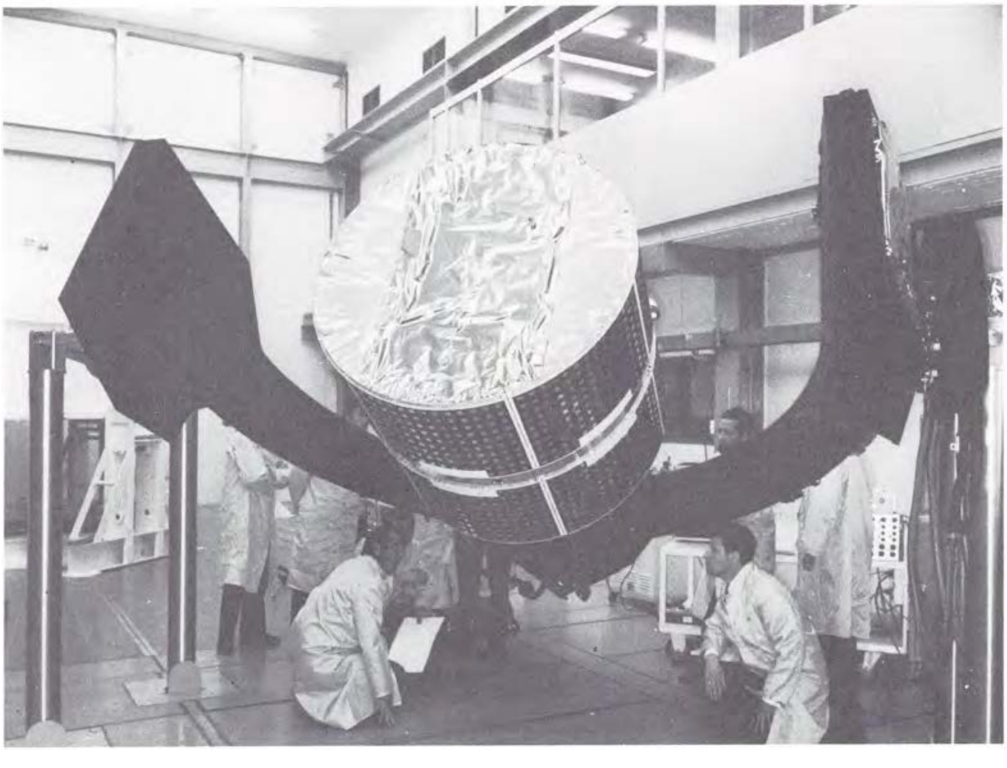
With the IME Mother/Daughter satellites, it is hoped to be able to continue previous experiments which, quite by chance, it had been found possible to conduct simultaneously with two spacecraft. When the heliocentric third satellite is launched, it will make it possible to observe solar wind variations and to correlate them with the storms occurring in the magnetosphere. It will also measure the electromagnetic radiation fluxes emitted by the sun, energy particle emissions, and cosmic ray fluxes, thereby providing a finer anlysis of earth-sun relations.

The two Mother/Daughter satellites, which will orbit in the same plane, will be launched from the Eastern Test Range. It is hoped to be able to control the distance between them with great precision once they have been placed in orbit. The attitude and orbit control system will employ small propane or freon thrusters which will maintain the spin axis at 10 degrees to the normal to the ecliptic and the satellite's spin rate at between 10 and 40 revolutions per minute.

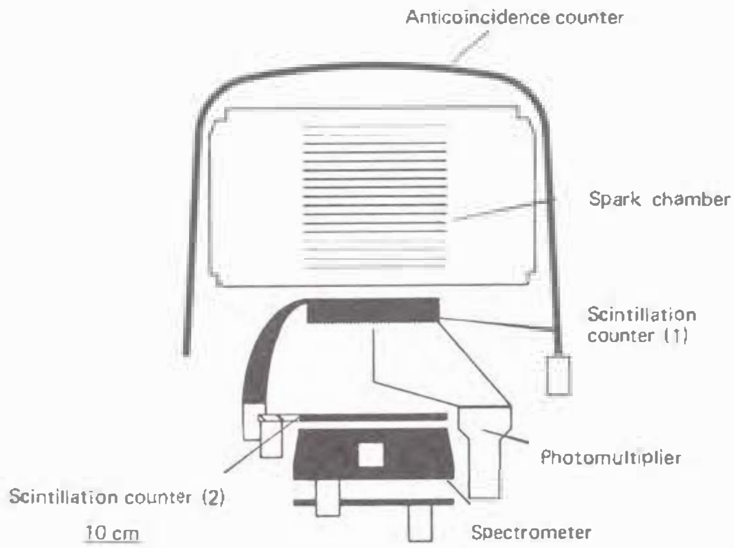
The number of scientific instruments on each satellite will be considerable, the current plan being for thirteen instruments on the Mother satellite and eight on the Daughter satellite. Some of the American and European instruments will be identical on both satellites in order to make it easier to correlate the measurements, especially electron and proton flux measurements in various energy ranges (1 eV-50 keV, 8-380 keV, 20-2000 keV) and electric and magnetic field measurements (10 Hz-200 kHz). Another experiment will study radio wave propagation between the two satellites. The other experiments, which will not be the same on the two satellites, will be concerned with measuring fields and particle fluxes, using different techniques.

High-Energy Astronomy: COS-B and Exosat

COS-B (to be launched in February 1975), IUE (to be launched in 1976) and Exosat (to be launched in 1979) are the successors to ESRO's first astronomical satellite, the TD-1A. Like the latter, COS-B will study the gamma ray sources by means of a spark chamber which is larger and heavier and also more complex than the TD-1A's. IUE will make a spectral analysis of stellar ultraviolet radiation, just as the TD-1A's two ultraviolet telescopes did, but with improved resolution (with 0.13 instead of 1.8 Å as the upper limit and 6 instead of 30 Å as the lower limit); it will also study stars of greater magnitude (7-12 instead of 4-9). As for Exosat, it will continue to study X-ray sources, but instead of mapping the sky it will locate the sources with great accuracy thanks to their occultation by the moon. Two other national satellites—the Netherlands' ANS and Britain's UK-5—must also be mentioned. In the coming months, the former will make ultraviolet spectroscopy studies of the stars and will chart X ray sources, while the latter will investigate the energy spectra of X-ray sources.



ESRO's COS-B satellite, to be launched in 1975 to study gamma ray sources.



Telescope of the COS-B *satellite.*

COS-B is the first ESRO satellite to carry only one experiment. Three laboratories—the Nuclear Research Centre at Saclay (France), Milan University (Italy) and the Max Planck Institute at Garching (Germany)—had previously joined forces to propose a common gamma ray detection experiment aboard the TD-1A. Three other scientific groups have since joined these three laboratories for the COS-B mission: Palermo University and Milan University are supplying the pulsar synchronizer and the electronic equipment for processing the scientific data, the Kamerlingh Onnes Laboratory at Leiden (Netherlands) is supplying the spectrometer, and ESTEC's Space Science Department is supplying the telescope which triggers energisation of the chamber. The Nucleonics Department of the Nuclear Research Centre at Saclay and the Max Planck Institute of Extraterrestrial Physics at Garching are responsible for the anti-coincidence counter and for the spark chamber, respectively.

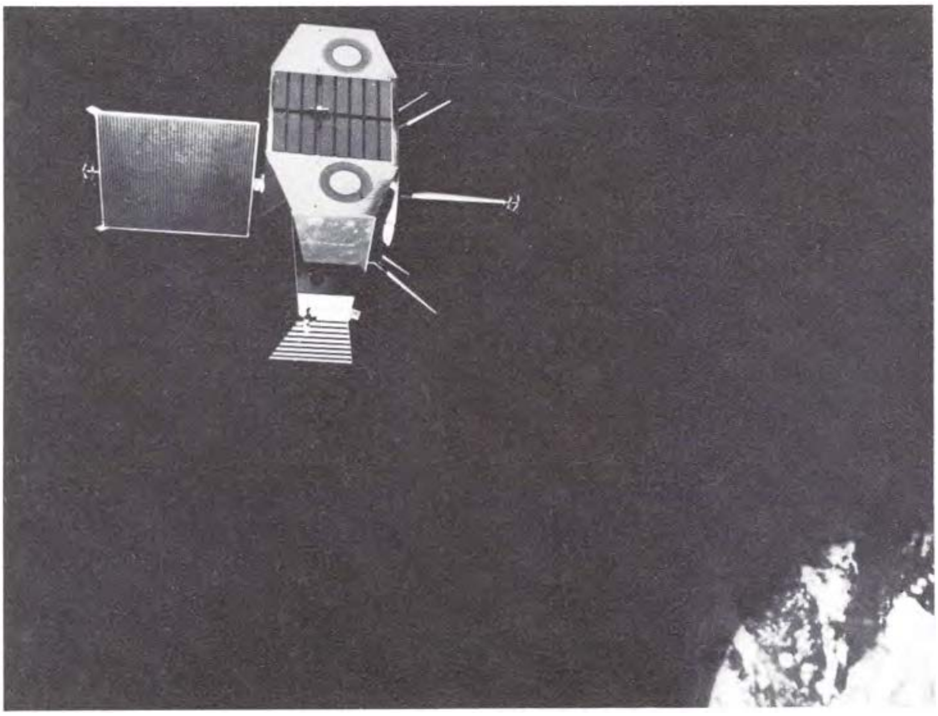
The spark chamber on COS-B will detect gamma rays of 20 MeV to 5 GeV energy thanks to the electron-positron pairs to which the rays give birth when they impinge upon the chamber's metal plates. The satellite is spin-stabilised and the spin axis coincides with the detector's optical axis. Changes of attitude in the satellite can be controlled by a cold-gas system. Observations can be made for 75 % of the time when COS-B is orbiting outside the earth's radiation belts.

Whereas the TD-1A's spark chamber weighed only 28 kg and had a detection area of 130 cm^2, COS-B's chamber weighs 115 kg for a detection area of 550 square centimetres. A spectrometer (a cesium iodide crystal) also enables the energy of the cascade of electrons produced by the gamma rays to be measured. This chamber will thus make it possible to determine the direction from which the rays arrive, their time of arrival, and their energy spectrum.

COS-B will study gamma ray sources more exhaustively than any satellite yet launched. In particular, it will observe emitter regions of the galactic plane, point sources already identified, and isotropic radiation from high galactic latitudes. It will determine the energy spectra of all these sources, and it will also attempt to highlight the timewise variations in intensity and the short-duration pulsations of these sources.

TD-1A, which recorded gamma rays in the 30-300 MeV energy spectrum, showed that these rays were extremely rare—one every five minutes. Background noise proved to be twice as high as had been expected, but the investigators hope nevertheless to be able to locate the sources to within about three degrees whith the help of the information transmitted by this first satellite.

With COSB it is hoped to go further still and to determine in particular whether gamma-ray point sources are as rare as previous experiments have suggested. For instance, the American Explorer XI and OSO III satellites have revealed a diffuse radiation which appears to have two components: an isotropic extra-galactic component and a component due to the galactic plane, the sources appearing to be mainly concentrated near the centre of the galaxy. This diffuse radiation field may be explained by the disintegration of neutral pi-mesons produced by



ESRO's EXOSAT *satel lite, to be launched in 1979 to study and determine the posi tion of X-ray sources.*

cosmic rays encountering interstellar and intergalactic material, or by non thermal emission processes (bremsstralhung radiation of cosmic electrons, on the inverse Compton effect of electrons and protons on stellar photons). Energy spectrum profiles should differ substantially, according as the gamma rays are produced by one or the other of these processes.

Because little is known so far about gamma radiation from the sky, COS B's mission will be one of general exploration. On the other hand, X-ray sources have been charted extensively enough by the American Uhuru and Copernicus satellites to make more specific the mission of any new satellite required to study these sources. One of the main problems posed by X-ray sources is that of identifying them with visible celestial objects. Some of these sources have been identified with low luminosity galactic stars, with the remains of supernovae, and with a few extragalactic objects. However, most of these sources have not yet been associated with visible objects or with radio stars, for in some cases identification calls for accuracy to within a few seconds of arc and no longer to within one minute of arc.

Thanks to its low orbital velocity compared to that of the moon, Exosat will be able to make broad use of the occultation of X ray sources by the moon to conduct measurements. In the space of one year it will observe approximately 20 % of the celestial sphere. Because the irregularities along the moon's edge and the satellite's position on its orbit will be known, it is hoped to be able to locate bright sources to within less than one second of arc. In the case of dim sources (mainly supernovae debris), the measurements will be repeated many times in order to achieve angular resolution to within a few minutes of arc. Thus, by comparison with the UK 5 and ANS satellites which will precede it, Exosat will furnish measurements about thirty times more accurate and permit definite identification with visible infrared sources or radio stars.

Measurements made by the lunar occultation technique are all the more advantageous in that the satellite's orientation and orbit can be modified. When it is not making measurements by occultation, it will be able to aim its sensors at any point sources in the sky for periods of up to ten to fifteen hours and will thus be able to measure temporal flux variations ranging from a few seconds to a few hours. It will also study the structure of extended sources like galaxies or galaxy clusters and make it possible to validate or invalidate theoretical models put forward to explain these emissions. Exosat will be able to perform approximately 3 000 manœuvres in two years.

The detectors employed will be proportional counters. For the 2-20 keV spectrum, sixteen counters will provide a detection area of 2 500 cm², for an efficiency of about 25 % between 1.5 and 16 keV. The energy spectrum will be divided into 128 intervals, and energy resolution will be 17 % at 6 keV. In the range of lower energies between 0.1 and 2 keV, two telescopes with a 300 sq. cm mirror each will be coupled to the counters.

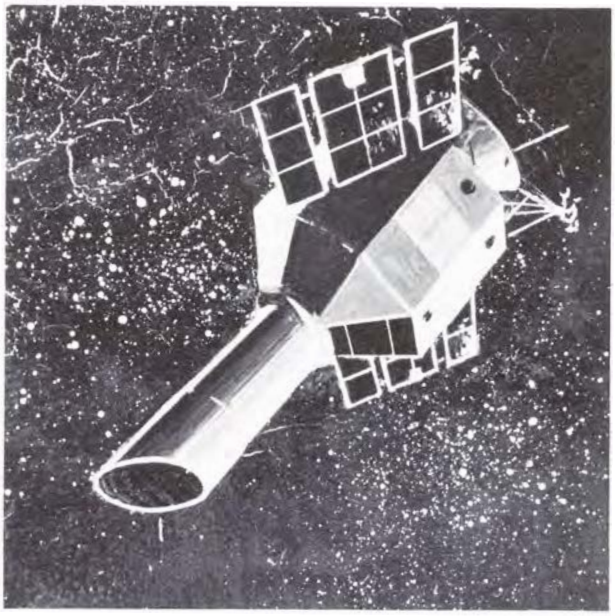
This mission was studied by an ESRO project definition group which included scientists from seven European laboratories: the Kamerlingh Onnes Laboratory at Leiden (Netherlands), Milan University, the Physics Institute of Bologna, Leicester University, the Nuclear Research Centre at Saclay (France), the Mullard Laboratory of Space Science, and the Astronomical Institute of Tübingen.

Four different orbits are being considered, two of which have an apogee above the northern hemisphere, two above the southern hemisphere. If the apogee lies in the northern hemisphere it will be necessary either to provide a ground station with a nine-metre diameter dish to receive the data transmitted in real time by Exosat at the rate of 4 000 bits per second, or to use an onboard memory with a capacity of one million bits for off-line processing.

UV Astronomy: IUE

The International Ultraviolet Explorer (IUE) will be orbited in the period between COS-B and will enable European astronomers to make astronomical observations in a third wavelength spectrum (1 150-3 200 Å). IUE will be the successor to the American OAO and European TD 1A astronomical satellites.

As its name indicates, IUE is a programme stemming from international collaboration between NASA, ESRO and the United Kingdom. This cooperation operates at two levels. In the first place, ESRO and the United Kingdom are supplying NASA with part of the satellite's equipment; secondly, observations will be made by both American and European astronomers and the results will be pooled.



IUE *(International Ultraviolet Explorer), a joint* NASA/UK/ESRO *satellite; after launch in 1976, it will be telecommanded by astronomers who will thus make their observations in real time.*

Under an agreement concluded between NASA and ESRO in 1971, Europe will participate in the programme to the extent of about $ 1 million. ESRO is to supply the flight model's deployable solar panels and their actuating mechanism and is to build a ground-station near Madrid to provide a direct link with the satellite. The United Kingdom has undertaken to supply the acquisition cameras, the camera associated to the spectrograph, and the logic system for calibration and data reduction. NASA is to build the satellite, the telescope and the latter's sunshade.

IUE is a new kind of satellite—an observatory capable of being remote-controlled from the ground by its operators, who will be able to assess the quality of its observations in real time. To achieve this, IUE will be placed on a synchronous orbit. It will carry a 45 cm-diameter telescope coupled to a spectrograph and to memory-type detectors which will record spectral data for immediate transmission to earth. The ground station will house monitoring personnel and the investigators. There will be two monitoring and observation stations, one at the

Goddard Space Flight Center in the United States, the other in Europe near Madrid. Each observer will have submitted his planned observations to a special committee, and the proposed sequence of observations will be optimised by the station's computer. The satellite will then be given the command to point the telescope at the selected object. A simplified image of the spectrum will be transmitted to the ground to enable the investigator to judge whether exposure time and focus are correct and to enable him to command the satellite to modify these parameters if necessary. The investigator will then tell the station computer which portion of the spectrum to use for generating the final spectrum. When the investigator leaves the station, he will have with him the « quick look » data, the full spectrum subsequent to processing, and a magnetic tape on which the spectrum intensity data will be stored. NASA and ESRO will place a copy of these tapes in a data bank after a given period of time.

Ground astronomers will therefore exercise almost as much control over their observations as if they were in an observatory. In fact IUE is intended to pave the way for NASA's (and possibly ESA's) future large orbiting telescopes. The satellite will be controlled for about 16 hours daily by the NASA station, and the rest of the time by the ESA station. An ESA committee will be responsible for allotting observation times to European astronomers. Additional observation time will be set aside for British astronomers at the suggestion of the United Kingdom's Science Research Council.

The scientific objective is to obtain UV spectra between 1 150 and 3 200 Å, with a resolution ranging from 0.13 to 6 Å. This will make it possible to observe the profiles of the resonance lines and of other absorption or emission lines and to deduce information from them about the ions and atoms in stellar atmospheres, the gases visible between double stars, the composition of planet and comet atmospheres and the properties of the interplanetary medium. It will also make it possible to observe, with a higher degree of resolution, the faint stars, the galaxies and quasars and pulsars up to the 12th magnitude (and even up to the 15th magnitude by increasing the observation time).

EXPERIMENTS BY ESTEC SPACE SCIENCE DEPARTMENT ABOARD ESRO SATELLITES

EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	PERIGEE APOGEE INCLINATION ORBIT	EXPERIMENT
D. E. Page	ESRO-I 3-10-1968 86 kg	253 km 1 534 km 93.8°	Angular distribution and total fluxes of electrons (> 40 keV) and protons (> 500 keV) in the ionosphere (1)
»	HEOS-A2 31-1-1972 117 kg	359 km 238 199 km 90°	Directions and energy spectra of electrons (0.5 - 3 MeV), protons (9 - 36 MeV) and alpha particles (36 - 142 MeV) within and outside the polar magnetosphere
A. Pedersen	ESRO-IV 22-11-1972 113 kg	280 km 1 100 km 90°	Qualification of an infra-red horizon interception sensor
»	COS-B Feb. 1975 280 kg	350 km 100 000 km 25°	Energy spectrum and direction of arrival of cosmic gamma rays (20 MeV - 5 GeV) (2)
»	GEOS mid-1976 180 kg	geostationary orbit	Electric (up to 77 kHz) and magnetic (0.17 - 5 kHz) fields of magnetospheric plasma, and its resonance frequencies (3)

(1) Experiment conducted in collaboration with the Danish Space Research Institute, Lyngby, and the Norwegian Defense Research Establishment, Kjeller.

(2) Experiment conducted in collaboration with other European laboratories: the Max Planck Institute for Extraterrestrial Physics, Garching (K. Pinkau), the Universities of Milan and Palermo (G. Occhialini), the Service d'électronique physique of the Centre d'études nucléaires, Saclay, and the Kamerlingh Onnes Cosmic Ray Laboratory of Leiden (H. C. van de Hulst).

(3) Experiment conducted in collaboration with the Groupe de recherches ionosphériques of the Centre national d'études des télécommunications (M. Petit) and the Danish Space Research Institute (E. Ungstrup).

ESRO/ESA SCIENTIFIC SATELLITES

SATELLITE LAUNCH DATE LAUNCH VEHICLE TOTAL WEIGHT AND (PAYLOAD)	ORBIT PERIGEE APOGEE INCLINATION	MISSION	SPECIFICATIONS
ESRO II/Iris 17-5-1968 Scout 75 kg (21 kg)	332 km 1 094 km 97.21°	Study of galactic and cosmic rays and particles 7 experiments (F, GB, NL)	• Magnetorquer and gas-jet spin-up (15-40 rpm) • Solar generator : 40 W • Telemetry: real-time: 0.2 W and 128 bps Play-back: 1.6 W and 4 096 bps • 36 telecommands
ESRO-I/Aurorae 3-10-1968 Scout 86 kg (21 kg)	253 km 1 534 km 93.76°	Study of polar ionosphere and auroral phenomena 8 experiments (DK, GB, NL and S)	• Alignment on Earth's magnetic field (permanent magnets) • Solar generator: 21 W • Telemetry: real-time: 0.2 W and 320 bps at low speed; 1.2 W and 5 120 bps at high speed; play-back: 1.2 and 10 240 bps
HEOS-1 5-12-1968 Thor-Delta 108 kg (27 kg)	424 km 223 428 km 28.28°	Study of interplanetary magnetic field and solar particles 7 experiments (B, D, F, GB and I)	• Reorientation of spin axis by gas jets (10 rpm) • Solar generator: 55 W • Telemetry: real-time: 5 W and 12 bps • 70 telecommands and range tone
ESRO-I/Boreas 1-10-1969 Scout 108 kg (27 kg)	306 km 393 km 85.13°	Study of polar ionosphere and auroral phenomena 8 experiments (DK, GB and NL)	• Alignment on Earth's magnetic field (permanent magnets) • Solar generator: 21 W • Telemetry: real-time: 0.2 W and 5 120 bps at high speed Play-back: 1.2 W and 10 240 bps • Telecommands
HEOS-A2 31-1-1972 Thor-Delta 117 kg (30.5 kg)	359 km 238 199 km 90°	Study of interplanetary magnetic field and solar particles 7 experiments (D, DK, F, I, GB and ESTEC)	• Reorientation of spin axis by gas jets (10 rpm) • Solar generator: 55 W • Telemetry: real-time: 6 W and 32 bps • 70 telecommands and range tone

SATELLITE LAUNCH DATE LAUNCH VEHICLE TOTAL WEIGHT AND (PAYLOAD)	ORBIT PERIGEE APOGEE INCLINATION	MISSION	SPECIFICATIONS
TD-1A 12-3-1972 Thor-Delta 471 kg (144 kg)	533 km 545 km 97.6°	Astronomical, solar and cosmic ray research 7 experiments (B, D, F, GB, I and NL)	• 3-axis stabilisation by momentum wheels and gas jets (2.5° in relation to the Earth and 1' in relation to the sun) • Solar generator: 330 W • Telemetry: real-time: 0.5 W and 1 700 bps Play-back: 2 W and 30 600 bps • 280 telecommands
ESRO-IV 22-11-1972 Scout 113 kg (32 kg)	280 km 1 100 km 90°	Study of the ionosphere and solar particles 6 experiments (D, GB, NL, S and ESTEC)	• Magnetorquer (65 rpm) • Solar generator: 60 W • Telemetry: real-time: 0.3 W and 640 bps Play-back: 2.8 W and 10 240 bps • 70 telecommands
COS-B February 1975 Thor-Delta 280 kg (115 kg)	350 km 100 000 km 25°	Study of cosmic rays from the galaxy 1 gamma ray telescope (D, F, I, NL and ESTEC)	• Reorientation of rotation axis by cold gas jets in all directions (10 rpm) • Solar generator: 90 W • Telemetry: real-time: 6 W and 160 bps • 140 PCM telecommands
GEOS Mid-1976 Thor-Delta 180 kg (31 kg)	Geostationary	Investigation of particle flux and electric and magnetic fields 9 experiments (CH, D, DK, F, GB, I, and ESTEC)	• 3-axis stabilisation by hydrazine motors (10 rpm) • Solar generator: 90 W • Telemetry: real-time: 2 W and 100 000 bps in VHF • 125 PCM telecommands
IME 1977 Thor-Delta 130-150 kg (25 kg)	300 km 140 000 km 28.5°	Study of the magnetosphere (D, F, GB, I, NL)	• Stabilisation by propane or freon jets (10-40 rpm) • Solar generator: 80 W • Telemetry: real-time: 1-5 W and 2 000 VHF and 16 000 bps • 150 telecommands
Exosat 1979 Thor-Delta 250 kg (42 kg)	300 km 200 000 km	High-energy astronomy 2 experiments	• 3-axis stabilisation by cold gas jets: orbit control by hydrazine motors • Solar generator: 100 W • S-band telemetry: 4 000 bps • 300 telecommands

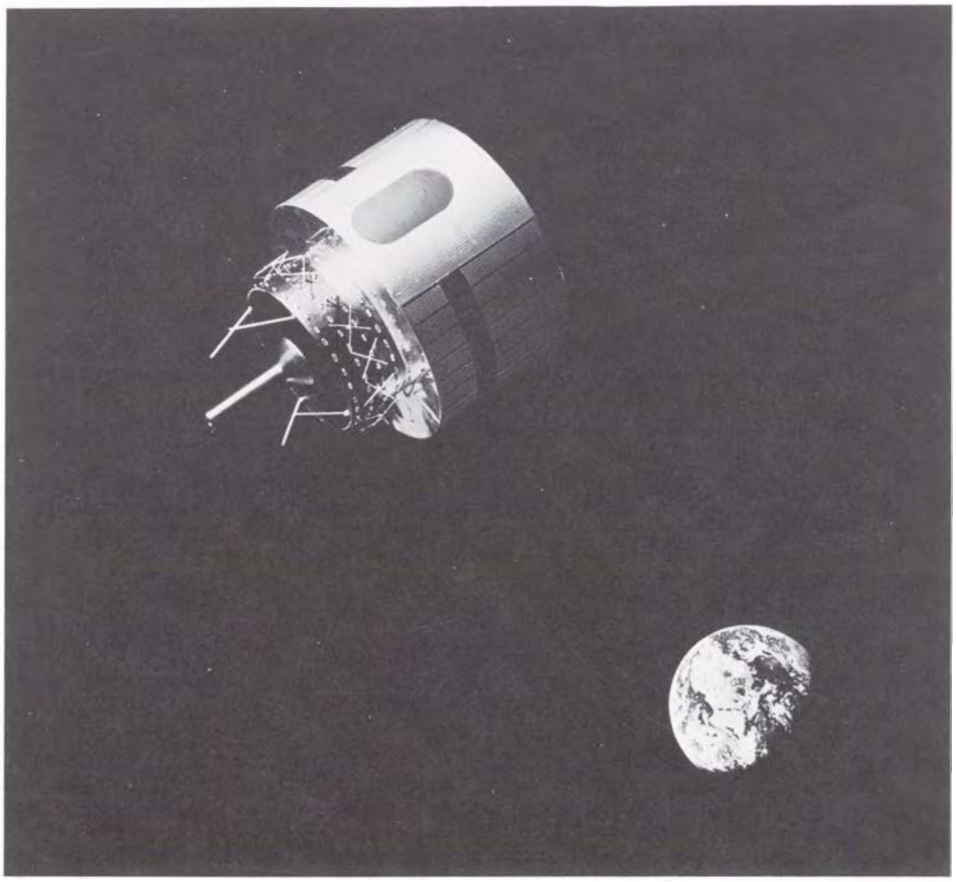
Meteorology: Meteosat

Meteosat, ESRO's first meteorological satellite, is due to be placed in a synchronous orbit by an American Delta rocket in December 1976.

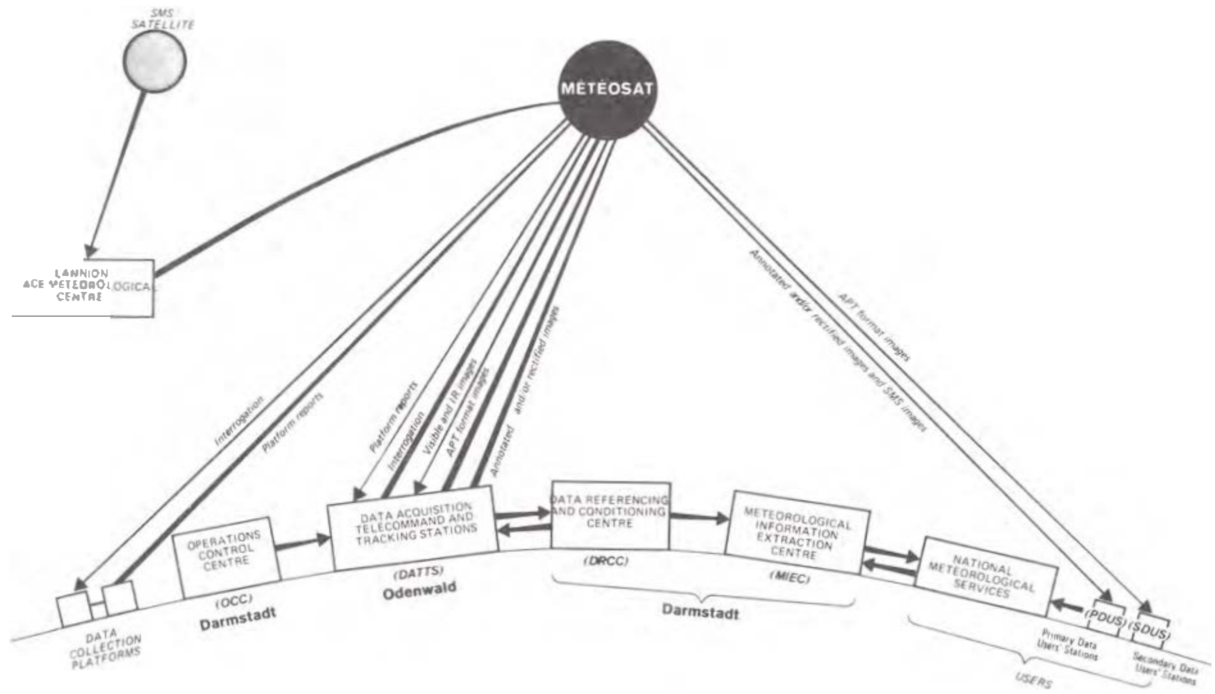
Stationed above the Atlantic at approximately 0° longitude, Meteosat is to be one of an international network of four or five stationary satellites due to participate in the Global Atmospheric Research Programme (GARP), in the context of the World Weather Watch. The others will be two American satellites stationed at 70° and 135° West longitude, a Japanese located at 140° East longitude, and possibly a Russian satellite stationed at 70° East longitude. Evenly spaced around the globe, such satellites will be able to provide full coverage of the planet except for the polar regions.

The decision to develop Meteosat was taken in December 1971. A two-year design study was then undertaken before ESRO selected the European industrial consortium COSMOS to build it. Meteosat is to be launched in time to take part, in 1977, in the first GARP global experiment. The satellite's lifetime will be about three years.

Weighing a total of approximately 705 kg, including nearly 350 for the apogee motor and 36 for the adapter section, Meteosat will first be placed in a transfer orbit by a Delta rocket launched from the Eastern Test Range in the US. The apogee motor will then be ignited, and once the satellite has reached its correct station it will weigh only about 315 kg. It will be reorientated to make its longitudinal axis almost parallel to the north-south line and it will be spin-stabilised at 100 rpm. It is anticipated that the satellite could be shifted through a maximum of 20° of longitude in the course of its life span. It will be possible to control its rotation speed to within 0.1 rpm, and its longitudinal axis will not be allowed to tilt through more than 0.1 deg. The satellite's attitude will be measured continuously by three infrared sensors and four solar sensors and will be controlled by six thrusters which will be able to burn up to 22.5 kg of hydrazine. The 14 296 solar cells on the body of the satellite will generate an onboard electric power of 250 watts initially, which will decay to 175 watts towards the end of the satellite's life.



ESRO's *Meteosat satellite, to be launched in 1976.*



Meteosat will have three principal missions:

— *Photography:* the satellite will generate and transmit to earth images of the terrestrial globe invisible light and in the infrared region of the spectrum.

— *Infrared image dissemination:* it will retransmit to users the images it has taken after they have been corrected or annotated by a ground-based processing centre.

— *Data collection:* the satellite will receive weather, oceanography or other data in the form of signals from platforms on the ground or at sea.

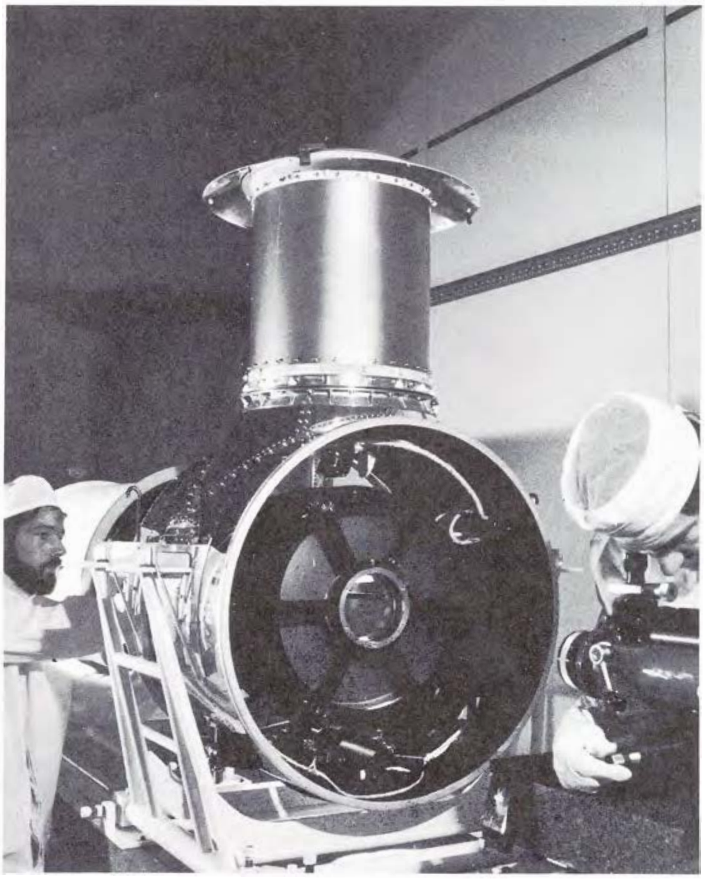
These three missions consequently imply extensive ground facilities.

Earth imaging

This mission has top priority. The satellite is equipped for the purpose with a radiometer weighing nearly 60 kg and enabling high resolution images to be taken of the portion of the globe viewed by the satellite in visible light (0.5-1 micron) and in the infrared region of the spectrum (10.5-12.5 microns). These images are transmitted to a ground-based Data Acquisition, Telecommand and Tracking Station (DATTS) and to possible receiving stations made available to users if specifically requested.

The satellite's motion as it rotates about its axis at 100 rpm is used to take these images. At each revolution the radiometer views the earth at a maximum angle of 18°. Hence a line is scanned during one-twentieth of a revolution, or 30 milliseconds, and the information is stored and transmitted to the ground during the remainder of the revolution. In order to obtain the same vertical definition, the axis of the radiometer, which is at right angles to the spin axis, is tilted a little more after each revolution.

Thus an image in visible light is composed of 5 000 horizontal lines of 5 000 dots each, while an infrared image is made up of 2 500 lines of 2 500 dots each. Consequently 25 minutes are needed to obtain a pair of visible-light and infrared images. The analog signals are immediately converted into digital signals—8 bits for each dot in the infrared image and 6 bits for each dot in the visible image, or 50 000 bits per line for the two images. The onboard memory can store 80 000 bits every 30 milliseconds (the time needed to scan one line) and can record both the radiometer signals and the synchronising signals from a clock stable to within better than 10^{6} per minute. The memory is read at the rate of 166 600 bits per second. The images are transmitted to the ground in the S-band by an electronically de-spun antenna and are used by the DATTS.



Radiometer of Meteosat, which will take pictures of the earth in the visible and infra-red light spectra (MATRA photo).

DATA DISSEMINATION

The aim here is to supply interested users with the meteorological data they require, using Meteosat as a relay station. The transmitted data are in fact duly corrected and annotated Meteosat images. The DATTS transmits them to two kinds of stations:

— Primary Data Users Stations (PDUS), if the images are in digital form and of high resolution. Equipped with antennae 4.5 to 5 metres in diameter and with uncooled parametric amplifiers, these stations are designed to receive both digital and analog data. They are equipped with high and low resolution display equipment and with digital data storage facilities.

— Secondary Data Users Stations (SDUS), if the images are in analog form. These stations employ antennae 3 metres in diameter with transistorised preamplifiers and are not very different from the Automatic Picture Transmission (APT) stations currently in use to receive pictures from US weather satellites. However, because the DATTS and the satellite transmit on S-band frequencies and not on APT frequencies, the receiving equipment will be somewhat different. Image definition will be provided by 800 lines of 800 dots each.

The DATTS will be able to disseminate other information as well, such as weather forecast charts and meteorological data. The satellite will carry two interchangeable transponders which can be used to disseminate images and data. International coordinating meetings are being held periodically to decide what standards to adopt for all these transmissions, so as to make the various segments of the global weather satellite system mutually compatible.

DATA COLLECTION

Here the Meteosat satellite will again be used as a relay, this time between platforms located within its coverage zone and the DATTS. These Data Collection Platforms (DCP) will transmit to the DATTS, via the satellite, meteorological data (pressure, humidity, temperature, and wind velocity and direction), hydrological data (sea swell), or alarm signals to give warnings of disasters such as earthquakes, floods or volcano eruptions.

It is planned to use three types of platforms: internally programmed platforms which will transmit data at predetermined moments in time, over pre-established frequency bands; platforms capable of being interrogated sequentially by the central station and of responding via the satellite; and warning platforms which will transmit a message as soon as a parameter exceeds a predetermined threshold. These platforms will be either fixed or mobile and will be placed on land, at sea or aboard ships. Depending on the length of the messages and the apportionment of the onboard power supply, Meteosat will be able to interrogate up to about 400 platforms at regular intervals.

Links between the platforms and the satellite will be in the lower UHF band, those between the satellite and the ground in the upper UHF band.

GROUND INSTALLATIONS

Continuous dialogue between Meteosat and the ground calls for an infrastructure of considerable importance which will consist of two stations:

— The Data Acquisition, Telecommand and Tracking Station (DATTS), located at Michelstadt (Odenwald).

— The Darmstadt station, about 40 kilometres from the DATTS.

The Darmstadt station will itself consist of three separate centres:

— An Operations Control Centre (OCC) to monitor the satellite and interrogate it as necessary.

— A Data Referencing and Conditioning Centre (DRCC), which relates the radiometer data to the satellite's position and attitude on its orbit and conditions the images.

— A Meteorological Information Extraction Centre (MIEC), which generates images from the temperature, wind velocity and other data.

A) THE DATTS

This station houses the receiving and transmitting equipment needed for links not only with Meteosat but also with other synchronous satellites currently under development, such as GEOS. For reasons of cost and ease of maintenance, the aim has been to maximize commonality of equipment for the different projects (antennae, receivers, preamplifiers, synchronisers, etc.). Meteosat's format synchroniser will be a specific item, however, and the amplifiers used for transmissions to the satellite will have a power of about 100 watts.

B) THE DATA REFERENCING AND CONDITIONING CENTRE (DRCC)

This Centre has two main functions: first, it generates an exploitable image from the signals transmitted by the satellite and stores the transmitted data; second, it interrogates the platforms and conditions the signals from them for retransmission to users.

(a) *Image processing:* The Centre is expected to have sufficient capacity to rectify approximately 20 % of the images. General distortions and positioning defects will be corrected, and a grid will be superimposed, after which the images will be made displayable for trans mission to users. The other images will not be rectified; they will merely be shifted in order to keep the same terrestrial point in the centre of the area. These images will be annotated, but the effect of the satellite's spin motion will not be corrected. A series of other operations (brightness standardisation, changes of projection, contrast modifications, contour enhance ment, etc.) are also contemplated.

Storing all these images and the enormous quantity of data they contain (200 millions bits for a visible-light image and an infrared image) would require a conventional magnetic tape with a capacity of 1 600 bits per inch for each image. A study has shown that with the new storage supports expected to be available in 1976 it will be possible to retain all these images. They will be recorded on 6 250 bit/inch magnetic tape, or rather on metallized-polyester film impressed by a laser beam, enabling the images to be recorded directly in picture form. This type of film consists of small polyester sheets measuring 31 1/4 " by 4 3/4 ", each equivalent to more than six 2 400-foot magnetic tapes of 1 600 bits per inch. The storage area required for three years of Meteosat image recording is only 5 square metres, and the total cost will not exceed 375 000 accounting units.

(b) *Data collection:* The Centre will be required to collect the data from the platforms, and possibly also to apply some degree of processing before retransmitting the data to users.

C) The Meteorological Information Extraction Centre (MIEC)

The role of this Centre will be to extract meteorological parameters onto a given rectangular grid. These parameters are as follows:

— *Wind velocity*, at 200-kilometre intervals on four different levels. These measurements at the different grid points will be sent out every six hours in the form of coded messages.

— *Ocean surface temperatures*, sent out every 12 hours, accurate to within at least 1° K.

— *Cloud cover*, at low, medium and high altitudes, for dissemination every 12 hours.

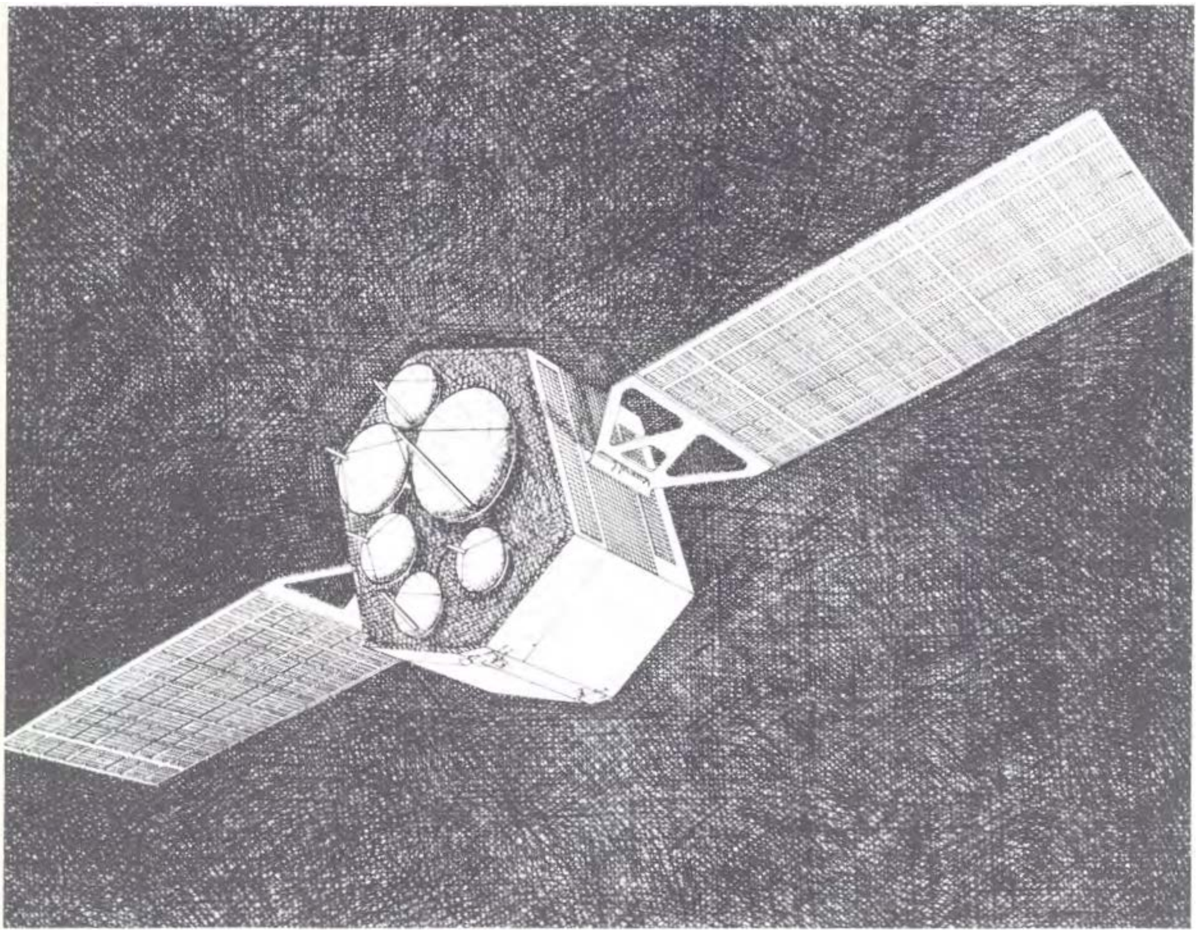
— *Cloud-top altitude*, sent out every six hours in the form of Wefax charts in the case of high nebulosity zones.

— *The Earth's radiant energy balance-sheet*, sent out daily in the form of coded values at the different grid points.

Telecommunications: OTS

The first telecommunications satellite projects emerged in Europe nearly seven years ago. In 1967 senior European Space Conference officials began to think about defining a future programme for Europe.

The Conference on European Telecommunications Satellites (CETS) turned at first to ESRO for the initial satellite design studies. Several versions were considered, one of which was a television broadcasting satellite for the European Broadcasting Union (EBU). In November 1969 it was decided to study a common radio broadcasting and TV distribution mission. The « Conférence Européenne des Postes et Télécommunications » (CEPT) and the EBU accordingly prepared a report indicating the expected growth of telecommunications networks in Europe from 1975-1980 onwards, and the anticipated satellite capacities required for them.



Experimental communications satellite OTS, *which will be launched by* ESRO *in 1977.*

EUROPEAN GEOSTATIONARY COMMUNICATIONS SATELLITES

	SIRIO (ITALY)	SYMPHONIE (FRANCE)	OTS (ESA)
launch date	1975	1975	early 1977
mission	experiments with transmission of sounds and images; propagation experiments; telephony multiple access tests	radio and TV programme distribution; telephone communications and data transmission; multiple access tests	in-orbit check of vehicle and payload technology: check of transmission techniques (multiple access, frequency re-use); proportional use within European telephone network: data transmission to small terminals
position and coverage	Atlantic Ocean: long. 15° W Central Europe; west coast of Europe and east coast of U.S.A.	Atlantic Ocean: long. 11.5 ± 0.5° W Europe and Africa from Scandinavia to Madagascar, American zone from Quebec to Brazil	Atlantic Ocean: long. 10 ± 0.1° E Eurobeam A and B: zones between Reykjavik, Helsinki, Tel-Aviv and Las Palmas; Spotbeam: zones between Dublin, Stockholm, Belgrade and Madrid
weight at launch and in orbit: diameter and height	398 and 220.5 kg 1.43 and 0.95 m (1.99 m with antenna and apogee motor)	387 and 237 kg 1.7 m (6.86 m with solar panels deployed) and 0.5 m	703 and 324 kg 1.66 m (8.84 with solar panels deployed) and 1.18 m (2.3 with antennae and apogee motor)
lifetime	2 years	5 years	3 years minimum
stabilisation	rotation, 90 rpm	3-axis (momentum wheel and gas jets)	3-axis (momentum wheel and gas jets)
frequencies capacity	12 and 18 GHz narrow range: 1.5 MHz wide range: 26 MHz	4 and 6 GHz 600 teleph. channels (2 × 90 MHz)	11 and 14 GHz 40 and 120 MHz channels: one 5 MHz channel
onboard power at beginning and end of life	118.5 and 93 W	175 W (end of life)	700 and 527 W (summer solstice)
antennae, pointing accuracy and gain	mechanical despun SHF; + 0.25°; 22.5 (12 GHz band) and 23.5 dB	for transmission, 2 parabolic antennae (13×8°); for reception, 2 horn antennae; — 1°; 19.5 dB minimum	Eurobeam A: 2 parabolic reception antennae (7.5 × 4.25°); Spotbeam: 1 directional transmission antenna (2.5°): Eurobeam B: 2 (5 × 3.5°); ± 0.2°; Eurobeam A: 20.5-26.5 dB max.: European B: 23.1-29 dB max.; Spotbeam: 29.5-35.5 dB
amplifier	2 travelling wave tubes: each 9 W on transmission	2 travelling wave tubes: each 13 W on transmission	6 travelling wave tubes: each 20 W on transmission
diameter of ground antennae		16 m	Eurobeam A and Spotbeam: 13 m; Eurobeam B: 3 m
apogee motor: propellants	aluminium and polybutadiene	aerozine 50 and nitrogen peroxide	polybutadiene

As the number of studies multiplied, France and the Federal Republic of Germany decided to develop a first experimental satellite—Symphonie. Italy followed with a broad definition of the Sirio telecommunications satellite.

In December 1971 the European countries finally decided to entrust ESRO with a programme of communications satellites to meet the needs of the CEPT and the EBU. The programme is to begin with an experimental phase, followed by an operational phase if the member countries so decide later.

The experimental phase, which began in 1972, took a decisive turn in December 1973 when ESRO issued a development contract for its first experimental telecommunications satellite, OTS (Orbital Test Satellite). Weighing approximately 325 kg, it is due to be launched early in 1977 by a Delta rocket from the Eastern Test Range in the United States.

Because the Franco-German and Italian projects have fallen behind schedule, the three communications satellites (Symphonie, Sirio and OTS) will be launched within the next two years. Thus, starting in 1975-1976, experiments will multiply in number in Europe. However, the OTS satellite is the only one which is part of a long-term programme and which foreshadows the operational satellites of the next decade.

Initial tests

The European telecommunications satellite programme involves two stages, each in turn broken down into two phases:

A) *The* OTS *phase* will serve to flight-rate the communications and housekeeping equipment of future operational satellites. It will be preceded by an experiment conducted jointly with Canada, following signature of an agreement in May 1972 pursuant to negotiations begun in December 1971. Under this agreement, the Canadian Technology Satellite (CTS), due to be launched in 1975, will be supplied with two onboard systems by ESRO: a 20-watt travelling-wave tube and a parametric amplifier. In addition, ESRO will fund the development of the satellite's solar panels up to flight qualification. In return, Canada will purchase the solar cell grid (substrate plus cells) for the first flight model, but excluding the actuating mechanism, which will be Canadian made.

B) *The operational phase* provides for development of two flight models ready for launch in the early 1980s. If ESA deems it necessary, these launches may be preceded by the construction and orbiting of a prototype model.

The experimental phase should last up to around 1978, development of the operational satellites being initiated sometime around 1975-1976. According to the joint report issued in 1970 by the CEPT, the EBU, ESRO, ELDO and the European Space Conference, between one-third and two-thirds of all long-distance telephone links of over 1 200 km could be handled by satellites from 1980 onwards. Moreover, beginning in 1980, the EBU will require two channels to distribute Eurovision TV programmes. Requirements for data transmission have still been incompletely assessed, but will no doubt be considerable.

In other words, the requirement for 1980 will be a satellite with a capacity of about 18 000 telephone circuits and two television channels and weighing between 650 and 800 kg, or alternatively a system of two smaller 400-450 kg satellites. Moreover, because satellites have a high transmission capacity, it is planned to use the same frequency twice over in the allocated 500 MHz band, unless twin satellites are available that are separated by adequate longitude distance. And in order to enable the earth stations to be located close to the principal European cities and at the same time avoid tricky frequency selection problems, operational satellites will have to use the 11-14 GHz band. Some thirty earth stations will be needed, at least initially; they be will equipped with antennae 15 to 18 metres in diameter, with low-noise parametric amplifiers and with 1-2 kW transmitters. The antennae on board the satellites will radiate two beams: a broad beam covering Europe and part of the Mediterranean, and a narrower beam which will serve only Europe and handle up to 80 % of the traffic.

A Modular Satellite

This investigation of European needs around 1980 resulted in the definition of a first satellite, the OTS, which is to be used to test and perfect the technologies which Europe will need later, and to demonstrate their dependability to future users. A forerunner of tomorrow's satellites, the OTS is more complex than Symphonie or Sirio. Stabilised about three axes and employing orientable solar panels, it operates in the multiple access mode and receives and transmits polarised signals to enable the frequencies to be reutilised.

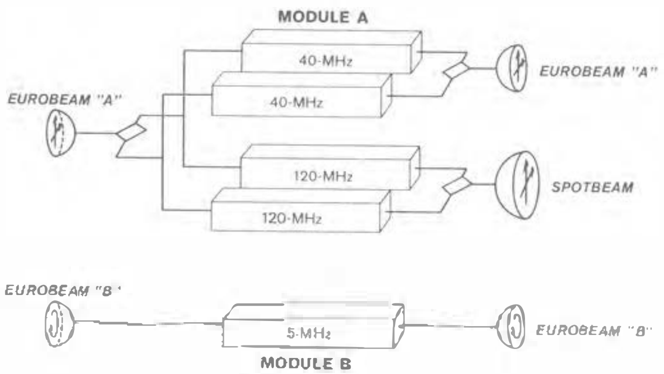
The techniques it embodies explain the sum needed to develop it: 115 MAU at mid-1972 price indices, plus support costs and overheads, or a total of 143 MAU. Two 400-500 kg operational satellites fairly similar to OTS are estimated to cost 160 MAU; two 650-800 kg satellites 283 MAU (including Agency expenses in both cases).

OTS employs a modular construction approach so as to come as close as possible to the configuration of future operational satellites. The onboard systems are installed in two modules:

— A service module carrying the housekeeping, telemetry and telecommand equipment, the attitude control system, the thermal regulating system and the apogee motor.

— A communications module housing the repeaters, the antenna mechanisms, the command decoder, the telemetry encoder, the UHF receiver and the SHF transmitter. The repeaters, antennae and antennae steering mechanisms weigh about 42 kg.

The solar panels are mounted on the body of the satellite. These panels are oriented towards the sun and make one complete revolution round the pitch axis each day in order to follow its apparent motion.



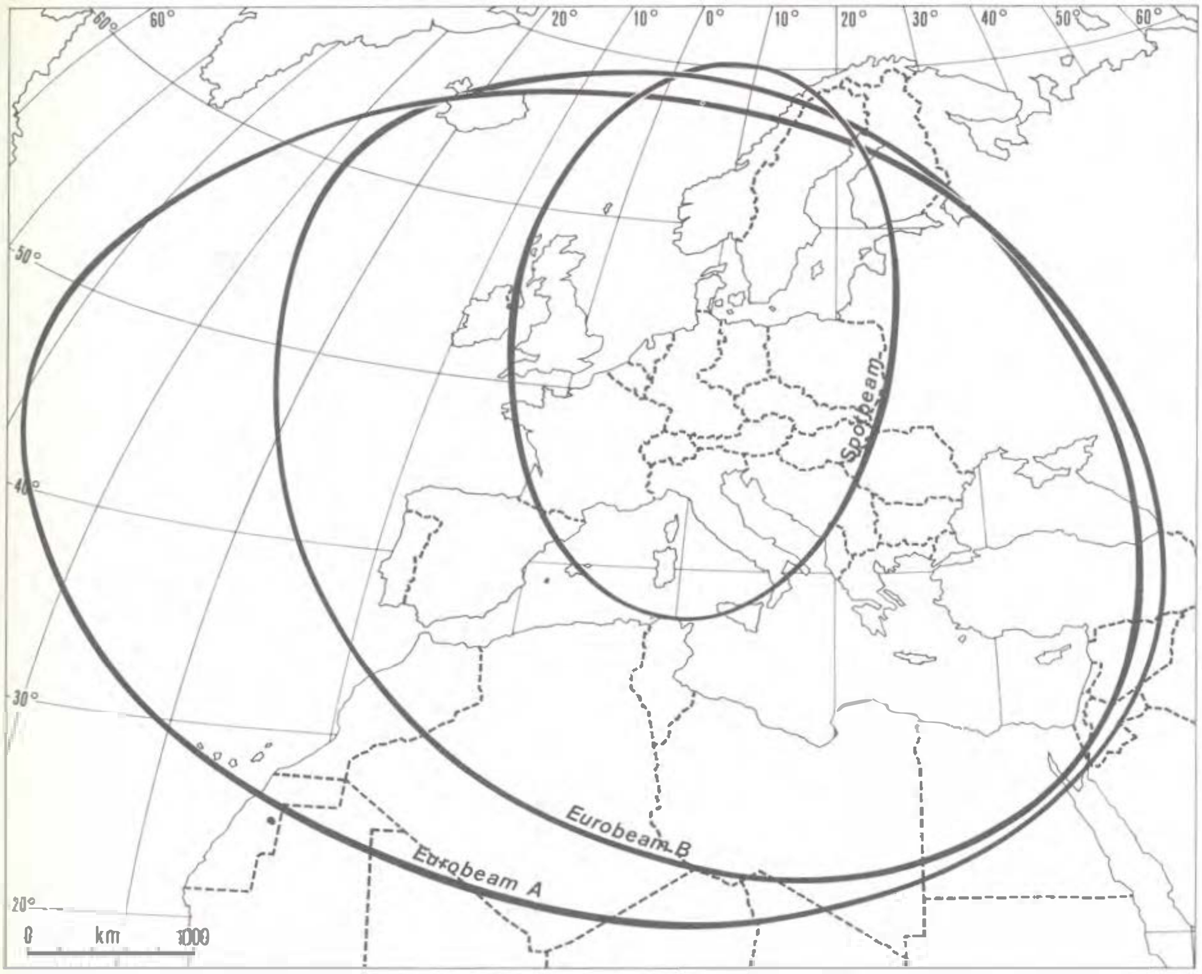
Two modules of OTS *communications satellite.*

The communications module in turn consists of two separate modules:

— Module A is rather like a scale model of the module which would be placed aboard an operational satellite. The principal parameters (receiver signal/noise ratio, transmitting power, channel width, antenna gain and coverage) are the same as for an operational satellite. This module will enable telephone links to be experimented with and television pictures to be transmitted. It consists of four transmission-reception channels, two of which have a bandwidth of 40 MHz and the other two a bandwidth of 120 MHz. The channels of equal bandwidth will employ the same frequency thanks to signals polarised in two mutually perpendicular planes. The receiving antenna for the two 120 MHz channels are parabolic, with beam dimensions of 7 1/2 × 4 1/4 degrees. The transmitting antenna for both these channels is orientable and its 2 1/2° « Spotbeam » can be centred upon various regions. The two transmission and reception parabolic antennae for the 40 MHz channels provide the same coverage as those of the two 120 MHz channels, i.e. 7 1/2 × 4 1/4 degrees. This is known as Euro beam A.

There are two redundant receivers aboard the satellite for each of the two 120 MHz channels. The signals are linearly polarised; they are transmitted from the ground on a frequency of 14 GHz and are beamed back to the ground by the orientable antenna on a frequency of 11 GHz after habing been circularly polarised. The signals transmitted over the 40 MHz channels are linearly polarised.

— Module B will make it possible to use small, low-cost ground antennae to conduct propagation and narrow-band transmission experiments. It employs only one 5 MHz bandwidth channel. Two separate parabolic antennae are used for transmission and reception over a 5 × 3 1/2 degrees beam. The signals are circularly polarised. This is known as Eurobeam B. Under remote control from the ground, this channel's gain can be varied twice as much as that of the Eurobeam A channels.



Three antenna coverage zones for the OTS *satellite.*

Experimentation

OTS will be used for a series of tests which may be divided into three categories:

1) *Onboard measurements:* operation of the satellite and its main subsystems will be checked from the telemetry data. The latter will be transmitted to a telemetry, telecommand and tracking station equipped with a directional SHF antenna about 13 metres in diameter. This monitoring function will cover the stabilisation system, the attitude control system, the repeaters, antenna performance, the degree of signal polarisation, etc.

2) *Ground-based measurements and tests:* the 13-metre-diameter ground antenna will be used for several kinds of checks and measurements:

— repeater tests: relayed-signal amplitude, transmission delay, transmitting power, receiver noise, frequency stability, gain as a function of frequency, etc. ;

— dynamic tests of the repeater: testing telephone transmission by pulse code modulation as well as television picture distribution;

— testing adjacent channels of the repeater: telephone link and video distribution tests on the two 120 MHz and 40 MHz channels; investigating attenuation effects and the effects of coupled polarisations under variable meteorological conditions, in the event of an eclipse, etc.

3) *Onboard and ground-based measurements:* the measurement data from the satellite and the ground will be correlated to study antenna aiming accuracy, beam shape and gain, the degree of signal polarisation, and so on. This will require several ground antennae to enable the satellite's attitude to be varied.

This programme of experiments is designed to prepare the operational programme. Within the weight limits of the OTS satellite (350 kg) it should be possible to develop a TV distribution satellite, while an increase to 400 or 500 kg would enable the capacity to be increased. The OTS satellite is designed to be adaptable to various operational missions and to be able to carry slightly modified equipment such as flexible rather than rigid solar panels, or a momentum wheel with double universal joints instead of a fixed wheel.

Maritime Communications: Marots

It was at the United Kingdom's instigation that the decision to develop Marots (Maritime Orbital Test Satellite) was taken in September 1973. It is the first experimental satellite intended for civil maritime communications.

A growing need has been felt for frequent and reliable communications between merchant vessels and land-based terminals. This need is felt mostly by countries with large merchant fleets like the United Kingdom, the Scandinavian countries, the Soviet Union, Japan, the United States and Liberia. Indeed, it is estimated that by 1980 some 3 500 ships will ply across the Atlantic and Pacific Oceans each year. Today communications with ships at sea are based on radio links using RF frequencies, which tend to be cluttered and unreliable. Approximately 93 % of all messages are sent by telegraph (in Morse code) and only 7 % by telephone. A message takes an average of six hours to reach its destination, and a reply just as long. Thus it can take twelve hours for a ship at sea to communicate with its owners.

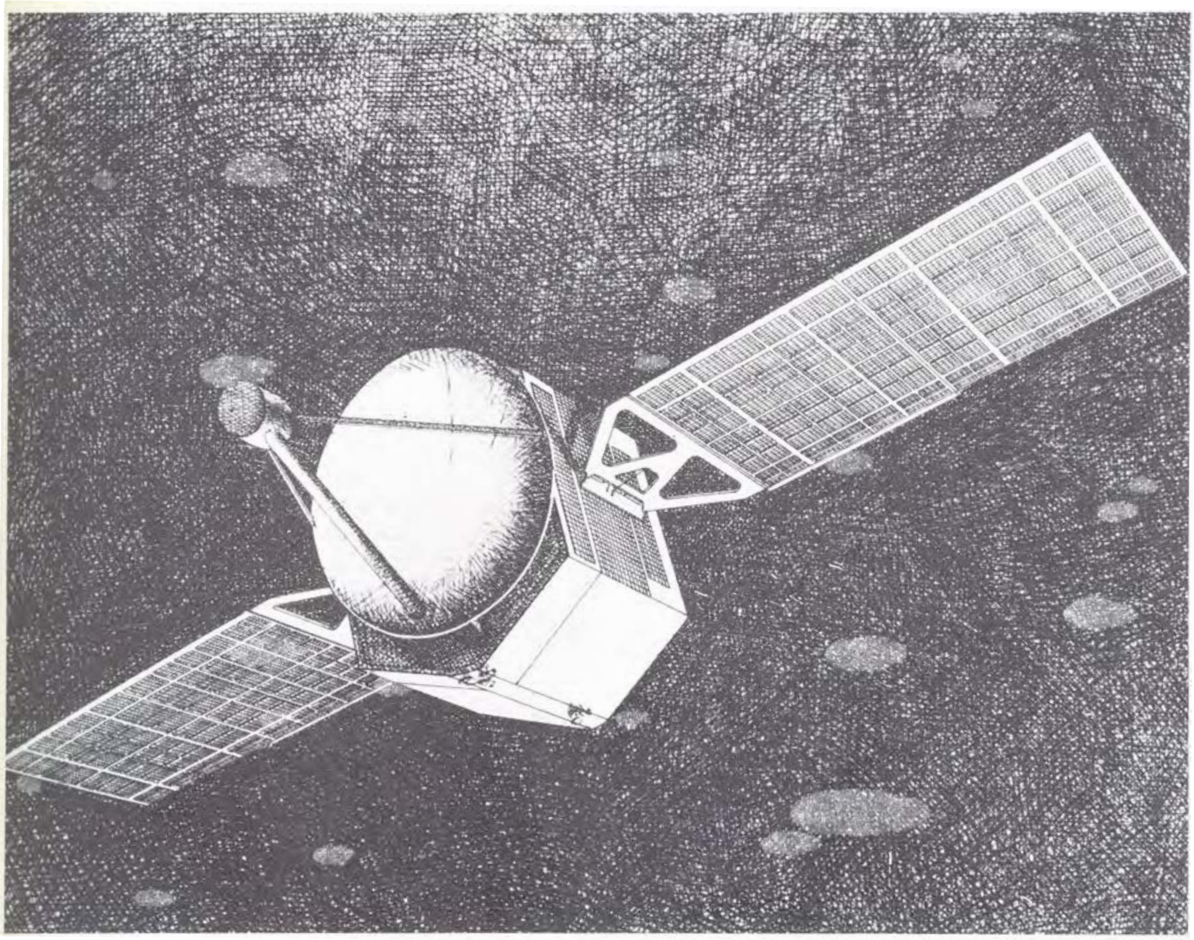
The Intergovernmental Maritime Consultative Organisation (IMCO) has been studying this situation since 1971. In February 1972, ESRO was admitted as an observer to meetings of IMCO's Marsat group formed to deal with maritime satellites.

Since 1971, moreover, ESRO's maritime advisory group has conducted a series of studies aimed at defining a maritime satellite's mission. It has interrogated users about their communications needs and has requested that initial industrial studies be carried out in order to determine more clearly the parameters of shipborne terminals.

Exploring this field of application of geostationary satellites still further, ESRO finally decided to develop an initial experimental, pre-operational maritime satellite by taking advantage of the fact that the platform of the OTS experimental telecommunications satellite could be adapted to this purpose.

The purpose of the programme is to try out techniques that could culminate in an operational system which would improve maritime communications and safety in general and facilitate ship navigation. This experimental programme will involve satellites, shipborne terminals and shore terminals.

CHARACTERISTICS OF MAROTS SATELLITE	
orbit	geostationary
position	Atlantic Ocean, 12.5 degrees longitude West
coverage	Atlantic Ocean, western part of Indian Ocean and eastern part of the Caribbean
lifetime	at least 3 years
frequency bands	11 and 14 GHz and band L — ground to satellite: 14-14.5 GHz — satellite to ground: 11, 45-11.7 GHz — satellite to ships: 1 535-1 542.5 MHz — ships to satellite: 1 636.5-1 644 MHz
capacity	two-way telephone links (40 kHz) and telex transmission (400 Hz) between ships and shore; message transmission (40 kHz) from shore to ship; telephone links and message transmission from shore to shore (80 kHz)
electric power at end of operational life	330 watts
stabilisation	3 axis



ESRO's MAROTS *satellite, which from 1977/1978 will transmit communications between ships at sea and coastal stations.*

The operational system should meet several needs: relieve congestion on the currently employed RF frequency bands, speeds up and improve the quality and reliability of communications, extend the geographical coverage of communications, offer more circuits and enable voice and telex transmissions to be automated, provide for high-speed data transmissions (currently non-existent), enable ships' positions to be determined by radio and provide more effective assistance to ships in distress.

To meet these requirements, it was therefore decided to use the 11-14 GHz frequency band between the satellite and shore terminals, and the L-band between ships and the satellite. Marots will enable extensive testing to be done, including:

— evaluation of various types of shipboard terminals,

— experiments with several signal modulation techniques;

— tests involving connecting the shore terminals to public telephone and telegraph networks in order to achieve total automation of telephone and telex links;

— testing techniques for giving distress messages priority access to the satellite, even if they are only faint signals;

— testing signal reception from position indicating transmitters used in the event of an accident;

— testing weather data transmission to ships;

— testing position fixing techniques.

Marots will be built on the basis of the OTS experimental telecommunications satellite and, like it, will be stabilised about three axes and will be based on the same modular concept. The communications module is expected to weigh 54 kg and will be equipped with a wide-band transponder (about 2.5 MHz) for two-way communications. As in the case of links with aircraft, the problem is to endeavour to limit the size of shipborne antennae and the degree of accuracy required in orienting them. This means that the satellite must have high transmitting power and must be equipped with a powerful amplifier. In contrast to satellites used for public communications, however, it need not offer a very large number of channels.

The satellite's transponder will be connected to several kinds of channels: telephone and data transmission channels with a two-way bandwidth of about 40 Hz; channels for telex links with a two-way bandwidth of about 400 Hz; and a few telephone and message transmitting channels for coast-to-coast links, with a bandwidth of 80 kHz.

In Europe a full complex of ground installations will be provided:

— a maritime service terminal which will receive and transmit all communications between the satellite and the maritime communications centre;

— a maritime satellite communications centre, to which traffic from the different countries will be channelled and which will distribute communications from the satellite;

— a satellite monitoring and control centre, which will handle telemetry, telecommand and tracking links.

Neither the satellite nor the terminals have yet had their specifications finalised in all their details. The detailed definition phase should be completed by mid-1974, and the cost of the programme is estimated at 75 MAU, including the Organisation's general expenses.

Air Traffic Control: Aerosat

The Aerosat programme, in which it is intended to launch the world's first experimental air navigation satellites, is a cooperative venture by Europe and the United States, who were subsequently joined by Canada.

Begun in 1969, ESRO's negotiations with the United States have proved difficult and no agreement has yet been concluded. If the agreement can be signed reasonably quickly, however, it is likely that two experimental pre-operational synchronous satellites will be built by the United States, Europe and Canada and stationed above the Atlantic Ocean.

The problems encountered in communications between aircraft and the ground are in some ways akin to those posed by maritime communications, namely cluttered frequency bands and signal attenuation and distortion. (118-136 MHz VHF bands are used close to air traffic control centres, otherwise the 4-27.5 MHz bands are used.) Moreover, more and more aircraft are flying the air corridors above the oceans, and the rules governing aircraft spacing, especially above the Atlantic, make it necessary to fly at altitudes at which engines do not always function at maximum efficiency.

Consequently satellites could not only alleviate current communications problems but also enable the positions of aircraft in flight to be determined more accurately and the standard horizontal and vertical spacing between aircraft to be reduced.

The International Civil Aviation Organisation (ICAO) has held numerous meetings over the past several years and, despite the reticence of certain airlines, in April 1972 recommended the development of experimental air navigation satellites operating in the L-band (1540-1650 MHz). These satellites would offer telephone channels and would precede the first operational satellites to go into service around 1980. The experimental satellites would enable voice and data transmission links to be tested and the first experiments in monitoring aircraft in flight to be conducted.

So far negotiations between the United States and ESRO have taken place in three successive stages. The first stage was when ESRO began negotiations with NASA in 1969-1970 in order to define an experimental programme. But in January 1971 a declaration of intent issued by the White House's Office of Telecommunications Policy (OTP) led to further joint technical studies, this time between ESRO and the Federal Aviation Agency (FAA). In 1971 a programme was formulated with the participation of Australia, Canada and Japan. This was the second stage.

In December 1971 the ESRO member states authorised the Organisation's Director General to sign a Memorandum of Understanding relating to an aeronautical satellite programme common to Europe, the FAA, Canada, Australia and Japan, with ESRO and the FAA enjoying equal ownership rights over Aerosat's space segment.

In February 1972 the American position was again revised. The US government informed ESRO that the Memorandum of Understanding was unacceptable in its existing form and that further consultations concerning ownership, management and industrial implementation of the system were necessary. This was the beginning of stage three. In the course of a visit to Europe, the OTP's director announced that a revised draft agreement would be submitted to ESRO in March 1972. However, it soon became clear that this draft proposal would not be forthcoming until the presidential elections had been held. ESRO therefore decided to pursue its industrial efforts and to investigate the possibilities of carrying out a programme alone or with countries other than the United States.

CHARACTERISTICS OF AEROSAT SATELLITE

orbit	geostationary
position	Atlantic Ocean
coverage	Atlantic Ocean, part of the United States and Canada, Africa, most of South America and the western part of the Indian Ocean
lifetime	7 years
frequencies	ground to satellite: 5 000-5 125 MHz ground to ground: 5 125-5 250 MHz satellite to aircraft: 1 543-1 558.5 MHz aircraft to satellite: 1 645-1 660 MHz
capacity	— **Communications channels** for telephone links and data transmission: 5 ground to satellite (80 kHz), 15 satellite to ground (40 kHz), 2 for links between ground stations (80 kHz) — **Surveillance channels:** ground to satellite, the 5 communications channels; satellite to ground, the 15 communications channels and 3 surveillance channels — **Experimental channels:** one two-way wide-band channel for communications experiments (400 kHz or 10 MHz)
surveillance	— length of interrogation: 0.5 seconds — accuracy of measurement of distance ground-aircraft-ground — accuracy of measurement of radial speed: 1.5 m per second — accuracy of localisation: 1-2 nautical miles above 40° latitude
additional experimental capacity in VHF	2 communications channels from ground to satellite and 4 from satellite to ground (telephony and data transmission): — satellite to aircraft: 125.425-125.975 kHz — aircraft to satellite: 131.425-131.975 kHz

In October 1972 the OTP suggested that a revised Memorandum of Understanding be negotiated between ESRO, the United States and Canada. The satellite programme would be funded equally by the European governments and a private US company, with Canadian participation as well. ESRO would choose its own American industrial partner. Once launched, the satellites were therefore to belong to ESRO, Canada and the American concern that had contributed its share of the development costs. The circuits available would be placed at users' disposal by the FAA, Canada and ESRO.

After the European countries had signified approval of this revised American proposal, in 1973 ESRO invited American companies interested in the project to submit proposals. Five companies responded: Comsat, Fairchild Industries, ITT World Communications, RCA Global Communications and Western Union International. Meanwhile a new Memorandum of Understanding between ESRO, the FAA and Canada was prepared, and ESRO undertook a series of industrial studies on certain major subsystems. Canada indicated that it was prepared to bear a 6 % share of the programme, the remaining 94 % being shared equally between Europe and the United States.

In July 1973 the United States requested the inclusion in the programme of certain additional tests in the VHF frequency band, over and above the experiments planned in the L-band, and the draft Memorandum of Understanding was modified accordingly. However, this added experiment capacity has increased the weight of the satellite and made it necessary to use a more powerful launcher, a Delta 3914.

The project currently provides for the launching of two geostationary satellites above the Atlantic. The first launch could take place by the end of 1977, the second in the course of the following 24 months. These satellites would serve to demonstrate that it is possible to give users the standard of service they expect of an operational system. Three kinds of tests would be conducted simultaneously:

— tests of voice and data links between aircraft and the ground;

— monitoring aircraft over the transatlantic routes by determining their positions in real time;

— wide-band transmission tests, also for monitoring purposes.

This programme of tests would be conducted jointly by the signatories of the Memorandum of Understanding and managed by a special board on which ESRO and the FAA would have six representatives at the most, and Canada three. Other participating countries could join the test pro gramme.

A small number of commercial aircraft would then be equipped with circularly polarised L-band antennae. Coverage would be provided for the Atlantic Ocean and would be divided into four zones. Within these zones the satellite could be viewed by an aircraft even if the elevation angle was down to five degrees, for the satellite would have to be placed between 15 and 40° West longitude. At least one group of air traffic control installations would be located on either side of the Atlantic and each group would include:

— Aeronautical Satellite Communication Centres (ASCC) for concentrating and distributing communications. In addition, these centres would perform the monitoring calculations by making two distance measurements and using the altitude indication given by each aircraft. Two satellites would be used for the distance measurements, by measuring the round-trip time of a signal transmitted from the ground, received by the aircraft and retransmitted to earth by each of the two satellites.

— Aeronautical Services Earth Terminals (ASET), which would transmit and receive all communications, plus the signals used for the distance measurements. The North American terminal would be composed of two mobile sections, one belonging to Canada, the other to the United States.

These tests would serve to assess the standards which could be expected of a future operational service, and the findings would thus enable ICAO to formulate recommended future standards and practices.

SPACELAB, THE MANNED ORBITING LABORATORY

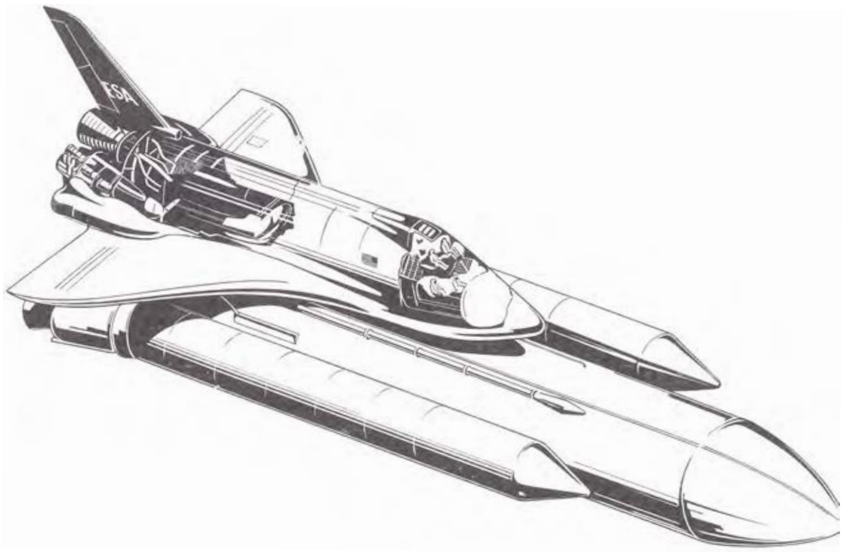
On 24 September 1973, Minister Charles Hanin, chairman of the European Space Conference, and Mr. Kenneth Rush, acting US Secretary of State, signed a Memorandum of Understanding in Washington relating to the construction of a manned orbiting laboratory (Spacelab) by the European countries. At the same time, the European governments signed an agreement binding them together for the purposes of this programme. Spacelab is to be placed in earth orbit early in 1980 for the first time by the American Space Shuttle and will carry European and American experiments. Thereafter it will be transported by the Shuttle regularly on relatively frequent flights, during each of which it will carry instrumentation appropriate to the missions entrusted to it by NASA and the European countries.

As such, the Shuttle built by NASA and the orbiting laboratory built by Europe will be fully integrated to constitute the post Apollo programme. Just as the Shuttle will be indispensable for launching the orbital laboratory, so the latter will for many years be the only space workshop at NASA's disposal.

For the first time ever, this exceptional agreement gives an European agency full responsability for developing a space vehicle as part of a joint programme with NASA. Moreover, this re-usable vehicle will be manned, and American and European astronauts will work and live in it.

Spacelab is a project between Skylab and future orbiting stations. Although it will be re-usable like the future station modules, it will not be in independent orbit. Installed in the Shuttle's hold, it will remain there after the Shuttle is in orbit. The doors of the hold will merely open, once in space, to enable the men inside the laboratory to conduct their observations and experiments. Spacelab will also take extensive advantage of the Shuttle's onboard systems.

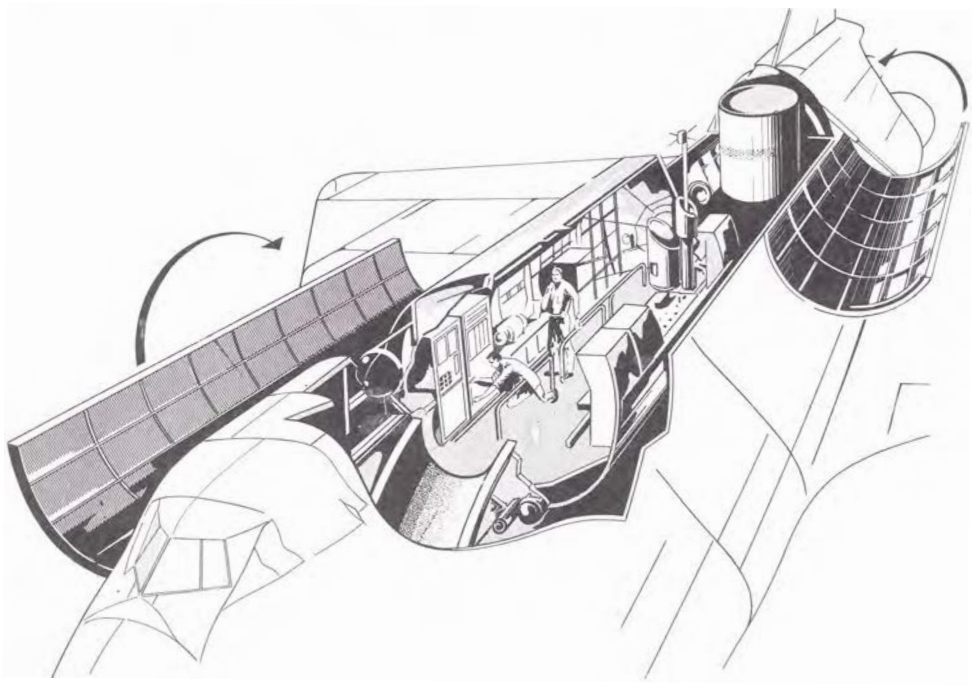
Spacelab will therefore not be as complex as a completely autonomous laboratory, but the European countries have been given full responsibility for it. Europe has undertaken to supply NASA, within fixed time limits, with a test model, a flight model and two complete sets of ground support equipment. For its part, the United States has undertaken not to build a laboratory of similar design and capacity for at least five years after Spacelab's first flight. The first Spacelab is to be delivered to NASA at no cost, but the US space agency may place orders, at prevailing industrial prices, for any similar laboratories it may require up to 1985. The first order would be placed at least two years before delivery of the first Spacelab. If present estimates turn out to be correct, American and European requirements will represent several flight models, plus spares, for the 1980 1985 period.

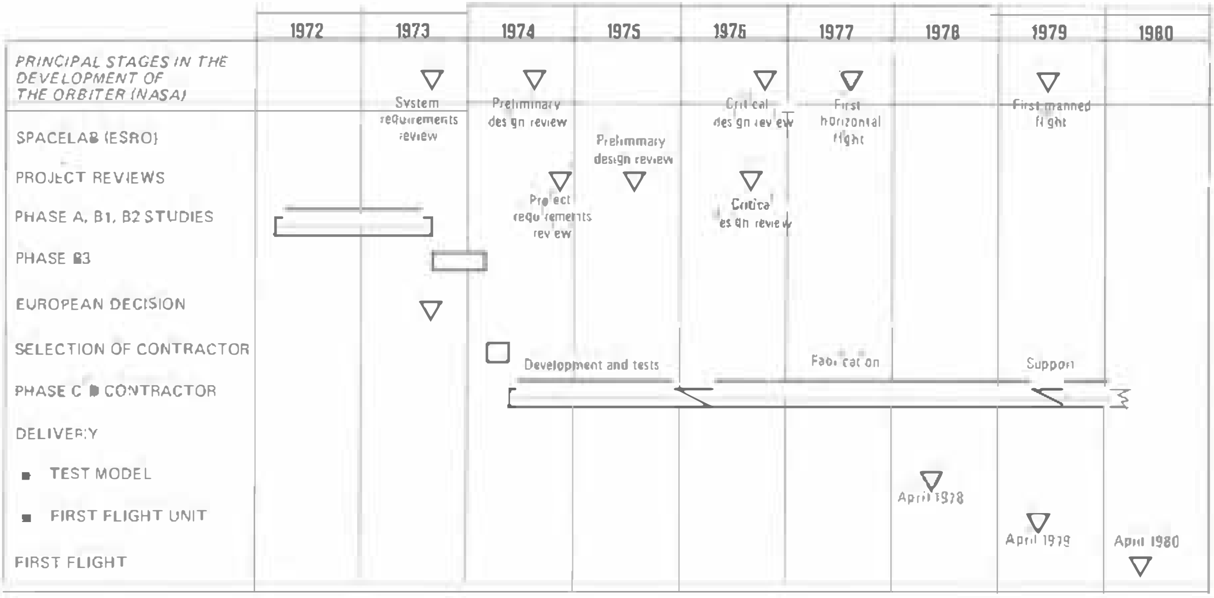


The American Space Shuttle.

Cooperation between Europe and the United States goes beyond the mere supply of European equipment to NASA and includes the use of the orbital laboratories, since NASA and the European countries are anxious to work together in defining joints experiments. Payloads will be designed on a cooperative basis, not only for Spacelab's first flight but also for any other flights for which collaboration appears desirable, in which case the Shuttle would be placed at Europe's disposal at no cost. Naturally, European scientific and industrial laboratories will be at liberty to propose their own experiments to NASA. Provided they are considered to be of equal interest, these proposals will be given priority over other foreign proposals, and in such cases the cost of the mission will be borne by the Europeans.

If collaboration proceeds smoothly between Europe and the United States, it will no doubt extend beyond the construction of the first laboratories. NASA and ESA will work together for many years and will no doubt formulate together subsequent programmes for improving these laboratories and possibly also for building future orbiting stations.





Spacelab programme schedule 1972-1980

Configuration of First Missions

Born in the United States in the late 1960s, the Space Shuttle concept remains inseparable from the concept of orbiting laboratories and space tugs—the package which came to be known as the post-Apollo programme.

The Shuttle is a re-usable vehicle which, having placed a payload in orbit, returns to earth and lands like an aircraft, ready to take up a fresh payload a few weeks later. These payloads could include manned self-contained modules which could be launched separately and assembled later into a station. Other payloads previously placed in low orbits by the Shuttle would be towed up to higher orbits by rocket stages, and vice versa if it were required to bring the payloads back to earth.

Having first interested themselves in the Shuttle, then in the space tug, the European countries finally agreed to NASA's suggestion that they build the orbiting laboratory, a forerunner of future space station modules.

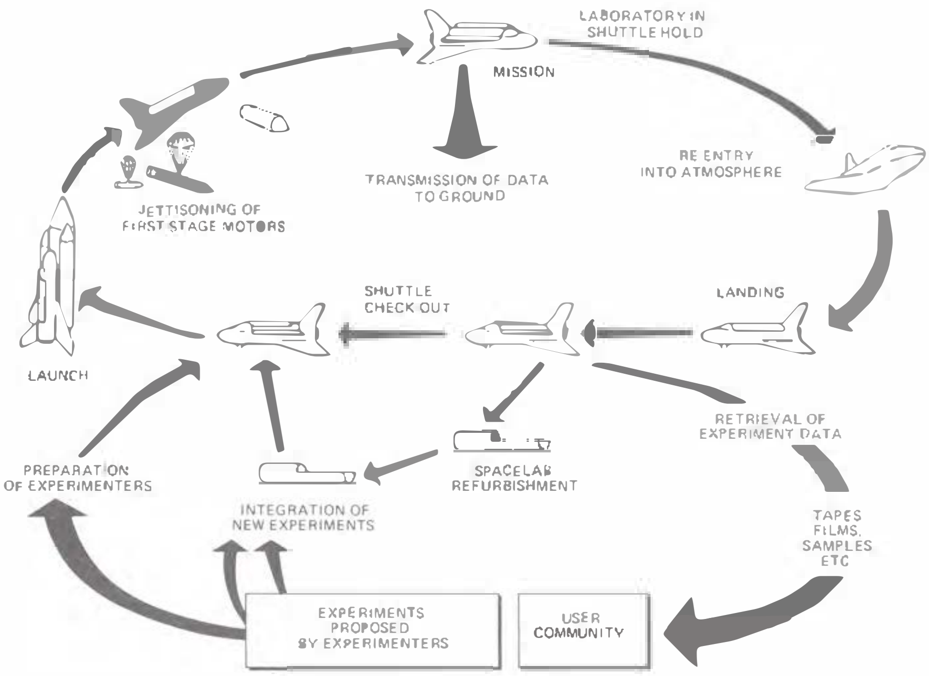
The laboratory will be installed in the Shuttle's vast hold, which is 4.5 metres wide and 18 metres long. The Shuttle will take off with its own three-man crew and Spacelab's crew of four. Once in orbit, the Shuttle will open the doors of its hold. The four men will then enter their laboratory, where they will work for seven to thirty days before returning to the Shuttle's cabin for the return to earth. While the Shuttle is being checked out, the laboratory will be unloaded, overhauled, and prepared for the next experiment. Its nominal useful life will be 50 flights, or a maximum of 10 years.

Uses of the Laboratory

The laboratory will therefore be re-usable like the Shuttle. Re-utilisation of both elements for several dozen missions should substantially reduce the cost of each mission and offer very diversified possibilities for experiments.

Still incompletely defined, Spacelab will have wide-ranging areas of application which are now being studied by NASA and ESRO. A joint US-European users group (Joint Users Requirements Group) composed of representatives of the different scientific disciplines and areas of application has been set up and has formulated a number of experiments which it considers desirable and which come under the following headings:

- — solar astronomy
- — optical and ultraviolet astronomy
- — infrared astronomy
- — high-energy astronomy
- — atmospheric and interplanetary plasma physics
- — life sciences
- — observation of the earth
- — communications and navigation
- — treatment and manufacture of materials
- — space technology.



Spacelab mission cycle.

Users will specify their requirements, the experiments they wish to conduct in each of these areas, and what they expect of the laboratory. In turn, the authorities in charge of Spacelab will stipulate the Shuttle and laboratory constraints to which investigators will be required to submit.

Although the Shuttle has considerable space to offer in its hold, allowance must be made for the tunnel giving access to the Shuttle. Moreover the laboratory's weight will depend on the Shuttle interface equipment, the orbital characteristics, and the maximum weight the Shuttle can return to earth (14 500 kg). Allowing a safety margin, European experts have allotted 11 500 kg to the laboratory, though it will no doubt be able to weigh more on certain missions; on the other hand, allowance must be made for the centre of gravity of the laboratory since the latter must be located at the rear of the Shuttle within fairly close limits in order to ensure better aerodynamic stability during re-entry.

Modules and Platforms

The Spacelab design has gradually crystallised over the last two years. The feasibility studies in 1972 were followed by the phase B definition studies in 1973, as a result of which two industrial teams, led by the German firms ERNO and MBB, concluded at the end of 1972 that it would be possible to build such a laboratory within the budget limit of 308 MAU (at 1973 prices). In February 1974, after completion of phase B, the tenders submitted by the two industrial teams began to be analysed to enable a final selection to be made in June 1974.

Spacelab will consist of pressurised habitable sections, and of unpressurised platforms (pallets) exposed to space on which observation instruments such as telescopes will be mounted. In no case will more than three members of the crew be in the pressurised modules at the same time, the fourth man being in the Shuttle. The men will not wear spacesuits and will breathe a 20 %/80 % mixture of oxygen and nitrogen at normal atmospheric pressure.

The three-man Shuttle crew will have received astronaut training, whereas the Spacelab crew could be composed of engineers or researchers having received only limited training. Studies are currently under way in order to determine the exact role of each man.

Three different mission configurations can be envisaged at this stage:

1) A pressurised section of modest size joined to a large platform, with two or three specialists taking turns in conducting observations. This is the configuration envisaged for astronomy, atmospheric physics and earth study missions.

involved, it was decided not to use that part of the Shuttle's computing facilities which is not in full use once the Shuttle is in orbit; instead, Spacelab will have its own computer.

Details of the final configuration have not been « frozen » yet, and there are many options still to be studied. In order to ensure compatibility between the Shuttle and the laboratory, the Memorandum of Understanding signed by ESRO and NASA provided for a Joint Spacelab Working Group, which takes all decisions affecting the two agencies. A document has been prepared laying down the basic specifications and overall guidelines for the Spacelab programme, while another sets out the joint working procedures, the phases of the programme, and the resources to be used. In this way the two agencies hope to be able to build a system which will satisfy users and at the same time remain within specified budget limits.

THE ARIANE LAUNCHER

Ariane will be a heavy launcher capable of placing a 1 500 kg payload in transfer orbit, corresponding to a 750 kg payload in geostationary orbit, or a 700 kg payload in escape trajectory. This programme was proposed to the European countries by France in December 1972 and stems from the preliminary studies of the Europa-3 launcher begun by ELDO in 1969-1970 as a successor to Europa-2.

The primary goal of the programme is to develop such a launcher; the second objective is to organise production of an operational launcher at a competitive cost. The production cost per launcher is now estimated at 10.3 MAU, provided two launches are made each year and not including launching costs (estimated at 2.2 MAU).

The Ariane launcher is aimed at a potential market of 35 to 50 satellites weighing from 400 to 800 kg, which could be built in Europe between 1980 and 1990. These satellites could be for Europe's own use, or could be built by Europe as part of a world-wide system or for countries of the Third World. Four test launches are to be made between 1979 and 1980 before the Ariane launcher makes its first operational flight at the end of 1980.

The Ariane launcher development programme has been the subject of an Arrangement between ESRO and the countries taking part in the programme, and of an Agreement between ESRO and the French space agency CNES, approved by the ESRO Council in December 1973. The programme is to be managed entirely by CNES and funded up to 62.5 % by France, with ESRO merely supervising its execution in conformity with the agreements signed.

The text of the arrangement stipulates that the participating countries—Belgium, Denmark, Federal Germany, France, Italy, Netherlands, Spain, Sweden and Switzerland—have, through

SPECIFICATIONS OF EUROPA-2 LAUNCHER

	1st STAGE (BLUE STREAK)	2nd STAGE (CORALIE)	3rd STAGE (ASTRIS)	PERIGEE STAGE
number of motors	2	4	1	1
empty weight (metric tons)	6.5	270	0.885	0.105
thrust (kN)	1.334	2.252	23	42
fuels	O_2, kerosene	N_2O_4, UDMH	N_2O_4, aerozine 50	solid
weight of fuels (metric tons)	89	10	3	0.685
height (metres)	18.4	5.8	3.8	1.8
diameter (metres)	3	2	2	0.8
specific impulse in vacuum (seconds)	286	281	298.5	275.5
combustion time (seconds)	160	103	36	45

Shroud: 4.3 m high; 2 m in diameter.

ESRO, entrusted to CNES execution of the development phase of the Ariane launcher programme and have made ESRO responsible for supervising the execution on their behalf. Though it is not a party to this arrangement, the United Kingdom has concluded a separate agreement with France. Its participation consists, *inter alia*, in studying and integrating the launcher's inertial guidance system.

The arrangement is restricted to the programme's development phase. The production phase will be the subject of a further arrangement to be concluded subsequently between the interested states.

The agreement between ESRO and CNES sets out how the tasks are to be apportioned:

CNES is to manage the programme technically and financially; define launcher configuration and performance; define and set up the necessary industrial organisation; select contractors and award contracts. CNES is required to comply with the rules for geographical apportionment of contracts; to give ESRO the information required for preparing annual budgets and supervising progress of the work; to make the necessary facilities available to the participating countries, particularly the facilities at the Guiana range; and to organise a project team.

ESRO is to supervise execution of the programme and to that end is to submit to the Programme Board the technical, financial and administrative documents prepared by CNES; pass on information and opinions to the Programme Board; duly notify the latter if ESRO's Director General feels that certain action taken by CNES runs counter to the Agreement or the Arrangement; define launcher/payload interface specifications; provide coordination with potential users; determine the content of the legal provisions and contractual clauses in industrial contracts; prepare annual programme budgets; and organise a team to assist ESRO's Director General.

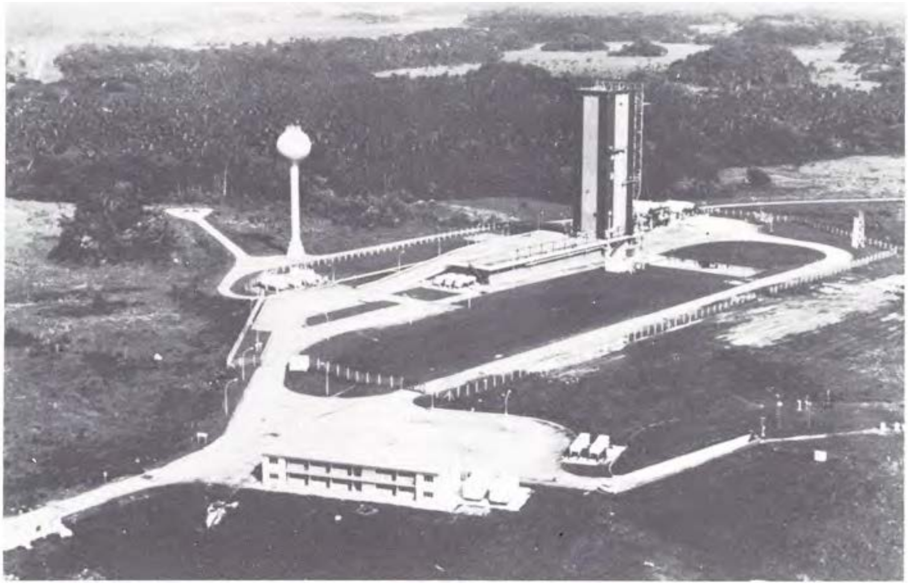
Coordination between CNES and ESRO will be all the more effective in that the members of the ESRO team will have access to CNES in-house meetings, to meetings organised by CNES, and to companies taking part in the development of the launcher. CNES is further required to provide ESRO with monthly and annual reports on progress of the work and on implementation of the funding schedule. For its part, ESRO will ensure that contracts are fairly apportioned geographically.

The Arrangement stipulates that the CNES project team will consist of about 100 people and that the costs incurred by it and by supporting technical personnel will be borne by the French government. Direct development costs on the launcher have been evaluated at 380 MAU. All the participating countries have furthermore agreed to cover additional expenditure arising from unforeseen technical snags, provided it does not exceed 20 % of direct development costs, thus raising the total commitment to 445 MAU. France is committed to bearing single-handed any further cost overruns up to 15 % of the direct development cost. Should the overrun be still larger, the participating countries would jointly decide what action to take on the programme.

SPECIFICATIONS OF ARIANE LAUNCHER

	1st STAGE (L 140)	2nd STAGE (L 33)	3rd STAGE (H 8)
number of motors	4	1	1
empty weight (metric tons)	13.270	3.24	1.13
thrust (kN)	2 712 ± 24	699 ± 6	60
fuels	N_2O_4, UDMH and H_2O	N_2O_4, UDMH and H_2O	liquid hydrogen and oxygen
weight of fuels (metric tons)	140	33.028	8
height (metres)	18.39	11.5	8.58
diameter (metres)	3.8	2.6	2.6
specific impulse in vacuum (seconds)	277.6	285.4	430
burning time (seconds)	140	131	563

Shroud: 8.65 m high; 3.2 m in diameter.



The EUROPA-II *launch site, situated at Kourou, in French Guiana, will be modified for the European launcher Ariane.*

The participating countries contribute to the cost of the programme's development phase in their own national currencies on the following basis: Belgium 5 %, Denmark 0.5 %, France 62.5 %, Germany 320 000 000 DM (fixed contribution), Italy 5 000 000 000 lire (fixed contribution), Netherlands 2 %, Spain 2 %, Sweden 1.1 %, Switzerland 1.2 %. ESRO receives further revenue with an upper limit of 11.250 MAU from the bilateral agreement signed between the French and British governments.

The contracts awarded by CNES to the industries of the participating countries are proportional in value to the countries' contributions to the overall project.

The budget is approved each year on a two-thirds majority by the Programme Board, which also supervises launcher construction and performance. This Board will also decide by a twothirds majority when the transition to the launcher production phase is to be made.

The project is to run for seven years. The definition phase was completed at the end of 1973 and the contracting concerns were selected in February 1974. Development of the launcher is to be completed by November 1980. An initial rocket stage component development and qualification phase will be spread over three years, development and qualification of the stages themselves over one year and a half, and the four test flights (two development and two qualification flights) over two years. The first test flight is scheduled for early 1979.

The production phase should be initiated 2 1/2 years before the operational phase begins. ESA will have ownership of all launcher components, as well as all installations and equipment acquired in the course of the launcher's development.

An offspring of the Europa-3 project, the Ariane launcher will have three stages instead of two. It will be 47.60 m high and weigh 202 tons at lift-off. It will be launched from the Kourou range in Guiana and will make partial use of the launch site built for Europa-2. Although the concrete launch pad will be strengthened and the existing tower suitably adapted, it will be necessary to build a new test cell. The launch facility's infrastructure (the firing blockhouse) and the rocket stage assembly area can be used virtually without modification. The modified launch site will be ready in 1977.

IV THE NATIONAL ORGANISATIONS

Through the centuries, Europe has been a land of diversity. And so it remains today, as any survey of the national space activities of the ten member countries of ESRO will show. National projects were initiated throughout the 1960s. The organisation of space programmes and the scale of funding vary widely from country to country, and the policies adopted testify to significantly different attitudes to the problems of advanced technology and industry promotion.

Nonetheless, it is possible to divide the European countries into three categories based on the scale of space activities:

1. Belgium, Denmark, Sweden and Switzerland have no national satellite programmes but participate in the European effort through ESRO and through bilateral cooperation projects.

2. The Netherlands and Spain recently undertook to develop their first national satellites, mainly in order to help their industries to expand more rapidly and participate more extensively in ESRO projects.

3. The Federal Republic of Germany, France, Italy and the United Kingdom have already developed several satellites. These satellite projects stem from space programmes which, as within ESRO, are formulated systematically several years ahead.

The way in which national projects or programmes are organised naturally depends on their importance. As a rule, countries which have developed or are developing satellites have made a government technical agency responsible for running or supervising the programmes. In many instances, such an agency existed already: initially aviation-oriented, it consequently assumed a space-oriented function as well. France and Germany are the only two countries to have set up their own national space agencies in the early 1960s (Centre National d'Etudes Spatiales (CNES) and Gesellschaft für Weltraumforschung (GfW), respectively). Even so, the stated missions of these two agencies are similar in some respects and different in others.

In three countries (the Netherlands, Sweden and the United Kingdom) two ministries are simultaneously responsible for space activities, with the Ministry of Education handling all research aspects and scientific experiments. Responsibility for technical and industrial aspects falls on the Ministry of the Economy or the Ministry of Industry.

In the other countries, responsibility for space matters is assumed by only one ministry, which differs according to whether the country is more concerned with space research activities or with industrial preoccupations. We have endeavoured to clarify the position in the following comparative table, the roles of the various bodies listed being explained in the text matter devoted to each country.

It might be thought that the national budgets allocated for space activities by countries placed in the same category would be roughly comparable, but this is not so. Since 1967, for instance, the United Kingdom's national space budget has been only half as large as those of France and Germany. Conversely, Sweden's budget has always been larger than those of Denmark and Switzerland. In fact, proportionately speaking, the effort devoted to space activities by these three countries is greater than that of France, Germany, Italy or the United Kingdom.

ORGANISATION OF SPACE RESEARCH IN THE EUROPEAN COUNTRIES

	RESPONSIBLE MINISTRY OR ORGANISATION	DEFINITION OF PROGRAMMES AND BUDGETS	CONSULTATIVE SCIENTIFIC BODY	MANAGEMENT OF PROJECTS AND INDUSTRIAL CONTRACTS	MAIN NATIONAL TECHNICAL CENTRES
Belgium	Services of Scientific Policy Planning	Universities and Institutes			
Denmark	Ministry of Education (Danish Research Administration)	Danish Space Board			
France	Ministry of Industrial and Scientific Development (SEPOR)	CNES	Comittee for Scientific Programmes Comittee for Application Programmes	CNES	Brétigny, Toulouse and Guiana Space Centre (CNES)
Germany	Ministry of Research and Technology	Ministry of Research, GfW and DFVLR		GfW-DFVLR	Oberpfaffenhofen (DFVLR) Porz-Wahn (DFVLR)
Italy		CNR (Commission for the study of space problems)		CNR CRA	
Netherlands	Ministry of Economic Affairs and Ministry of Education and Science		Committee for Geophysics and Space Research	NIVR	Amsterdam (NLR)
Spain	Air Ministry	National Commission for Space Research (CONIE)		INTA	Madrid (INTA)
Sweden	Ministry of Industry and Ministry of Education	Swedish Board for Space Activities	Scientific Committee of the Swedish Board for Space Activities	Swedish Space Corporation and Technical Development Board	
Switzerland	Federal Dept. of the Interior		Commission for Space Research of the Swiss Natural Sciences Society	Scientific laboratories	
United Kingdom	Departement of Trade and Industry and Ministry of Education and Science	Department of Trade and Industry and Science Research Council		Contracts Division of the Ministry of Defence	Farnborough (RAE)

Belgium

Space activities are the responsibility of the Scientific Policy Planning Services (Services de Programmation de la Politique Scientifique), which come directly under the Prime Minister's department. These Services include a four-man Space Section.

MAIN BELGIAN LABORATORIES INVOLVED IN SPACE ACTIVITIES
— Astrophysics Institute of Liège University
— Aeronautical Laboratory of Liège University
— Institute of Space Aeronomy, Brussels
— Laboratory of Mechanics, Mineralogy and Astrophysics of the Free University of Brussels
— Institute of Astronomy of the Free University of Brussels
— SimonStévin Institute, Bruges
— Royal Observatory
— Royal Meteorological Institute
— Catholic University of Louvain (Faculties of Applied Science, Geography and Geology)
— Institute of Geology, Ghent University
— von Karman Institute of Fluid Dynamics

However, other ministries are also involved in space matters: the Ministry of Foreign Affairs (for international commitments and agreements), the Ministry of Communications (for telecommunications and air navigation), the Ministry of National Education (for meteorology) and the Ministry of Defence.

As a rule, research activities based on instrumentation placed on board satellites, sounding-rockets or balloons are funded as part of the particular scientific discipline to which they relate, rather than collectively under « space activities ». It is therefore impossible to assess the Belgian space budget as such.

Denmark

Responsibility for space matters in this country falls to the Danish Research Administration. There is no government department for exclusively handling space activities, but these are taken care of by an international section within the administration. The Danish Research Administration is a branch of the Ministry of Education.

Other ministries are concerned with space matters too, however. The ministry of Foreign Affairs provides Danish representation at the European Space Conference. The Ministry of Public Works assumes responsibility for the use of communications satellites and for Danish participation in Intelsat, the Ministry of Defence for the use of weather satellites.

Proposals for experiments received from the Danish Space Research Institute, laboratories and industries are submitted through the Danish Space Board. Upon recommendations by the Board a major part of the experiments is financed by the means of a special fund in the budget.

Over the last years grants to the Danish Space Research Institute have amounted to about 50 % of the fund. The remaining part has been distributed between the Meteorological Institute and Elektronikcentralen (a private, non-profit institute, which began its space activities in January 1967). It has test facilities and can in principle assume prime contractorship.

MAIN DANISH LABORATORIES INVOLVED IN SPACE ACTIVITIES
— Danish Space Research Institute (DSRI) — Ionosphere Laboratory of the Danish Meteorological Institute — Laboratory of Electromagnetic Theory of the Technical University of Denmark

In the coming years proposals for experiments are also expected from other institutes and some industries.

France

Since 1969 the ministry in charge of space matters has been the Ministry for Industrial and Scientific Development; previously this had been the responsibility of the ministry in charge of scientific research. France is the first European country to have set up a national space agency, the Centre National d'Etudes Spatiales (CNES). The latter prepares space programmes and the national space budget and submits them to the Ministry for Industrial and Scientific Development for discussion and approval. CNES also advises the government on French participation in multinational programmes and, together with the Ministry of Foreign Affairs, provides French representation in ESRO.

Within the Ministry for Industrial and Scientific Development, the Department of Research Agency Programmes (Service des Programmes des Organismes de Recherches - SEPOR) is primarily responsible for space matters. There are three people concerned with space problems in this Department.

Other ministries also have an interest in space research. The Ministry of Posts & Telecommunications is concerned with communication satellites in liaison with CNES, while the Ministry of Transport investigates aeronautical, maritime and meteorological satellite problems, also in liaison with CNES.

In preparing the national space programme and the corresponding budget, CNES solicits the opinions of several consulting bodies. The director-general of CNES is assisted by a senior scientific adviser. Proposals for experiments from laboratories are discussed also by a Scientific Programmes Committee and an Applications Programmes Committee. The strictly national programme and budget, together with projects for experiments to be carried out on a cooperation basis with ESRO or with other countries, are submitted by CNES to the Ministry for Industrial and Scientific Development.

Having discussed the programme and the budget, the Ministry for Industrial and Scientific Development formally turns them over to the government for approval. Decisions on multi-annual programmes are usually taken by an interministerial council on which all the interested ministries are represented.

All national programmes are controlled by CNES. Created in December 1961, CNES succeeded the National Space Research Committee (Comité National de Recherches Spatiales) formed in 1959, and went into operation on 1st March 1962. It currently employs approximately 1 100 people, not counting the personnel of service concerns working under contract for CNES.

The contracts relating to the different programmes are issued directly to industry and laboratories by CNES. The latter may also act in the capacity of project integrator, both for satellites and for launchers and sounding-rockets. CNES has acted as prime contractor for all French satellites launched to date, as well as for the Diamant-B rocket, and has performed the integration work on these satellites in its technical facilities.

This industrial policy of project management by CNES, which was necessary in the early stages of French involvement in space matters, is being gradually relaxed. Thus the D-2B satellite was designed and integrated entirely by industry.

CNES runs several technical centres equipped with extensive design and test facilities (the Brétigny Technical Centre, the Toulouse Space Centre, the Guiana Space Centre and the Balloon Launching Centre at Aire-sur-l'Adour).

The first to be set up, the Brétigny Centre became operational in 1964 and employed 420 people in January 1973. This Centre has very substantial testing equipment, including a 30-cubic metre simulation chamber and a computing facility that was endowed in 1972 with a CDC 6 600 computer. The FR-1, D-1A, D-1C, D-1D, Peole, D-2A, Eole, SRET-1, D-5A and D-5B satellites were all tested in the 30-cu.m simulation chamber. Beginning in 1968-69, the activities and equipment of the Brétigny Space Centre were gradually transferred to Toulouse. The Brétigny centre is due to be closed down sometime in 1974-75.

The decision to move some of the CNES teams to Toulouse dates back to 1963. Work on the Toulouse Space Centre was begun in 1966 and the new facility was officially inaugurated on 1st March 1968. In January 1973 the Toulouse Centre employed 410 people and this figure is expected to rise to about 1 000 when the centre is completed. In it are concentrated the former Brétigny Satellite, Sounding-Rocket and Balloon Divisions, an Administration and Financial Division and two Electronics and Aerospace Technical Divisions, and by 1975 these will be joined by the Mathematics, Ground Equipment and Operations Divisions.

The Toulouse Centre operates test facilities formerly installed at Brétigny, as well as new facilities. In September 1971 a new space simulation chamber 6 metres in diameter and 7 metres high became operational and is used for tests on the Symphonie satellite and the Meteosat radiometer. Operation and maintenance of the test equipment is entrusted to a servicing concern (Société pour le Perfectionnement des Matériels et des Equipements Spatiaux—SOPEMEA).

At first, the launcher programmes were organized differently from the satellite programmes. Because initial design work on rocket stages had been done by the military, in 1962 the French government instructed the Ministerial Delegation for Armament to build a first Diamant satellite launcher which, up to 1967, was launched from the military range at Hammaguir in Algeria. CNES took over prime contractorship on this rocket in 1966 and has since built a civil launch facility at Kourou (French Guiana).

The Guiana Space Centre became operational on 9 April 1968 and the first satellite was launched in March 1970. This Centre is equipped to launch liquid—and solid—propellant sounding-rockets, Diamant rockets, and heavy European launchers. It is from this facility that the European Ariane rocket is to be launched, beginning in 1978-1980.

The Diamant launcher or its rocket stages are tested either in the Technical Centres or by the manufacturer. Compatibility tests and integration of all the rocket's functional subsystems are carried out at Saint-Médard-en-Jalles (Gironde, France), in the CNES launcher integration building.

In addition to the Guiana launch, facility, CNES uses the military bases of the Landes proving-ground and the Mediterranean Test Centre for sounding-rocket launches. It also operates a mobile base that can be set up at various points on the globe, for instance in the Kerguelen Islands. At Aire-sur-l'Adour, in south-western France, CNES has set up a balloon launching facility covering over 1 100 square metres, and in summer carries out other balloon launches from a smaller station at Gap-Tallard (Hautes-Alpes).

MAIN FRENCH LABORATORIES INVOLVED IN SPACE ACTIVITIES

- Space Astronomy Laboratory, Marseille
- Centre for Space Research on Radiation, Toulouse
- Ionosphere Research Group, Orléans
- Department of Space Radio Research of the National Telecommunications Research Centre
- Space Geodesy Research Group
- Aeronomy Service
- Stellar and Planetary Physics Laboratory
- Space Astronomy Group of Paris-Meudon Observatory
- Electronic Physics Department of the Nuclear Research Centre, Saclay
- Dynamic Meteorology Laboratory
- Laboratories of the Universities of Paris VI, Paris XI, Aix-Marseille I, Toulouse III, Montpellier II

CNES has also set up a network of six ground stations located at Brétigny-sur-Orge (France), Las Palmas, in the Canary Islands (Spain), at Brazzaville (People's Republic of the Congo), at Ouagadougou (Upper Volta), at Pretoria (South Africa) and at Kourou. The locations of these stations, which have been operational since 1966, were selected to enable signals to be received at least once per orbit from equatorial satellites or from satellites in orbits inclined at between 0 degree and 45 degrees. The network's six stations are equipped to be able to track, receive telemetry data from and telecommand the satellites. When satellite launches are made, these stations, as well as the Guiana Space Centre, are in constant voice communication with COBY (Centre d'Opération de Brétigny), an operations centre located at Brétigny. This centre, as well as the telemetry and telecommand station at Brétigny, are due to be transfered to Toulouse.

Federal Republic of Germany

Since 1962 space research in the Federal Republic of Germany has been the responsibility of a ministry known since 1972 as the Federal Ministry for Research and Technology (Bundesministerium für Forschung und Technologie). This ministry's responsibilities are wide-ranging, since it prepares the national space programme, determines the funding needed and fixes the extent of German participation in European programmes. It is assisted in this field by a 100 % government funded, space managing company, the GfW (Gesellschaft für Weltraum-forschung m.b.H.), and uses the scientific and technical expertise of an aerospace research organisation, the DFVLR (Deutsche Forschungs- und Versuchsanstalt für Luft und Raumfahrt E.V.). In 1972, the GfW and the DFVLR merged to form a single aerospace organisation.

The department « Space and Transportation Systems » of the Ministry for Research and Technology includes a sub-department which employs 24 people, and is concerned solely with space matters. Another 5 people in the department deal partly with space matters (administrative matters of national space institutions). International cooperation is dealt with by another department of the ministry through its sub-department « International and Inter-German cooperation » which is concerned with multilateral and bi-lateral cooperation in the space field. Other federal ministries have limited responsibilities in the space field, mainly representing certain governmental user interests.

The Ministry prepares the scientific space programme, the corresponding budget requirements (which are part of the Federal research and technology budget) and represents the Federal Republic in ESRO and in the field of bi-and multilateral scientific cooperation. A programme « Rahmenforschungsprogramm der extraterrestrischen Forschung in der Bundesrepublik Deutschland 1972-1980 » of the Ministry was issued and a preparatory programme for earth resources survey is under review. The Ministry coordinates the German participation in Meteosat. Proposals for scientific experiments from 10 university institutes, 5 institutes of the Max-Planck-Gesellschaft and 5 other research institutions are submitted to the ministry for approval through GfW and DFG (Deutsche Forchungsgemeinschaft). Experiments are funded by the Ministry through the same channels. In scientific matters the Ministry is advised by a scientific working group.

Space projects are managed by GfW, the Federal space agency which was set up in 1962 and currently employs approximately 320 people. It does not assume prime contractorship but awards contracts to industry and scientific laboratories for all space programmes and supervises the industrial work connected with them. GfW also assists the government on request in planning and defining national, European and bilateral space programmes.

In preparing and fulfilling national space programmes, the government is among other advisers assisted by a research institution, the DFVLR (Deutsche Forschung- und Versuchsanstalt für Luft und Raumfahrt E.V.). DFVLR was born in 1969 of the merger of three aerospace research institutions: the AVA (Aerodynamische Versuchsanstalt Göttingen), the DVL (Deutsche Versuchsanstalt für Luftfahrt) and the DFL (Deutsche Forschungsanstalt für Luftfahrt). In addition to doing aeronautical and space technological research DFVLR gives functional support to space projects.

DFVLR has since concentrated all its space activities within a single department, the BRP (Bereich für Raumflugprojekte), which comprises a space operation control centre and a mobile sounding rocket base both at Oberpfaffenhofen (near Munich) and the central German tracking, telemetry and telecommand station at Weilheim (near Munich). In 1973 it employed about 350 people out of the 3 600 in DFVLR, while the proportion of DFVLR's budget—144 million DM in 1971 and 166 million in 1972—devoted to space has increased steadily, reaching 41 % in 1972.

In January 1972 the GfW was attached to the DFVLR and more specifically to the BRP. GfW's annual budget was about 15 million DM in 1971 and 1972.

In order to overcome the geographical dispersion of the institutions coming under it, the DFVLR created five research departments in addition to the BRP. Some of these departments are primarily concerned with aeronautics (aeronautical research and testing at Braunschweig, aerodynamics at Göttingen), while the Stuttgart facility conducts research on chemical and electrical propulsion (about 240 employees). Most of the DFVLR's technical space research activities are concentrated at Oberpfaffenhofen (584 employees) where there are electronics laboratories and space system laboratories. At the Porz Wahn centre (660 employees), there are both space activities—space simulation chambers (45 employees)—and aeronautical activities. GfW also has its headquarters at Porz Wahn. The 1973 budget of the DFVLR including the internal budget of the GfW (not including GfW's payment appropriations for external contracts) amounts to 192 million DM, out of which 103 million are devoted to space activities.

MAIN GERMAN LABORATORIES INVOLVED IN SPACE ACTIVITIES

— Astrophysics and Extraterrestrial Research Institute of Bonn
— Astronomy Institute of Bonn
— Physics Institute of Bonn
— Radio Observation Station of Bonn
— Geophysics Institute of the University of Göttingen
— Institute of Pure and Applied Nuclear Physics, University of Kiel
— Institute of Meteorology, University of Munich
— Department of Extraterrestrial Physics, University of the Ruhr, Bochum
— Institute of Astronomy, University of Tübingen
— DFVLR's Institute of Physics of the Atmosphere, Oberpfaffenhofen
— DFVLR's Radio and Microwave Institute, Oberpfaffenhofen
— Max Planck Institute of Astronomy, Heidelberg
— Institute of Extraterrestrial Physics of the Max Planck Institute of Physics and Astrophysics, Garching
— Institute of Ionospheric Physics of the Max Planck Institute of Aeronomy, Lindau
— Max Planck Institute of Nuclear Physics, Heidelberg
— Biophysics Research Group, Frankfurt
— Space Physics Research Group, Freiburg
— Institute of Geophysics and Meteorology, Braunschweig

Although these five departments have extensive research and testing facilities, they do not assume prime contractorship on satellites or sounding rockets as does GfW.

In space matters the federal government also relies on the assistance of IABG (Industrie Anlagen Betriebgesellschaft), a public company with a broad spectrum of activities in technical testing and systems analysis. It runs especially extensive aerospace test facilities which are made available to all organisations as well as to industry. Since 1963 IABG has been interested in space matters and has installed a large space simulation chamber 3 metres in diameter, shock machines, vibrators, magnetic and electrical measurement laboratories, etc. Located at Ottobrunn, near Munich, the IAGB employs in all its departments 400 people, out of which about 60 are solely concerned with space matters. As for the DFVLR, at Lampoldshausen it has seven rocket test-stands capable of handling thrusts ranging from one kilogramme to 100 tons, and has other test-stands at Trauen with capacities up to 10 tons of thrust.

Italy

The National Research Council (CNR), which coordinates national research and development activities, is the body in charge of space activities in Italy and is responsible for funding them. Within the CNR, this responsibility is assumed by the Space Activities Department, which coordinates national and international programmes and follows the activities of ESRO and the European Space Conference.

Several ministries are also interested in space research: the Ministry of Scientific Research (which does not have a budget); the Ministry of Foreign Affairs, whose Directorate of Economic Affairs and Office of Space Affairs share the political and administration aspects of matters arising from Italy's membership of ESRO; the Ministry of Posts and Telecommunications; the Ministry of Transport and Civil Aviation (for matters concerning air navigation); the Ministry of Defence and Aeronautics (meteorology satellites), and the Ministry of Trade and Industry (for matters relating to technological development).

Space programmes are formulated by the National Research Council's Space Problems Study Commission (CISPS), whose members are elected by the CNR committees on physics, mathematics, engineering and architecture, technology, biology and medicine. Proposals for national and European programmes are submitted for approval by the CNR to the Interministerial Committee on Space Activities (CIAS), which is chaired by the Minister of Scientific Research. Once technical approval has been obtained from the CIAS, projects are submitted in turn to the Interministerial Committee on Economic Programming (CIPE) which is empowered to authorise the funding of such projects. After the budget has been approved by the Cabinet and Parliament, the CNR releases the space credits to scientific laboratories and industry.

The CNR runs the Sirio experimental communications satellite, while the Aerospace Research Centre (CRA) in Rome manages the San Marco scientific satellites programme.

In 1960 the CNR and the Ministry of Defence were each allotted a space budget of 300 million lire. In 1963 a sum of 4 500 million was assigned for three years to the San Marco programme; in 1967 this programme was granted a further 1 000 million and 1 200 million were also released to Rome University's CRA. A budget of 1 700 million lire was granted to national laboratories for the years 1967-1968.

The CRA concerns itself with aeronautics as well as with space matters and has a large technical centre at its disposal. The Compagnia Industriale Aerospaziale (CIA), which is prime contractor for the Sirio satellite, also operates test facilities of its own, as do other companies and various state-run laboratories. There is no national space agency in Italy.

MAIN ITALIAN LABORATORIES INVOLVED IN SPACE ACTIVITIES

Laboratory	
— Laboratory for the study of Space Plasmas, Rome	of CNR
— Laboratory of Cosmic Physics, Milan	of CNR
— Laboratory for the study of Extraterrestrial Radiation, Bologna	of CNR
— Institute for Research on Electromagnetic Waves, Florence	of CNR
— Frascati Laboratory	of CNR
— Laboratory of Geophysics of the Lithosphere, Milan	of CNR
— Institute of Applied Mechanics and Machines, University of Padua	
— Aerospace Research Centre of Rome University	

Netherlands

The Ministry of Education and Science first began to concern itself with space matters in 1960, and the following year the Ministry of Economic Affairs also turned its attention to space.

These two ministries share prime responsibility and funding for space projects. The Ministry of Economic Affairs is concerned primarily with industrial aspects. The Ministry of Education and Science is responsible and provides funding for the national scientific programme and for the ESRO programme except where industrial and user interests are concerned.

Five persons deal with space matters in each of these two ministries. Other ministries are also involved, however: the Ministry of Foreign Affairs (international commitments, collaboration with other countries), and the Ministry of Transport (representing users in the fields of communications, meteorology and air and maritime navigation). Coordination between the ministries is provided by the Interdepartmental Committee for Space Research and Space Technology (ICR).

The advisory body for space matters for the Ministry of Education and Science, which submits proposals for experiments to be carried out by ESRO, is the Netherlands Committee for Geophysics and Space Research (GROC), formed under the Royal Netherlands Academy of Arts and Sciences. This committee coordinates the work of five working groups, which are concerned respectively with solar and stellar space research, cosmic radiation, photometry, and satellite geodesy, the fifth being concerned with the activities of the National Aerospace Laboratory (NLR), Amsterdam.

Another body also advises the government on space matters: the Netherlands Agency for Aerospace Programmes (Nederlands Instituut Voor Vliegtuigontwikkeling en Ruimtevaart), or NIVR. Created in 1946 to deal with aircraft development programmes, the task of NIVR was extended to space matters and notably to managing the ANS (Astronomical Netherlands Satellite) project, by a government decision in 1971.

NIVR currently employs 26 people, nine of whom deal with space matters. NIVR has no technical centres or laboratories and cannot act as prime contractor; it may award contracts and it manages the contract awarded to the industrial consortium for developing and building the ANS satellite. Its operating budget was 9.6 million guilders in 1971 and 25.3 million in 1972. in 1972.

Space budget expenditure in the form of industrial contracts rose from 34 % in 1970 to 53 % in 1971 and levelled off at around 51 % in 1972. During that same period, the proportion of contracts awarded to laboratories fell from 66 % to 47 %, then rose to 49 %. The Universities place the contracts for their experiments.

The Netherlands has had a space research organisation since 1960: the National Lucht en Ruimtevaart-laboratorium, Amsterdam. Currently the NLR employs 645 people, 26 of whom are in the space sector, and its space budget was 2.4 million guilders in 1971 and 2.7 million in 1972. It possesses test facilities (vacuum chamber, simulation chamber; vibrators) and conducts technology-oriented research on behalf of ESRO and NIVR. It is participating in the ANS project and has programmed the environmental tests and the procedure and software required at the operations centre.

MAIN DUTCH LABORATORIES INVOLVED IN SPACE ACTIVITIES

- University of Utrecht (solar and stellar astronomy)
- University of Leiden (cosmic radiation)
- University of Groningen (photometry)
- Technological University of Delft (geodesy)
- National Aerospace Laboratory (NLR), Amsterdam

Spain

Created in 1964, CONIE (Comision Nacional de Investigacion del Espacio), the National Commission for Space Research, coordinates and is responsible for space activities in Spain. Although CONIE comes under the Air Ministry, its essentially national character is reflected in the fact that all interested government departments, the University, the National Research Council and industry are represented on it. CONIE prepares all space-related programmes and funding and submits them for government approval. In defining scientific programmes, it is advised by a Scientific and Technical Committee composed of representatives of Spanish scientific bodies.

CONIE is backed by a technical body, the National Institute of Aerospace Technology (INTA). Created in 1942, INTA is concerned with aviation and space matters and with Spanish industry in general. It has a total of 1 700 employees, 1 200 of them in its different centres and 500 in the satellite tracking stations and the El Arenosillo sounding-rocket launch facility. INTA's annual aerospace budget naturally varies with the programmes in hand. It was 1 108 million pesetas for 1973, of which 494 million was for basic activities at INTA and CONIE, 324 million for operation of the ground facilities (tracking stations and launching-range) and 290 million for collaboration with international organisations (chiefly participation in ESRO).

INTA awards contracts to industry and to scientific laboratories and oversees the conduct of the programmes there. INTA may also act as prime contractor, as it is doing for the Intasat satellite and the Inta-255 and Inta-300 sounding-rockets. It has research laboratories and rocket-motor and payload assembly halls, as well as test facilities (a rocket-motor test-stand capable of handling thrusts up to twenty tons and test facilities for antennae and satellite subsystems).

INTA is responsible for operating and maintaining the sounding-rocket launching-range at El Arenosillo, near Huelva. First commissioned in 1966, this facility is capable of handling American Nike sounding-rockets, British Petrel and Skua sounding-rockets, Spanish Inta sounding-rockets and Britain's Skylark rockets.

INTA also helps to run three ground stations: the Robledo de Chavela complex about sixty kilometres from Madrid (on a collaboration basis with NASA since 1965); the Maspalomas station, set up in 1960 on one of the Canary Islands, again jointly with NASA; and the Llanos de Sardinia station erected 36 kilometres from Las Palmas by the French space agency CNES in 1965.

MAIN SPANISH LABORATORIES INVOLVED IN SPACE ACTIVITIES

- National Institute of Aerospace Technology (INTA)
- National Meteorological Service
- Autonomous University of Barcelona
- Leonardo Torres Quevedo Physics Research Centre
- Atomic Energy Commission
- Geographical and Cadastral Institute
- Ebro Observatory and San Fernando (Naval) Observatory, Astronomical Observatory of Madrid and Astronomy Group (Barcelona)

The Robledo complex includes the Robledo and Cebreros centres, both of which form part of NASA's « Deep Space Network », and the Fresnedillas-Navalagamella centre, which is part of NASA's « Manned Space Network ». Each of these three centres is equipped with a 26 m-diameter antenna, and a new antenna with a diameter of 64 metres has just been erected at Robledo. Since 1968 management and operation of these stations has been turned over entirely to INTA. There are 376 Spanish and 40 American citizens working in these centres, which were used in particular to track the Lunar Orbiter and Surveyor moon probes, the Pioneer and Mariner interplanetary probes and the Apollo flights.

The Las Palmas station, which is manned by 25 Spanish and 4 French nationals, was used to track the ESRO-II satellite, the French D-1A, Péole, Eole and D-2A satellites, and a number of American satellites. The Canary Islands station was used to follow the flights of a number of US interplanetary probes and manned capsules as well as certain unmanned satellites.

Sweden

The Ministry of Education has dealt with space matters since 1959 and the Ministry of Industry has come into the picture gradually since 1964. In 1972 the Swedish Board for Space Activities was created under the Ministry of Industry and took over responsibility for all Swedish space work, both national and international. Industry, the scientific community and the four ministries for Industry, Education, Communications and Foreign Affairs are represented on this Board. The Ministry of Industry is concerned with space applications and industrial policies; the Ministry of Education with the scientific aspects of space exploration. The Board has one full-time executive member who is also Chairman of the state-owned Swedish Space Corporation. The planning and administrative functions of the Board are performed by the Corporation under special contracts. The Corporation is responsible for the technical execution of the national space research programme and it directs activities at the sounding rocket range Esrange at Kiruna.

The annual Swedish space budget is approximately 8 MAU including the contribution of about 6 m to ESRO. About 4.5 MAU comes from the Ministry of Industry and 3.5 m from the Ministry of Education.

Proposals for experiments which laboratories and universities wish to carry out as strictly national projects, in cooperation with ESRO or in cooperation with other countries, are submitted to the Swedish Board for Space Activities through its Science Committee. Preparatory work in other fields is performed by advisory committees on remote sensing and on general space applications.

Industrial contracts relating directly to space projects are channelled through the Swedish Space Corporation, while more general development contracts are awarded by the Swedish Board for Technical Development out of its own funds. The Corporation is backed by its two technical centres at Stockholm (25 employees) and Kiruna (35), which have special test and other facilities. This enables them to keep track of work being done in industry and to conduct some development work of their own.

MAIN SWEDISH LABORATORIES INVOLVED IN SPACE ACTIVITIES

— Kiruna Geophysical Institute

— Space Physics Group, Department of Plasma Physics, Royal Institute of Technology (Stockholm)

— Geodetic Institute (University of Uppsala)

— Ionospheric Observatory (Uppsala)

— Section for Atmospheric Physics, Institute of Meteorology (University of Stockholm)

— Astronomical Observatory (University of Lund)

— Stockholm Observatory

— Cosmic High Energy Physics Group, Department of Physics (University of Lund)

— Cosmic Ray Group (University of Uppsala)

— Onsala Space Observatory, Chalmers Institute of Technology (Gothenburg)

Switzerland

Responsibility for space research falls on the Federal Department of the Interior. Other Federal departments are also interested in space matters, however. The Political Department's international scientific affairs section is concerned with multinational cooperation programmes. The Finance and Customs Department assumes responsibility for budget matters. The Public Economy Department's Trade Division is concerned with industrial matters, the Air Bureau of the Federal Department of Transport, Communications, Fuel and Power deals with air navigation matters, and telecommunications are covered by the Posts and Telecommunications authority.

Within the Federal Department of the Interior, space research activities are the province of the Science and Research Division. Swiss space research experiments are financed by the National Scientific Research Fund, a private foundation which draws most of its funds from the Federal Department of the Interior.

The Space Research Commission of the Société helvétique des Sciences Naturelles informs the Political Department and the Federal Department of the Interior of proposals for experiments which laboratories would like to set up either with ESRO or on a bilateral collaboration basis. This Commission is composed of government representatives and scientists belonging to groups engaged in space research.

There is no body specifically responsible for running the space budget in Switzerland. The budget is shared between the different laboratories, and experimenters themselves issue instrumentation manufacturing contracts to industry where necessary. Engineering and tests facilities are all located in industry.

MAIN SWISS LABORATORIES INVOLVED IN SPACE ACTIVITIES	
— Physics Institute of the University of Bern	
— Applied Physics Institute of the University of Bern	
— Astronomy Institute of the University of Bern	
— Observatories of Geneva and Bern Universities	
— Solid Physics Laboratory — Physical Chemistry Laboratory — Applied Mathematics Seminar — Physics of the Atmosphere Laboratory — Crystallography and Petrography Institute	of the Federal Polytechnic School of Zurich
— Geography Institute of the University of Zurich	
— Mineralogy and Petrography Institute of the University of Basle	

United Kingdom

Responsibility for space activities in the United Kingdom is shared between a number of Government departments and agencies. Of these, the Department of Trade and Industry (DTI) has had responsibility for civil space activities since May 1971. The Department is responsible for the industrial aspects of space activities and for technological research. The Department is also responsible for European applications satellite programmes. The Department of Education and Science supports scientific aspects of space research programmes (including ESRO scientific activities) through the Science Research Council (SRC), an independent body set up in 1965.

Other Departments are also involved in space matters:

The Ministry of Posts and Telecommunications is responsible for governmental policy regarding telecommunications satellite systems. Its representatives thus participate in the work of the International Telecommunications Union (ITU) and its technical organs. The Post Office is concerned with the practical applications of communications satellite systems and helps in the operation and management of Intelsat.

The Foreign and Commonwealth Office is concerned with all international aspects of the UK's space programme.

The Ministry of Defence (MOD) is responsible for defence communications and for meteorology programmes. Its Procurement Executive is responsible for the management and conduct of R and D programmes for MOD, DTI and SRC.

The allocation of responsibilities among the various departments applies alike for national programmes and international programmes. Each Department prepares its own projects and the related budget proposals. The latter are submitted for Treasury approval each year in the same manner as other expenditure proposals within the relevant fields of responsibility. The UK delegation to the European Space Conference is provided by the DTI. The UK delegation to ESRO is drawn from DTI and SRC and from other bodies as appropriate.

The Department of Trade and Industry (DTI)has a small « Space Division » concerned primarily with financial, administrative and technical policy matters. Whilst DTI can place contracts directly for work to be undertaken in industry and research laboratories, most of its budget is distributed through the Procurement Executive (see below).

2. *The Procurement Executive* places and manages most of the industry and research contracts on behalf of DTI and SRC. For instance, during the UK financial year 1972-1973 (April 1 to March 31) the Procurement Executive made payments to industry worth £ 3.48 million and £ 2.56 m in respect of contracts placed for DTI and SRC respectively. The headquarters staff of the Procurement Executive engaged directly in space activities numbers approximately 50 people (excluding contract and costing staff). The Procurement Executive's main sources of space expertise are:

— The Space Department of the Royal Aircraft Establishment, Farnborough, employing approximately 200 people, including 106 engineers and technicians. Founded in 1962, the Space Department is concerned more particularly with developing new technology and conducts R and D and sponsors other research in industry. It operates numerous test facilities, including a vacuum chamber 2.5 m in diameter.

— The Rocket Propulsion Establishment, Westcott, where a small number of people are employed on civil R and D, notably in connection with propulsion and hydrazine thrusters for attitude control.

— Other Government establishments, several of which have space communications expertise. Most of these establishments, however, are not concerned solely with space activities and were set up well before 1960.

These technical establishments seldom assume prime contractorship. This is usually given to industry with the Procurement Executive's establishments acting in a supervisory role. Since 1970 approximately 60 % of the funds allocated for space activities have been spent in British industry each year, the remainder going to universities and Government establishments.

The Science Research Council (SRC) is responsible for funding scientific space research in the UK and for the management of the UK's national scientific space activities. Its Astronomy, Space and Radio Board has delegated responsibility for policy and finance in this field. Under the Board is the Space Policy and Grants Committee. The Astronomy Space and Radio Division has the central responsibility for administration and the Council's Appleton Laboratory, Slough, for project management and technical support. The Laboratory, of which the Astrophysics Research Division at Culham is now part, has a staff of about 400 of whom half are engaged in space activities and half in radio propagation and other research. Proposals for scientific experiments submitted to the SRC originate in most cases directly from university experimenters and involve the use of balloons, sounding rockets, and satellites both in the national programme and elsewhere. If accepted, these proposals are implemented by the provision of facilities such as rockets, balloons and satellites either nationally or through ESRO, NASA or otherwise. Contracts for major space hardware, such as satellites and sounding rockets, have usually been placed in industry for the SRC by the Procurement Executive. Experimental payloads and instrumentation are usually developed under grants to university departments. When these involve work by industry, the grants are placed and managed by the university concerned.

MAIN BRITISH LABORATORIES INVOLVED IN SPACE ACTIVITIES

— Imperial College of Science and Technology, London
— Mullard Space Science Laboratory, London
— University College, London
— Universities of Birmingham, Bristol, Cambridge, Leeds, Leicester, Oxford, Reading and Southampton
— Queen's University, Belfast
— Radio and Space Research Station, Slough (now Appleton Laboratory)
— Meteorological Office of Bracknell

V - THE NATIONAL PROGRAMMES

The approach to space projects in each of the three groups of European countries covered in the previous chapter (countries with no satellite programme, countries having developed or in the process of developing their first satellite, and countries having had satellite programmes for several years) is not as different as one might imagine. Notwithstanding some diversity in the projects themselves, certain common trends may be perceived.

First, a common historical trend: projects have evolved from the simple to the complex, from exploration of the near earth environment to interplanetary exploration and astronomical observation. Second, there has been an economic trend: national space budgets expanded fairly rapidly from 1960 to 1970 in the countries with satellite programmes. Third and last, there has been a political trend: in the four countries having satellite programmes, strictly scientific projects are now supplemented by applications programmes.

Unquestionably, however, some of the national programmes are too similar not to lead to some regrettable duplication. It would be attractive, for example, to be able to group national satellites with a similar mission (ultraviolet or X-ray astronomy, say) into a single family that would gradually evolve towards increasingly complex and accurate spacecraft. Indeed the most important and most delicate task of the European Space Agency will be to achieve better-coordinated national programmes.

Belgium

Belgium has no organised national space programme as such. Activities in this field are covered by various independent programmes formulated by the universities and scientific institutes that come under the Ministry of National Education. Space experiments have been conducted with balloons and ESRO sounding-rockets and satellites.

The Astronomy Institute of the Free University of Brussels and the Astrophysics Institute of the University of Liège have each placed an experiment on board ESRO satellites in collaboration with other European laboratories. Both these institutes have also used ESRO sounding-rockets to make regular studies of the upper amosphere, auroral spectra and star spectra, and stratospheric balloons to study ultraviolet and infrared solar radiation, the night sky and crepuscular light. The Belgian Royal Observatory has used American Pageos and Geos satellites to make geodesic observations.

Belgium has cooperated with France and the United States for its balloon launches. Nacelles and payloads alike have been manufactured in Belgium and have weighed an average 1.1 metric tons as a package. A balloon has been launched each year since 1969.

EXPERIMENTS OF BELGIAN LABORATORIES ABOARD ESRO SATELLITES			
LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Univ. of Brussels			
M. Coutrez	HEOS-I 5-12-1968 108 kg	424 km 223 428 km 28.3°	Energy spectrum and angular distribution of solar wind protons (0.15 - 15 keV) (1)
Inst. d'astrophysique, Liège			
L. Houziaux and A. Monfils	TD-1A 12-3-1972 472 kg	533 km 545 km 97.6°	UV (1 350 - 3 000 Å) mapping of celestial objects up to the 9th magnitude (2)

(1) Experiment conducted in collaboration with the Universities of Rome (G. Pizzela) and Florence (A. Bonetti).
(2) Experiment conducted in collaboration with the Royal Observatory of Edinburgh (H. Butler).

Denmark

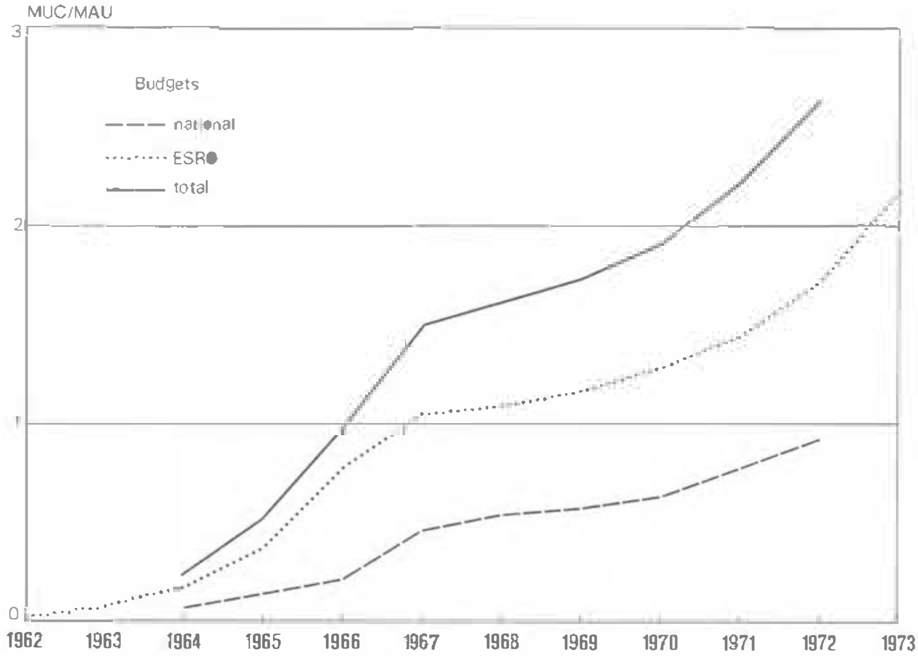
Denmark has no national space programme. Nearly all experiments are undertaken cooperatively, either within ESRO or with an other country. Experiments have been flown in ESRO satellites and sounding rockets, American sounding rockets, and in balloons. Denmark does not build sounding rockets, but only payloads for them.

There are three main establishments with an interest in space: the Danish Space Research Institute (DSRI), the Ionosphere Laboratory of the Danish Meteorological Institute and the Laboratory of Electromagnetic Theory of the Technical University of Denmark.

The Danish Space Research Institute has flown experiments in ESRO satellites and sounding rockets; since 1968, in sounding rockets of the US Air Force Air Weather Service; and in sounding rockets fired under the Scandinavian Space Collaboration scheme. The Meteorological Institute has also flown experiments in ESRO satellites.

The two establishments also carry out research by means of balloons purchased abroad. Each year, the Danish Research Institute uses one or two balloons, varying in size from 70 000 to 270 000 m³ and carrying payloads of up to 500 kg, to investigate cosmic rays. The Meteorological Institute is studying the electrons precipitated during magnetic storms; in 1969 and 1970, some 15 balloons of 4 700 cubic metres capacity were released, carrying Geiger counters and scintillators.

Denmark's space budget.



EXPERIMENTS BY DANISH LABORATORIES ABOARD ESRO SATELLITES			
LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENTS
Danish Space Research Institute, Lyngby B. Peters	ESRO-1 3-10-1968 86 kg	253 km 1 534 km 93.8°	1. Angular distribution and total fluxes of electrons (> 40 keV) and protons (> 500 keV) in the ionosphere [1] 2. Trapped and precipitated protons (100 keV - 6 MeV) in the auroral zone [2]
E. Ungstrup	GEOS mid-1976 180 kg	geostationary orbit	Electric (up to 77 kHz) and magnetic (0.1 - 5 kHz) fields of magnetospheric plasma and its resonance frequencies [3]
Danish Space Research Institute, Copenhagen B. Peters	HEOS-A2 3-1-1972 117 kg	359 km 238 199 km 90°	Very low frequency radio noise (20 - 250 Hz)

(1) Conducted in collaboration with the Norwegian Defence Research Establishment (B. Landwark) and the Space Science Department of ESTEC.
(2) Conducted in collaboration with the University of Bergen, Norway (B. Trumpy).
(3) Conducted in collaboration with the Groupe de recherches ionosphériques of the Centre national d'études des télécommunications (M. Petit) and the Space Science Department of ESTEC (A. Pedersen).

Denmark has a launch site at Sdr Stromfjord, from which an average of three sounding rockets are launched annually. The United States have another site at Thule Air Force Base, from which about 1 000 Arcas, Super Arcas and Loki rockets were fired between 1960 and 1972. Denmark has also built a mobile telemetry station for use with balloons.

France

Space research was initiated in France before 1960. Since then the country has launched, or had launched, nine satellites, including a technological capsule (A-1), two technology satellites (Péole and Sret-1), five scientific satellites (FR-1, D-1A, D-1C, D-1D, D-2A), and a meteorological satellite (Eole). As a cooperative venture with Germany, France has also built an experimental telecommunications satellite (Symphonie). Between now and 1975 it is due to launch three technology satellites (D-5A, D-5B and Sret-2) and two scientific satellites (Starlette and D-2B).

Between 1962 and 1972 France also launched approximately 250 sounding rockets as part of its national space programme, and over 1 200 stratospheric balloons.

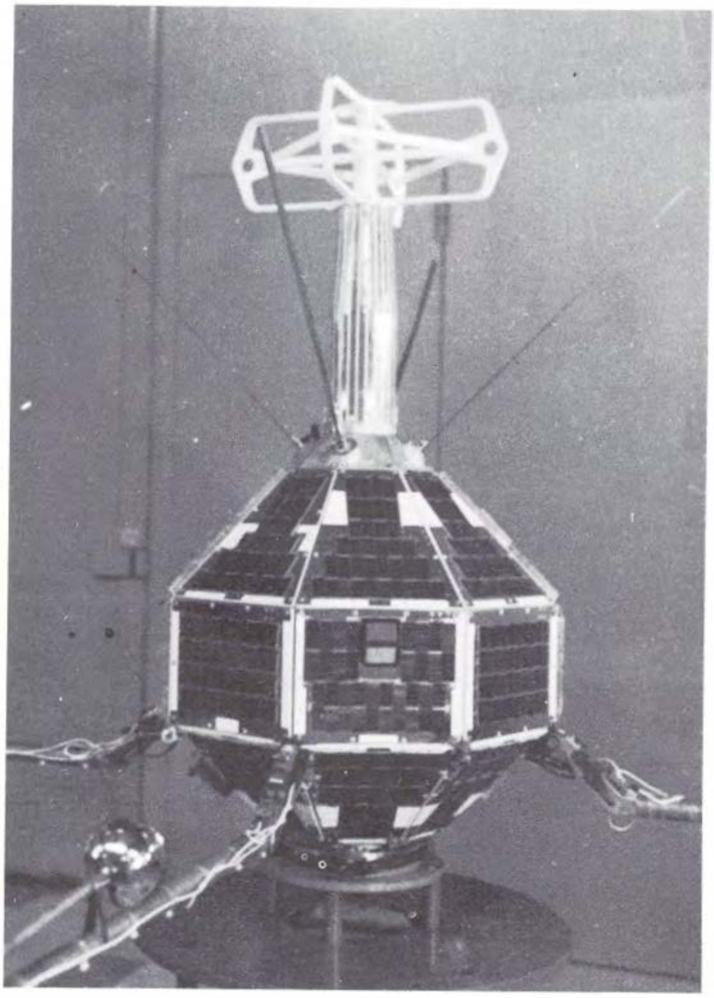
In 1962 France undertook development of the Diamant satellite launcher, which has since been modified twice in order to increase its power. An equatorial launch facility has been built at Kourou, in French Guiana, and a network of six telemetry and telecommand stations has been set up in France and in Africa. The Kourou facility can be used to launch the Diamant rocket, heavy European launchers and sounding rockets.

Concurrently with its national programme, France has undertaken bilateral cooperation projects, initially with NASA and Germany, and from 1966 onwards with the Soviet Union.

When CNES, the French national space agency, was created in 1962, sounding rockets had already been developed in France, along with the rocket stages for the future Diamant launcher. At the same time as CNES began to build the infrastructure it needed (the first technical centre at Brétigny and a network of ground stations) and its first scientific satellites, the French Ministerial Delegation for Armament was given the task, under a directive of 9 May 1962, of designing, developing and testing the Diamant A satellite launcher.

Around 1962-1963 CNES began design work on the future satellites to be orbited by the Diamant rocket. Meanwhile, in February 1963, a first formal agreement was signed with NASA for an American rocket to launch a scientific satellite (FR-1) developed by the Centre National d'Etudes des Télécommunications. The FR-1 was launched in December 1965, and from 1965 to 1967 four Diamant A rockets were successfully launched from the military range at Hammaguir in Algeria. These rockets were used to orbit the A-1, D-1A, D-1C and D-1D satellites.

Because the French government was required to evacuate the Hammaguir base in 1967, CNES was directed in April 1964 to build a civil test range at Kourou, in Guiana, close to the equator. Then, early in 1966, a Launcher Division was created within CNES, and the decision was taken to upgrade the Diamant-A rocket. The new Diamant-B version, for which CNES acted as prime contractor, was equipped with a new first stage utilising liquid propellant. A further improvement was decided on early in 1972: the Diamant BP-4 version, which is to be test-flown in 1974 and has a more powerful second stage and a new nosecone based on Britain's Black Arrow launcher. The Diamant BP-4's power will be comparable to that ot the first American Scout rockets.



FR-1, *the first French scientific satellite, launched in 1965.*

Since 1967 CNES has pursued a threefold policy in the realm of satellites:

- scientific or technological satellites built for launching by the Diamant rocket;
- heavier scientific or technological satellites built for launching by the United States or the Soviet Union;
- scientific experiments placed aboard European, American or Soviet satellites.

EXPERIMENTS ABOARD FRENCH SATELLITES

SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	LABORATORY EXPERIMENTER	EXPERIMENT
FR-1 6-2-1965 60 kg	780 km 780 km 75.8°	Groupe de recherches ionosphériques L.R.O. Storey	*Study of of the ionosphere* Studying the ionosphere from the propagation of very low frequency waves transmitted from the ground and received by the satellite (2 groups of antennae and a Sayers probe for measuring electron density)
D-1A (Diapason) 17-2-1966 19 kg	506 km 2 740 km 34°	Bureau des Longitudes [1] J. Kovalevsky J. Kovalevsky and P. Muller	*Geodetics* Measuring the Doppler effect on signals transmitted by the satellite (150 and 400 MHz) Photographing the satellite against a stellar background from 3 earth stations
D-1C (Diadème-1) 8-2-1967 22.7 kg D-1D (Diadème-2) 15-2-1967 22.7 kg	572 km 1 353 km 40° 592 km 1 885 km 39.5°	Bureau des Longitudes [2] J. Kovalevsky	*Geodetics* Measuring the Doppler effect on signals transmitted by the satellite (150 and 400 MHz) Measuring the distance of 3 stations from the satellite by laser ranging Photographing the satellites against a stellar background
Péole 12-12-1970 58 kg	516 km 748 km 15°	Observatoire de Paris-Meudon [3] F. Barlier	*Technology and geodetics satellite* Qualifying a stabilization system based on gravity gradient Testing the Eole satellite tracking system (transponder) Geodetics by laser ranging. Péole was also used during the international satellite geodetics (Isagex) campaign by 6 countries (laser beaming stations plus cameras)
D-2A (Tournesol) 15-4-1971 96 kg	455 km 703 km 46.3°	Service d'aéronomie J.-E. Blamont	*Sun and geocorona studies* Intensity of Lyman alpha emissions from the sun Lyman alpha emissions from the geocorona, the stars, the nebulae and the Milky Way in the direction opposite the sun Emission of atomic hydrogen (1 216 A) and oxygen (1 302, 1 304 and 1 306 A) from the geocorona Polarization of Lyman alpha emissions from the geocorona Fluxes emitted by geocoronal, auroral or stellar hydrogen at 6 563 A

1. Experiments conducted in collaboration with the Observatoire de Paris, the Institut Géographique National (IGN) and the Marine Nationale.
2. Experiments conducted in collaboration with the Observatoire de Paris, the Institut Géographique National (IGN), the Service d'aéronomie of the CNRS, the Office national d'études et de recherches aérospatiales (ONERA) and the Marine Nationale.
3. The scientific programme for the various countries participating in the Péole campaign was prepared by a committee headed by J. Kovalevsky (Bureau des Longitudes).

SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	LABORATORY EXPERIMENTER	EXPERIMENT
Eole 16-8-1971 82.5 kg	678 km 903 km 50°	Lab. de météorologie dynamique P. Morel	*Meteorological satellite* interrogating 500 balloons drifting in the atmosphere at an altitude of 12 000 metres. Studying the balloon trajectories and using the balloons to measure atmospheric pressure and temperature
SRET-1 4-4-1972 15 kg	460 km 39 248 km 65.48		*Technology satellite* Behaviour of thin-film solar cells Radiation doses received by solar cells
Starlette Sept. 1974 47 kg		Groupe de recherche de géodésie spatiale Mme Cazenave	*Geodetic study of the earth* Geodetics by telemetry and photography against a stellar background
SRET-2 Oct. 1974 21.5 kg	450 km 39 000 km 65		*Technology satellite* Flight tests of a radiant cooling system for the Meteosat satellite
D-5B Dec. 1974 36 kg			*Technology satellite* Qualification of a hydrazine thruster for attitude control (2.5 newtons thrust)
D-5B Dec. 1974 76 kg		Groupe de recherche de géodésie spatiale [4] Office nat. d'études et de rech. aérospatiales F. Barlier M. Marec	*Technology and geodetics satellite* Qualification of a three-axis microaccelerometer (10^{-5} to 10^{-9} g) Using the microaccelerometer to study variations in atmospheric density Laser ranging and photography against a stellar background Micrometeorite fluxes and velocities
D-2B April-May 1975 120 kg	500 km 700 km 37	Lab. de physique stellaire et planétaire J.-P. Delaboudinière Lab. d'astronomie spatiale G. Courtès	*UV radiation from the sun and stars* Emission lines in the far UV spectrum (170 - 1 216 Å) of the sun's chromosphere and corona UV photometry of the stars in the satellite's field Distribution of UV radiation in the celestial vault (800, 1 216, 1 600, 2 200 and 3 075 Å) UV spectrophotometry (800 - 3 500 Å) of stars of greater than 8th magnitude lying within 12 deg on either side of the ecliptic
Symphonie (Franco-German) 1975 237 kg	geostationary orbit		*Experimental communications satellite* 300 two-way circuits to transmit radio and TV programmes and experiment with telephone links (4-6 GHz)

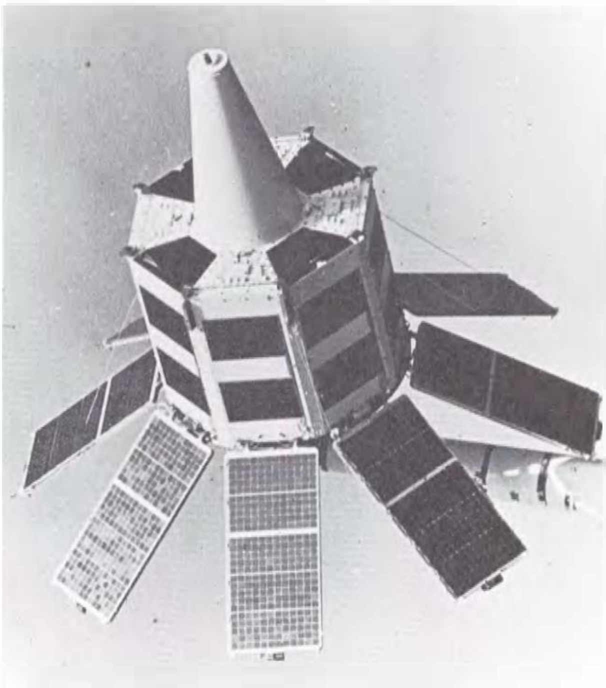
4. The Groupe de recherche de géodésie spatiale can call on the facilities of the Bureau des Longitudes, the Institut Géographique National (IGN), the Observatoire de Paris-Meudon and the Centre National d'Etudes Spatiales.

1. **The Diamant programme**

After 1970 the Diamant programme proceeded with launchings from the Guiana facility of scientific or technological satellites orbited by Diamant B rockets. On its first launch in March 1970, the Diamant B rocket carried a German satellite (Wika). Three French technological satellites (Péole, D-5A and D-5B) and two scientific satellites (D-2A and « polar D-2A ») were launched subsequently. Owing to two consecutive failures of the launch vehicle, however, the « polar D-2A » and the D-5A and D-5B failed to be orbited in December 1971 and May 1973. The programme will therefore now continue with launches of the Diamant BP-4 rocket, which is due to be qualified when the Starlette geodetics satellite is launched in the second half of 1974. The other two flight models of D-5A and D-5B will also be launched in 1974.

2. **Bilateral cooperation**

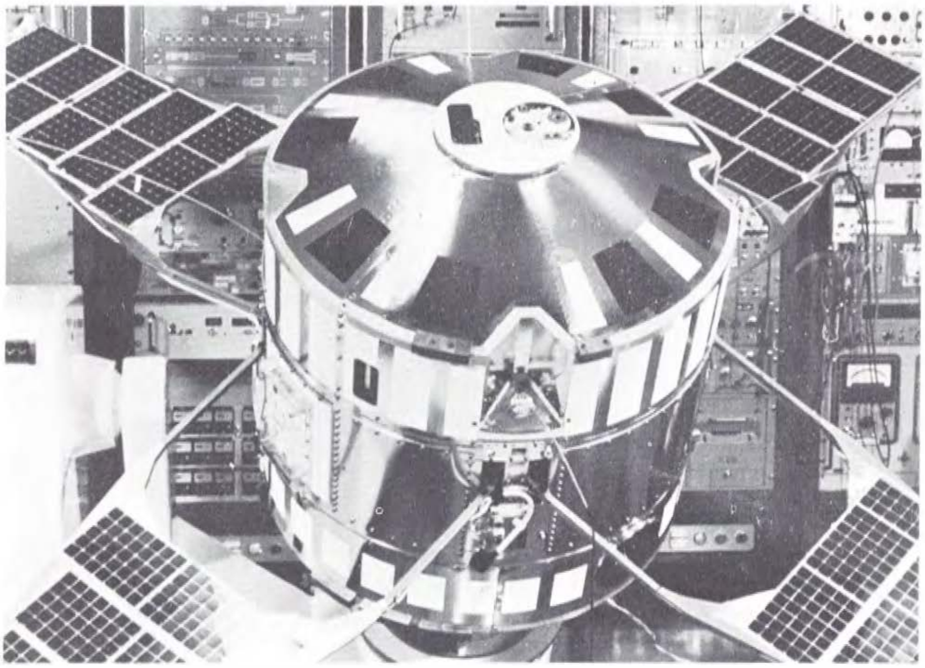
From 1966 onwards France intensified its bilateral cooperation programmes with the United States, the Soviet Union, Germany and the developing countries. With the US, the USSR and Germany, collaboration encompassed satellites and sounding rockets, while with the developing countries it mainly involved sounding rocket firing and balloon launching campaigns.



EOLE, *meteorological satellite launched in 1971 to interrogate 500 balloons drifting in the atmosphere.*

2.1. *United States:* On 27 May 1966, a second formal agreement was signed with NASA for the launching, by an American rocket, of the Eole weather satellite, which was orbited in 1971. A series of French instrumentation packages was placed on board the US OGO geophysical and OSO solar satellites, as a result of which the Aeronomy Department discovered that comets are surrounded by huge hydrogen clouds and that the solar system itself is moving through an immense cloud of hydrogen. A further experiment is to be placed in the aimed part of the OSO-I solar satellite.

Collaboration with the United States also provided an opportunity for the LAS (Space Astronomy Laboratory) of Marseilles to place a first stellar UV observation instrument in the Skylab orbiting laboratory. Together with the United States, France is now preparing a data gathering experiment aboard the US's Tiros-N meteorological satellite in 1977. French recorders and electronic data processing instruments derived from those used on board the Eole will pick up the information transmitted by beacons on the ground, or drifting at sea, and will localise them.



The D-2A satellite, launched in 1971, to study the sun and the geocorona.

2.2. *Soviet Union:* CNES has also initiated several cooperation projects with the Soviet Union. Contacts were established in 1966, and on 30 June 1966 an initial agreement was signed by CNES and the USSR's Academy of Sciences. As a result of this collaboration, French researchers were able to conduct experiments aboard Soviet lunar and planetary probes for the first time: two French laser reflectors were set down on the moon and several particle detectors and radio antennae were carried aboard spacecraft launched towards Mars.

EXPERIMENTS BY FRENCH LABORATORIES ABOARD ESRO SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Service d'électronique physique, Centre d'études nucléaires, Saclay			
J. Labeyrie	ESRO-II 17-5-1968 75 kg	332 km 1 094 km 97.2°	Solar and galactic proton (35 MeV - 1 GeV) and alpha particle (140 - 1 200 MeV) fluxes
Mme L. Koch and M. Engelman	HEOS-1 5-12-1968 108 kg	424 km 223 428 km 28.3°	1. Energy spectrum of solar and galactic protons, electrons and alpha particles
J. Labeyrie			2. Flux and energy spectrum of primary cosmic ray electrons (50 - 600 MeV) (1)
"	HEOS-A2 31-1-1972 117 kg	359 km 238 199 km 90°	Flux and energy spectrum of cosmic electrons (7 - 500 MeV) (1)
Mme L. Koch	TD-1A 12-3-1972 472 kg	533 km 545 km 97.6°	1. Spectrum of charged particles between $Z = 2$ and $Z = 28$ of energy in excess of 220 MeV per nucleon
"			2. Energy spectrum of X-ray sources (2 - 30 keV)
Y. Koechlin			3. Intensity of galactic gamma radiation (70 - 300 MeV), using a spark chamber (2)
J. Labeyrie	COS-B Feb. 1976 280 kg	350 km 100 000 km 25°	Energy spectrum and direction of arrival of cosmic gamma ray (20 MeV - 5 GeV) (3)
Groupe de recherches ionosphériques			
M. Petit	GEOS mid-1976 180 kg	geostationary orbit	Electric (up to 70 kHz) and magnetic (0.1 - 4 kHz) fields of magnetospheric plasma and its resonance frequencies (4)

(1) Experiment conducted in collaboration with the University of Milan (G. Occhialini).
(2) Experiment conducted in collaboration with the Max Planck Institute for Extraterrestrial Physics and the Physics Institute, Milan (G. Occhialini).
(3) Experiment conducted in collaboration with other European laboratories: the Max Planck Institute for Extraterrestrial Physics, Garching (K. Pinkau), the Universities of Milan and Palermo (G. Occhialini), the Space Science Department of ESTEC and the Kamerlingh Onnes Laboratory.
(4) Experiment conducted in collaboration with the Space Science Department of ESTEC (A. Pedersen) and the Danish Space Research Institute, Lyngby (E. Ungstrup).

EXPERIMENTS BY FRENCH LABORATORIES ABOARD NASA SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Services d'astronomie			
J. E. Blamont	OGO-2 14-10-1965	412 km 945 km 86°	Observation (1) of night light and auroral light in the ultraviolet (6 300, 5 577 and 3 914 Å)
»	OGO-4 28-7-1967	410 km 990 km 86°	Observation (1) of night light and auroral light in the ultraviolet (2 630, 3 914, 5 577, 5 890, 6 225 and 6 300 Å)
»	OGO-5 4-3-1968	278 km 148 160 km 31°	Density and temperature of geocorona hydrogen
»	OSO-5 22-1-1969	550 km 550 km 33°	Lyman alpha solar radiation
»	OGO-6 5-6-1969	396 km 1 068 km 82°	Observation of night light and auroral light, in the ultraviolet (6 300 and 3 914 Å) (2)
»	Gemini-12 11-11-1968	297 km 297 km	Photograph of a sodium vapour cloud ejected by a sounding rocket at 160 km; study of wind velocity
Lab. de biologie médicale, Toulouse			
M. Planel	Apollo-16 16-4-1972	lunar trajectory	Effect on biological tissues of bombardment by primary cosmic radiation heavy ions (Biostack experiment) (3)
	Apollo-17 6-12-1972	lunar trajectory	
Lab. d'astronomie spatiale, Marseille			
G. Courtès	Skylab 30-4-1973	435 km 435 km 50°	Spectrum and photography of celestial objects in 2 UV bands (1 800 and 3 100 Å)
Lab. de physique stellaire et planétaire			
R. N. Bonnet	OSO-1 mid-1974	550 km 550 km 33°	Study of the solar chromosphere's structure by observing 4 emission lines (1 216, 1 025, 3 933-3 968 and 2 803-2 795 Å)

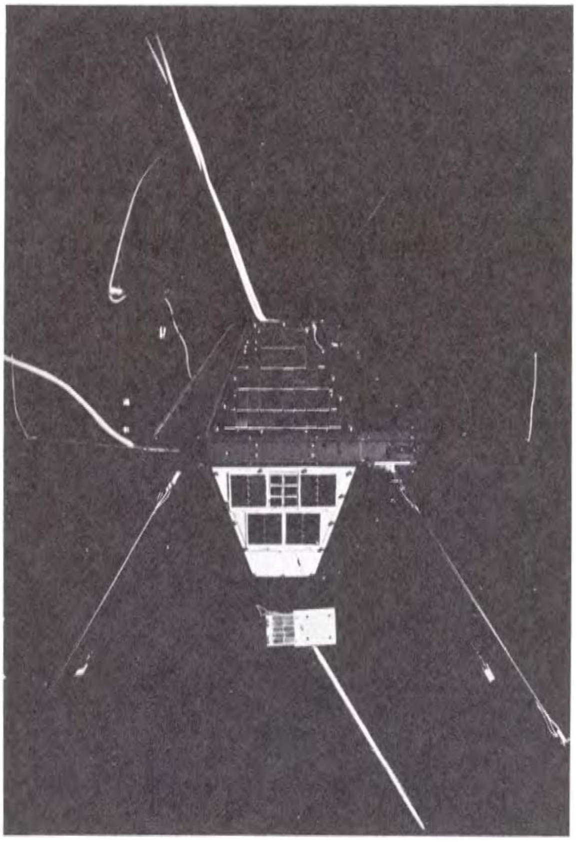
(1) Experiment conducted in collaboration with the Goddard Space Flight Center.

(2) On the OGO-6 satellite, the Service d'aéronomie was also co-experimenter with the University of Pittsburg in the study of sodium (5 890 and 5 896 Å) and oxygen (5 577 Å) spectral lines.

(3) Experiment conducted in collaboration with Frankfurt University (H. Bucker); the Laboratorie de biologie médicale, Toulouse, coordinated the activities of 4 French laboratories: the Centre d'enseignement et de recherche de médecine aérospatiale (CERMA), the Laboratoire de physique corpusculaire, Strasbourg, the Centre d'étude spatiale des rayonnements of the University of Toulouse and the Centre de dosimétrie of the Centre d'études nucléaires, Fontenay.

NB Together with London University, the Observatoire de Paris will be a co-experimenter with the Jet Propulsion Laboratory in exploiting the television pictures from Mariner/Venus Mercury (1973).

Cooperation with the Soviet Union also provided France with an opportunity to launch a small technology satellite (SRET 1 - Satellite de Recherches et d'Etudes Technologiques), which accompanied a Soviet Molnyia telecommunications satellite, and to prepare for the launching of a second SRET in October 1974. Collaboration is extended to sounding rockets as well: several common launching campaigns were carried out on the Kerguelen Islands and other French sounding rockets were fired from a Soviet research vessel off Kourou in 1971. A joint balloon launching campaign was planned at Kiruna for the winters of 1973-1974 and 1974-1975.



SRET-1, *French technological satellite launched in 1972 by a Russian rocket.*

A further joint experiment—Araks—is to be conducted in the winter of 1974-1975 from the Kerguelen Islands. Two French Eridan rockets will be launched from these islands and electron accelerators developed by the Patton Institute of Kiev will inject particles into the ionosphere. The electron accelerators are derived from those used aboard the Soyuz 6 manned spacecraft to carry out welding experiments in space. Antennae and magnetometers located in the nosecones of sounding rockets will measure the electrical and magnetic fields of the ionospheric plasma. At Sogra, in the Soviet Union, at the conjugate point of the Kerguelen Islands, Soviet experimenters will attempt to detect electrons accelerated by guns that will have followed the lines of the earth's magnetic field, and will use highly sensitive TV cameras to observe the artificial auroras created by the electrons entering the ionosphere.

2.3. *Federal Republic of Germany:* After the small German satellite (Wika) launched by the first French Diamant B rocket, France signed an agreement on 6 June 1967 with the Federal Republic for the construction of an experimental telecommunications satellite (Symphonie).

The Symphonie project is the outcome of the merging of two somewhat similar projects—the French Saros and the German Olympia projects. Weighing 386 kg in transfer orbit and 237 kg in synchronous orbit, the Symphonie satellite will offer 600 telephone channels (300 two-way circuits), or up to two television programmes, and will make it possible to distribute radio and TV programmes, route telephone and telegraphic communications, and transmit data. A time-sharing multiple-access system will be experimented in particular.

The Convention signed between France and Germany provides for the development of two flight models and the construction of two earth stations for the telecommunications experiments.

EXPERIMENTS BY FRENCH LABORATORIES ABOARD SOVIET SATELLITES AND PROBES

LABORATORY EXPERIMENTER	SATELLITE OR PROBE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Groupe de recherche de géodésie spatiale, Observ. du Pic du Midi			
L. Orszag	Luna-17 17-11-1970	lunar trajectory	Laser ranging using a reflector deposited on the moon's surface by the Lunakhod-1 rover
"	Luna-21 8-1-1973	lunar trajectory	Laser ranging using a reflector deposited on the moon's surface by the Lunakhod-2 rover
Groupe de radio-astronomie spatiale, Observ. de Meudon			
J. L. Steinberg	Mars-3 28-5-1971 Mars-6 5-8-1973 Mars-7 9-8-1973	towards Mars	Directivity and intensity of radio bursts (169 MHz) from the sun (Stéréo-1 experiment) Directivity and intensity of radio bursts (30 and 60 MHz) from the sun (Stéréo-5 experiment)
Centre d'étude spatiale des rayonnements, Univ. de Toulouse			
F. Cambou	Oréol-1 27-12-1971 ≃ 300 kg	410 km 2 500 km 74°	Energy spectrum of solar wind protons and electrons (200 eV - 15 keV) (Arcade experiment)
"	Prognoz-2 29-6-1972 600 kg	550 km 200 000 km 65°	1. Energy spectrum of solar wind protons and electrons (200 eV - 15 keV) (Calipso-1 experiment)
"			2. Solar neutrons (1 - 16 MeV) and gamma-ray (300 keV - 9 MeV) fluxes (Signe-1 experiment)
	Mars-6 5-8-1973 Mars-7 9-8-1973	towards Mars	Temperature and composition of solar wind particles (Gémeaux-T experiment)
Service d'électronique physique, Centre d'études nucléaires, Saclay			
J. Labeyrie	Mars-6 5-8-1973 Mars-7 9-8-1973	towards Mars	Heliocentric gradient of cosmic radiation in interplanetary space (Gémeaux-S experiment)
Service d'aéronomie			
J. E. Blamont	on one or several of 4 probes launched July-August 1973	towards Mars	Hydrogen and helium in interplanetary space (1)

(1) Experiment conducted in collaboration with the Soviet organisation Intercosmos.

The antennae used by these stations have a diameter of about 16 m. One of them is located at Raisting in Germany, the other at Pleumeur-Bodou in France, i.e. at the present locations of the German and French Intelsat stations. The satellites will be monitored from Oberpfaffenhofen (Germany) and Toulouse (France) and all telemetry and telecommand operations will be conducted from Weilheim and Toulouse.

The Franco-German convention provided for the creation of a Programme Board consisting of three French and three German representatives, implementation of the programme being handled by an Executive Committee having one German and one French executive secretary. The two countries make equal technical and financial contributions on all space aspects, but the ground stations are financed separately by each partner.

Following a request for proposals issued early in 1968, a Franco-German industrial consortium (CIFAS) was selected as prime contractor. In March 1969 a first project definition study contract was awarded. A further contract was issued in 1970, and the French and German governments approved the definition studies and the financial protocol. The definitive industrial contract for development of the satellites was awarded to CIFAS on 15 January 1971. However, after the decision in March 1973 to abandon the Europa 2 European rocket, which was to have orbited the Symphonie satellite, the latter had to be modified slightly to enable it to be launched by an American Thor-Delta 2914 rocket early in 1975.

2.4. *Other countries:* France has cooperated with Argentina, Brazil, India, Pakistan and Spain. With Argentina, France conducted several Centaure rocket launching campaigns from 1962 to 1967, launched two Titus rockets in 1966 on the occasion of a solar eclipse, and two Dragon sounding rocket launching campaigns in 1970 and 1971. In 1969-1970 France also set up three stations in Argentina at Mendoza, Neuquen and Lago-Fagnano, from which the pressurized balloons for the Eole experiment were released.

France has concluded agreements with Brazil, Spain and various African countries, authorising it to erect telemetry and telecommand stations abroad.

A general agreement was signed in 1963 with India. This country acquired licence rights on the Belier, Centaure and Dragon sounding rockets, and several joint launching campaigns were held between 1963 and 1970.

During the coming years CNES will continue the Diamant programme and pursue a policy of bilateral cooperation. Final decisions on two new satellites are expected fairly shortly, namely development of a new D-2 satellite for observing celestial gamma-ray sources (the « D-2B gamma » satellite), to be launched by a Diamant BP-4 rocket, and development of a Dialogue technology satellite which, like the Péole, will serve as, a test platform for the equipment to be placed on board a future geodesy satellite (Géole).

PERFORMANCES OF DIAMANT LAUNCHERS

	DIAMANT-A	DIAMANT-B	DIAMANT-BP 4
circular equatorial orbit (5° 14')			
— 300 km	115 kg	160 kg	195 kg
— 500 km	79 kg	115 kg	150 kg
— 800 km	26 kg	55 kg	85 kg

Since 1965-1966 CNES has shown a growing interest in application satellites. After the agreement reached with Federal Germany concerning a first communications satellite, it initiated a study on air navigation satellites (the Dioscures series), then on a geostationary meteorological satellite (Meteosat). The air navigation satellite studies were taken up by ESRO and produced the Aerosat project, while the Meteosat satellite became an European project. CNES is currently interested in two other areas of application: data gathering and earth resources. A satellite like Géole should be able to localise fixed or moving beacons on land or at sea to within about one metre and pick up data from them.

CHARACTERISTICS OF DIAMANT LAUNCHER

		HEIGHT DIAMETER	PROPELLANT	STRUCTURE WEIGHT PROPELLANT WEIGHT	THRUST SPECIFIC IMPULSE IN VACUO BURN TIME
1st stage	Diamant-A	10 m 1.4 m	1 nitric acid and turpentine engine	1.95 t 12.76 t	274-300 kN 203 s 93 s
	Diamant-B	14.21 m 1.4 m	1 hydrogen tetroxide and UDMH engine	2.33 t 18.35 t	350-400 kN 259.1 s 115 s
	Diamant-BP 4	14.95 m 1.4 m		2.2 t 18.35 t	316-400 kN 259.1 s 115 s
2nd stage	Diamant-A	4.7 m 0.8 m	4 isolane solid propellant engines	0.67 t 2.26 t	150 kN 259 s 44 s
	Diamant-B	4.7 m 0.8 m		0.68 t 2.26 t	156 kN 259 s 43 s
	Diamant-BP 4	2.28 m 1.5 m		0.78 t 4 t	180 kN — 55 s
3rd stage	Diamant-A	2.06 m 0.65 m	1 isolane solid propellant engine	68 kg 641 kg	27-53 kN 273 s 45 s
	Diamant-B	1.67 m 0.8 m		95 kg 685 kg	30-50 kN 278 s 46.5 s
	Diamant-BP 4	1.67 m 0.8 m			

		HEIGHT	DIAMETER	USABLE VOLUME
Shroud	Diamant-A Diamant-B Diamant-BP 4	2.39 m 2.8 m 4.08 m including connecting skirt	0.65 m 0.85 m 1.378 m	0.5 dm^3 0.75 dm^3 1.45 dm^3

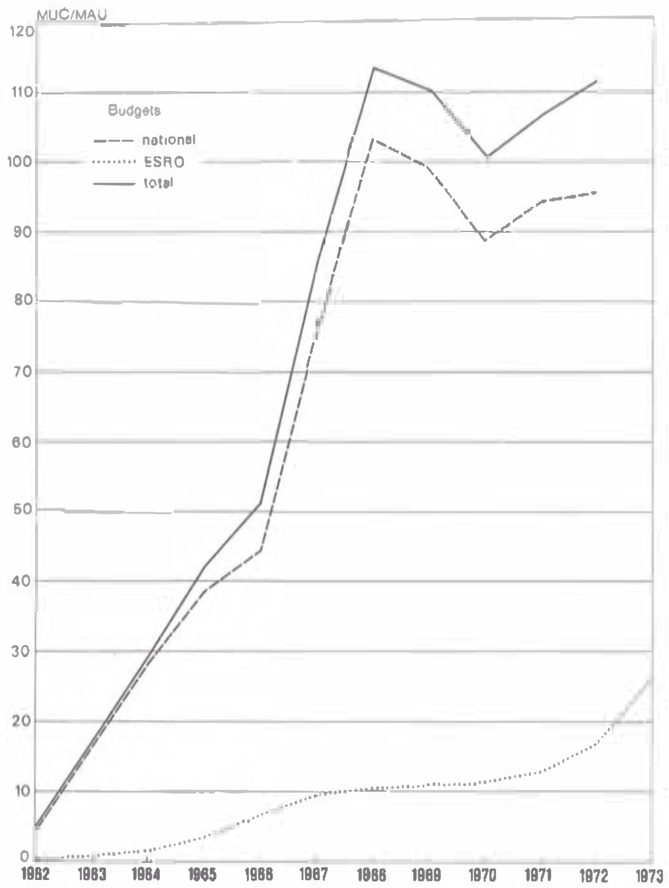
For a few years now, CNES has reduced the number of sounding rocket launches under the national programme but has continued with large numbers of balloon launchings. The average volume of these balloons has risen from 25 000 cubic metres in 1967 to 100 000 cubic metres in 1973, while the average payload has increased from 60 kg to 200/250 kg. French laboratories use the balloons for experiments relating to aeronomy and meteorology, the physics of the atmosphere, solar physics, cosmic-ray physics, earth resources studies and space biology.

The sounding rocket programme was curtailed somewhat to permit development of a new Véronique 61M rocket equipped with a stabilised nosecone to enable stellar observations in ultraviolet light to be made (the Faust project). Launchings of Faust rockets are due to begin in 1974 from Kourou.

SOUNDING ROCKETS AND STRATOSPHERIC BALLOONS LAUNCHED UNDER THE FRENCH NATIONAL PROGRAMME

	SOUNDING ROCKETS	BALLOONS		
		SCIENTIFIC FLIGHTS	TECHNICAL FLIGHTS	TOTAL
1962	42			
1963	31			100
1964	38	111	52	163
1965	27	94	60	154
1966	26	125	72	197
1967	18	141	42	183
1968	15	109	37	146
1969	22	115	19	134
1970	4	120	22	142
1971	18			
1972	3			
total	244	815	304	1 219

France's space budget.



Federal Republic of Germany

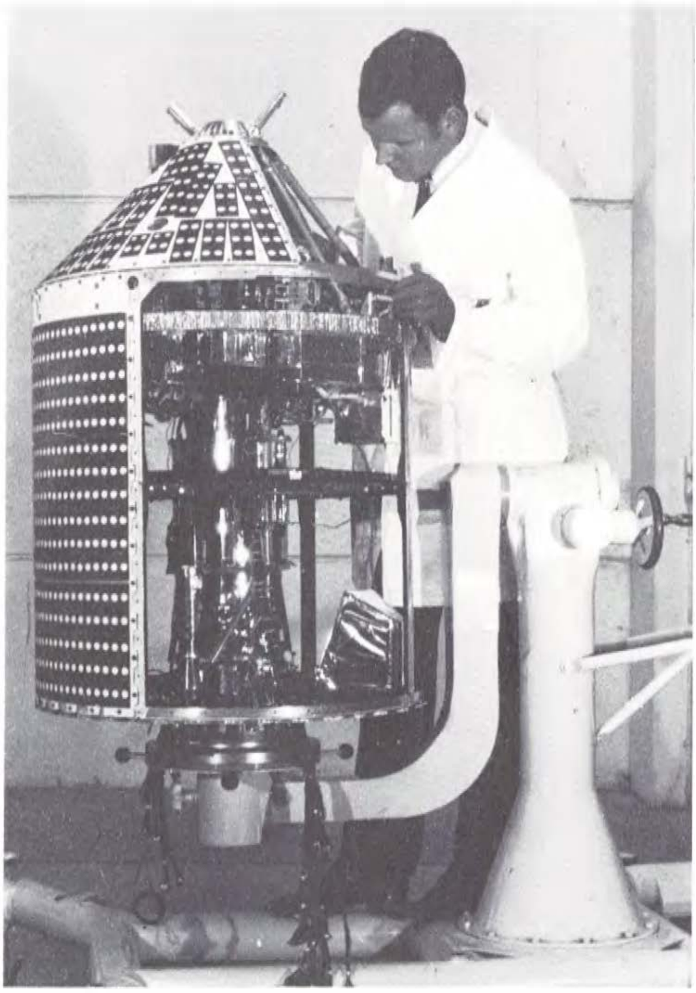
Space research activities in the Federal Republic of Germany go back to 1962. Since then Germany has orbited three scientific satellites, has built a telecommunications satellite (Symphonie) as a joint venture with France, and is to launch two Helios interplanetary probes towards the sun in 1974 and 1976 respectively. From 1963 to 1971, more than 250 sounding rockets have been launched as part of the national programme, and experiments with balloons have also been conducted.

Germany has not developed a national satellite launcher nor set up a central federal space facility. However many research institutions and industrial companies which have been engaged in integrating national or European satellites have extensive technical facilities. The government has built a satellite tracking and control centre at Oberpfaffenhofen and several telemetry and command guidance stations, which belong to the DFVLR.

The initial phase of the German space programme was devoted primarily to setting up new institutions, mainly in the Max-Planck Institute, and installing the necessary research equipment in laboratories. At the same time, researchers and technicians developed onboard instrumentation packages for sounding rockets, balloons and satellites.

The second phase of the programme began in 1964-1965 when German scientific institutes began to prepare their first experimentation payloads for ESRO or national satellites, and initial contracts for the development of these satellites were awarded to industry by ESRO and the GfW.

In 1965 the Federal Government concluded an agreement with NASA to enable the first German satellite for studying the magnetosphere and earth-sun relations—the GRS-A or Azur satellite—to be launched by an American rocket. Preliminary studies on a second scientific satellite, Aeros—designed to study the upper atmosphere and the ionosphere—were initiated at about



Thermal model of German satellite AEROS (Dornier photo).

the same time, as well as on an interplanetary probe which would approach to within 0.30 astronomical units of the sun. Discussions concerning US collaboration on this project began in 1966. Studies and negotiations continued until July 1968, and the mission definition phase lasted until April 1969.

The contract for the launching by NASA of two German Helios solar probes was signed on 10 June 1969, together with the agreement to use an American rocket to orbit Germany's second Aeros scientific satellite.

During the time it was negotiating with the United States, Germany had embarked upon two other cooperative ventures, this time with France: one was to develop a first applications satellite (the Symphonie experimental telecommunications satellite), the other to develop a small scientific instrumentation capsule (Wika) to be sent aloft on the French Diamant-B rocket at the time of the latter's first test flight. The intergovernmental agreement between France and Germany to develop the Symphonie satellite was signed on 6 June 1967. The contract relating to the launching—under conditions comparable to those offered by NASA—of the Wika instrumentation capsule, along with a French Mika technology capsule, was signed in February 1969 (DIAL project).

The Azur-1 and Aeros scientific satellites were launched at the end of 1969 and 1972 respectively and have yielded a large amount of important scientific data. In March 1970, France's first Diamant-B rocket carried a DIAL payload consisting of two capsules: the Mika technology

German satellite WIKA launched in 1970 from Guiana by a French DIAMANT-B rocket.

capsule which formed part of the launcher's upper stage and was intended to furnish data on operation of the rocket, and the Wika scientific instrumentation capsule for studying hydrogen geocorona and the ionosphere. Unfortunately the Wika capsule was disturbed by excessive vibration during launch and this made the evaluation of scientific data difficult.

For the French-German communications satellite project Symphonie, see page 75.

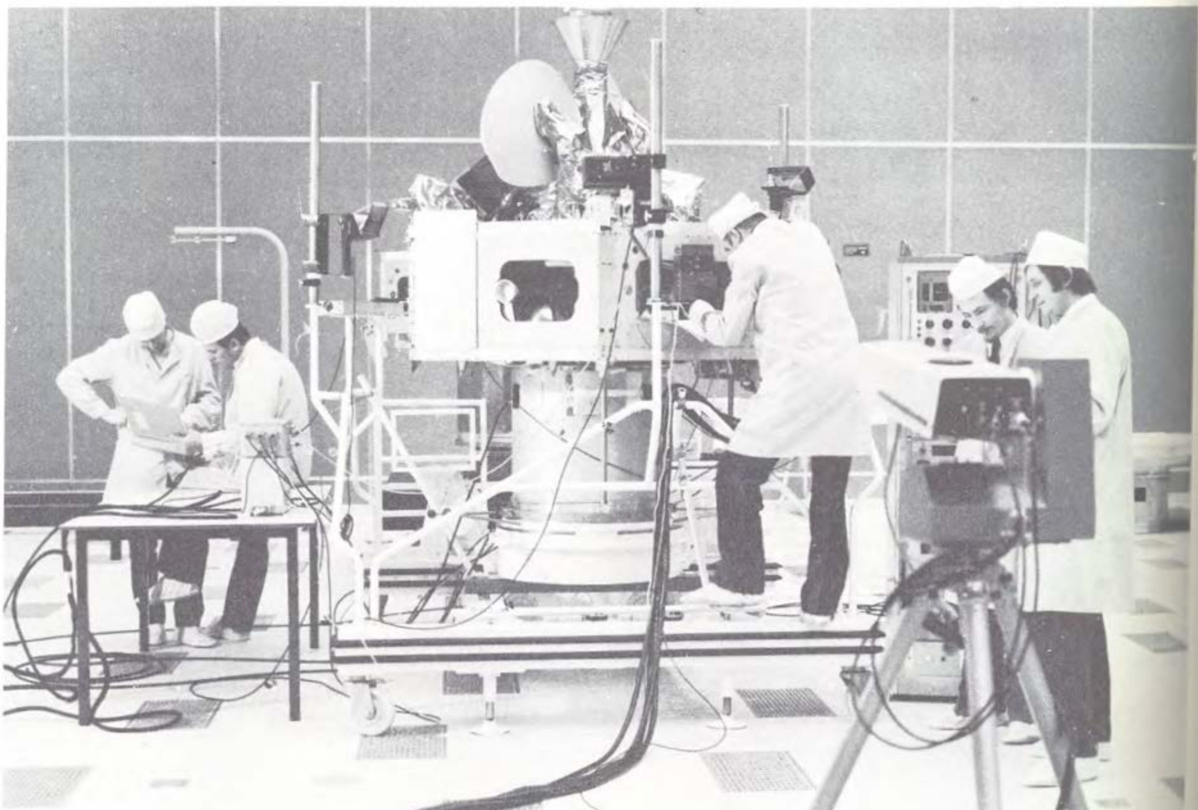
EXPERIMENTS ABOARD GERMAN SATELLITES

SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE INCLINATION	LABORATORY EXPERIMENTER	EXPERIMENT
GRS-A (Azur-1) 8-11-1969 71 kg	382 km 3 128 km 103°	Inst. of Geophysics and Meteorology, Braunschweig G. Musmann	*Study of the magnetosphere and of earth-sun relations* Measurement of the earth's magnetic field
		Max Planck Inst. for Extraterrestrial Physics, Garching D. Hovestadt	1. Angular distribution and time variations of proton fluxes (1.4 - 100 MeV) and alpha particles in the Van Allen belts 2. Omnidirectional proton (20 - 45 MeV, 40 - 80 MeV) and electron (1.55 - 4.2 MeV) fluxes in the Van Allen belts
		Max Planck Inst. for Aeronomy, Lindau E. Kirsch	Omnidirectional proton flux (> 30 MeV) in the Van Allen belts
		Inst. of Nuclear Physics of the Univ. of Kiel J. Moritz	Angular distribution and time variations of the proton flux (0.25 - 2 MeV) in the Van Allen belts and during solar eruptions
		Max Planck Inst. for Aeronomy, Lindau L. Rossberg	Variation of the flux of incident and reflected electrons in the polar regions and the Van Allen belts
		Inst. of Atmospheric Physics, Oberpfaffenhofen A. Rossbach	Light intensity in the auroral regions (314 and 5 577 A) and correlation with the electron flux
Wika (Dial) 10-3-1970 63 kg	328 km 1 629 km 5°	Inst. of Atmospheric Physics, Oberpfaffenhofen H. D. Schlichter	*Study of the ionosphere* Intensity of Lyman radiation (1 150 - 1 350 and 1 250 - 1 350 Å)
		Max Planck Inst. for Extraterrestrial Physics, Garching F. Melzner	Density of thermal electrons
		Univ. of Kiel H. Fischer	Energy spectrum of protons (5 - 40 MeV) electrons (> 1.3 MeV) and alpha particles (5 - 40 MeV)
		Inst. of Geophysics and Meteorology, Braunschweig G. Musmann	Variations of the magnetic field due to the equatorial electrojet

SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	LABORATORY EXPERIMENTER	EXPERIMENT
Aeros 16-12-1972 127 kg	230 km 800 km 97.2°	Space Physics Group, Fribourg K. Spenner E. Neske	*Study of the upper atmosphere and ionosphere* [1] Energy spectrum of electrons and ions Electron density of the ionosphere
		Max Planck Inst., Heidelberg D. Krankowsky	Density and composition of neutral particles and ions
		Space Physics Group, Fribourg G. Schmidtke	Remote solar UV radiation fluxes (155 - 1 062 Å)
		Inst. of Astrophysics and Extraterrestrial Research of the Univ. of Bonn M. Roemer	Study of drag phenomena to determine variations in atmospheric density
Helios-A Sept. 1974 355 kg	ecliptic orbit perihelion = 0.3 AU	Inst. of Geophysics and Meteorology, Braunschweig F. M. Neubaer and A. Maier	*Interplanetary space and solar studies* [2, 3] Measurement of interplanetary magnetic field's static component (3-axis magnetometer)
Helios-B Sept. 1976 355 kg	aphelion = 1 AU	F. M. Neubaer and G. Dehmel	Measurement of interplanetary magnetic field fluctuations (induction magnetometer)
		Max Planck Inst. for Aeronomy, Lindau E. Keppler and B. Wilken	Directions and energy spectra of electrons (30 keV - 1 MeV), protons (40 keV - 2.5 MeV) and positrons (50 - 215 keV)
		Max Planck Inst. for Extraterrestrial Physics, Garching H. Rosenbauer and H. Pellkofer	Direction and velocity of solar wind protons (180 eV - 15 keV) and electrons (0.5 eV - 1,2 keV) [4]
		Univ. of Kiel H. G. Hasler and H. Kunow	Energy spectrum and variations of solar and galactic fluxes of protons, alpha particles and heavy ions
		Univ. of Heidelberg C. Leinert and E. Pitz	Zodiacal light

SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	LABORATORY EXPERIMENTER	EXPERIMENT
		Max Planck Inst. for Extraterrestrial Physics, Garching H. Fechtig and M. Kissel Univ. of Hamburg W. Kundt	Micrometeorites Sun's quadrupole moment and improved ephemerides for the inner planets (relativity experiment) [5]
Symphonie (French/German) 1975 237 kg	geostationary orbit		*Experimental telecommunications satellite* 300 two-way circuits to transmit radio and TV programmes and for experimental telephone links (4 - 6 GHz)

1. The Goddard Space Flight Center mounted an experiment onboard the Aeros satellite to measure the neutral atmosphere's temperature and the molecular nitrogen concentration.
2. In addition to the onboard experiments, the Helios probes will be used to measure the Faraday rotation of the S-band signals passing through the corona (University of Bonn) and to measure the refraction indices through the different regions of the corona (Microwave Institute, Oberpfaffenhofen).
3. Three experiments are scheduled aboard the Helios probes by the Goddard Space Flight Center (N. F. Ness) and Rome University (L. F. Burglaga); the University of Iowa (D. A. Gurnett) and the Goddard Space Flight Center (S. J. Bauer); and the Goddard Space Flight Center (E. C. Roelof) and Australia's CSIRO (K. G. McCrackan), respectively.
4. Experiment conducted in collaboration with Ames Research Center (J. Wolfe).
5. Experiment conducted in collaboration with the Jet Propulsion Laboratory, Pasadena (W. G. Melbourne, J. D. Anderson).



SYMPHONIE, *Franco-German experimental communications satellite to be launched at the end of 1974 (MBB photo).*

German solar probe HELIOS *which will approach to within approximately 45 million km of the sun in 1974-1975 (photo* MBB*).*

The development of two Helios solar probes is the Federal Republic's second major cooperative programme. These 355 kg probes, which are to be launched by powerful Titan IIIE Centaur American rockets, will approach to within 0.30 astronomical units (45 million km) of the sun. This cooperative space project between the United States and Germany ranks second in importance only to the Spacelab orbiting laboratory and will cost a total of 650 million DM (including launcher and launch services).

The hardest technical problem to be overcome stems from the extreme variations in solar irradiation which the probes will have to withstand during their voyage (1 to 16 times the terrestrial irradiation). These probes, which have a special shape to enable them to withstand the heat better, will be equipped with both passive and active thermal control systems and with special thermal protection for the solar cells. They will carry high-gain (23 dB), medium-gain and low-gain antennae and will be capable of transmitting up to 2 048 bits per second.

A thermal model of the Helios was checked out in IABG's infrared simulation chamber at Ottobrun and by the Jet Propulsion Laboratory at Pasadena during 1972. After a few further modifications had been made, integration of the first prototype was begun in 1973 by the German prime contractor, Messerschmitt-Bölkow-Blohm, which has selected 14 subcontractors in Europe and the United States.

Each of the Helios probes will contain eight German and three American instrumentation packages. They will be tracked by NASA's « Deep Space Network » stations and by the German radio-telescope et Effelsberg, which has a parabolic antenna 100 metres in diameter. The expected lifetime of the probes is 18 months (three orbits round the sun) and their onboard systems will be capable of receiving 256 different commands. The central German ground station at Weilheim includes special telecommand facilities for the Helios project.

So far the German government has reached no decision regarding follow-on projects after Symphonie and Helios. The GfW together with scientific institutes are now studying a smaller scientific project which might result after modification in a cooperation with other nations. (The United Kingdom scientists are interested to combine their plans of an X-ray-astronomy satellite with the German ones.) Other technological studies are being funded with the aim of developing a communications satellite to enable TV programmes to be relayed over Germany towards the end of the century.

EXPERIMENTS BY GERMAN LABORATORIES ABOARD ESRO SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Max Planck Inst. of Extraterrestrial Physics, Garching			
R. Lüst and M. Gollnitz	HEOS-1 5-12-1968 108 kg	424 km 223 428 km 28.3°	Study of the geomagnetic field by means of an artificial cloud of barium and copper oxide created at an altitude of 75 000 km
H. Rosenbauer	HEOS-A2 31-1-1972 117 kg	359 km 238 199 km 90°	Profile and direction of solar wind protons (231 eV - 16 keV) and magnetospheric plasma electrons and protons (100 eV - 50 keV)
R. Lüst	TD-1A 12-3-1972 472 kg	533 km 545 km 97.6°	Intensity of galactic gamma radiation (70 - 300 MeV) (1)
	ESRO-IV 22-11-1972 113 kg	280 km 1 100 km 90°	Flux and energy distribution of solar protons (0.2 - 90 MeV) and alpha particles (2.5 - 360 MeV)
K. Pinkau	COS-B feb. 1975 280 kg	350 km 100 000 km 25°	Energy and direction of arrival of cosmic gamma rays (20 MeV - 5 GeV) (2)
H.J. Völk	GEOS mid-1976 180 kg	geostationary orbit	1. DC electric fields and magnetic gradient 2. Composition, energy spectrum and pitch-angle distribution of magnetospheric plasma particles (3)
Max Planck Inst., Heidelberg			
H. Fechtig	HEOS-A2 31-1-1972 117 kg	359 km 238 199 km 90°	Flux, velocity and mass of micrometeorites close to the earth
Inst. of Physics of Bonn University			
U. von Zahn	ESRO-IV 22-11-1972 113 kg	280 km 1 100 km 90°	Density and composition of neutral particles in the F region of the ionosphere
Max Planck Inst. of Aeronomy, Lindau			
J.W. Münch	GEOS mid-1976 180 kg	geostationary orbit	Energy-spectrum and angular distribution of protons (20 keV - 1.4 MeV) and electrons (20 - 300 keV) fluxes

1. Experiment conducted in collaboration with the Service d'électronique physique du Centre d'études nucléaires de Saclay and the University of Milan (G. Occhialini).
2. Experiment conducted in collaboration with other European laboratories : the Universities of Milan and Palermo, the Service d'électronique physique du Centre d'études nucléaires de Saclay, the Kamerlingh Onnes Laboratory for cosmic ray studies, of the University of Leiden (H. C. van de Hulst) and the Space Science Department of ESTEC.
3. Experiment conducted in collaboration with the University of Bern (J. Geiss, P. Eberhardt).

EXPERIMENTS BY GERMAN LABORATORIES ABOARD NASA SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE	ORBIT	EXPERIMENT
Univ. of Frankfurt H. Bucker	Apollo-16 16-4-1972	lunar trajectory	Effects of heavy cosmic ions on various biological tissues (Biostack experiment) [1]
•	Apollo-17 6-12-1973	lunar trajectory	As for Apollo-16
Univ. of Frankfurt	Apollo-16 16-4-1972	lunar trajectory	Effect of the space environment on 5 bacteria strains
Max Planck Inst. for Extraterrestrial Physics, Garching R. Lüst (co-experimenter)	Pioneer-10 3-3-1972	heliocentric trajectory	Density and energy of solar wind particles along the Earth-Jupiter trajectory; interaction of solar wind with Jupiter
•	Pioneer-11 6-4-1973	heliocentric trajectory	As for Pioneer-10

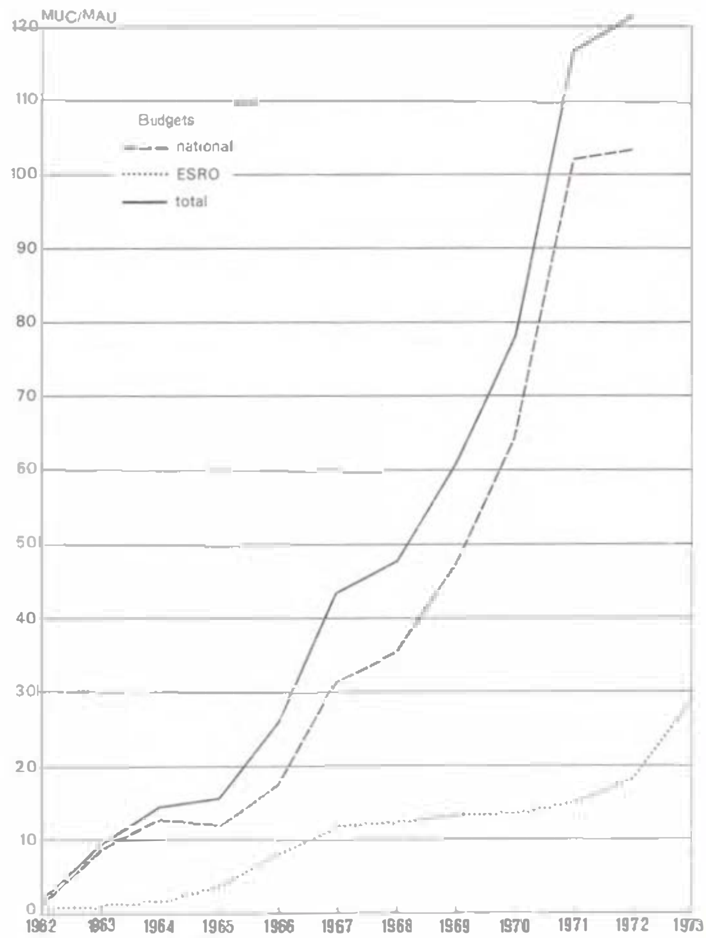
(1) Experiments conducted in collaboration with the Laboratoire de biologie spatiale, Toulouse (M. Planel).

German science laboratories have undertaken experiments not only with German satellites but also with the help of ESRO and NASA satellites and by means of several hundred sounding rockets launched in collaboration with ESRO, Argentina, Brasil, Canada, France, India, Spain and the United States. Eight groups at universities and in the Max-Planck Institute have been engaged in investigations of lunar material since 1969. Some institutes are engaged in experiments with balloons, notable examples being the Fraunhofer Institute at Freiburg (Spectro-Stratoscope), the Max-Planck Institute of Astronomy at Heidelberg, the Max-Planck Institute of Extra-Terrestrial Physics at Garching, and the Nuclear Physics Institute of Kiel University. A number of institutes are engaged in the evaluation of satellite observations (air and ion density), satellite meteorology and satellite geodesy. In the field of earth resources surveys other institutes and government laboratories are engaged in the evaluation of pictures taken during the Gemini, Apollo and ERTS-1 flights.

Although no sounding rocket proving ground exists in Germany, the DFVLR has developed a mobile launching base, the MORABA (Mobile Raketenbasis), which is shipped abroad for sounding rocket launches. This facility was completed in 1967, and until 1972 was used to launch 43 solid-propellant sounding rockets of the Nike, Javelin, Skylark and Black Brant type. The mobile base, which weighs 17 tons, is housed in two containers and can be erected in 24 hours. In 1970 it was used to launch Canadian Black Brant sounding rockets as a preliminary to the Azur satellite experiments.

The Nuclear Physics Institute at Kiel operates a balloon releasing facility, but the balloons themselves are purchased abroad.

The DFVLR has also set up a highly automated network of ground stations which is designed to be compatible with the existing networks operated by ESRO, NASA and CNES (the French space agency). This network is capable of handling such different satellites as the Aeros scientific satellite, the Symphonie communications satellite and the Helios solar probes.



Germany's space budget.

The DFVLR's control centre is located at Oberpfaffenhofen. It is linked to the central telemetry and command guidance station at Weilheim, to three solar telemetry and command stations—Kevo (Finland), Reykjavik (Iceland), Fort Churchill (Canada)—to the large telemetry receiving station at Effelsberg and to the antenna erected at Raisting specifically to provide experimental data links with Symphonie.

Facilities at Weilheim include a VHF telemetry and command antenna, a VHF tracking interferometer and an S-band command station for the Helios project.

GERMAN SCIENTIFIC EXPERIMENTS LAUNCHED BY SOUNDING ROCKET

	SOUNDING ROCKET LAUNCHES OUTSIDE ESRO	ESRO SOUNDING ROCKET LAUNCHES	TOTAL
1963	6	1	7
1964	8	2	10
1965	9	7	16
1966	9	10	19
1967	18	8	26
1968	37	6	43
1969	21	9	30
1970	55	14	69
1971	17	13	30
Total	180	70	250

Italy

Italy's space programme dates back to the early 1960s. The Italian government decided to begin by initiating a scientific satellites programme in close collaboration with NASA. Up to now Italy has launched four scientific satellites in its San Marco series, and is currently conducting experiments on sounding rockets and balloons and developing its first communications satellite. It has not yet built a satellite launcher, nor sounding rockets or balloons. Technical centres and satellite test facilities exist in industry, and also at Rome University's Aerospace Research Centre (CRA), Italy's largest aerospace laboratory.

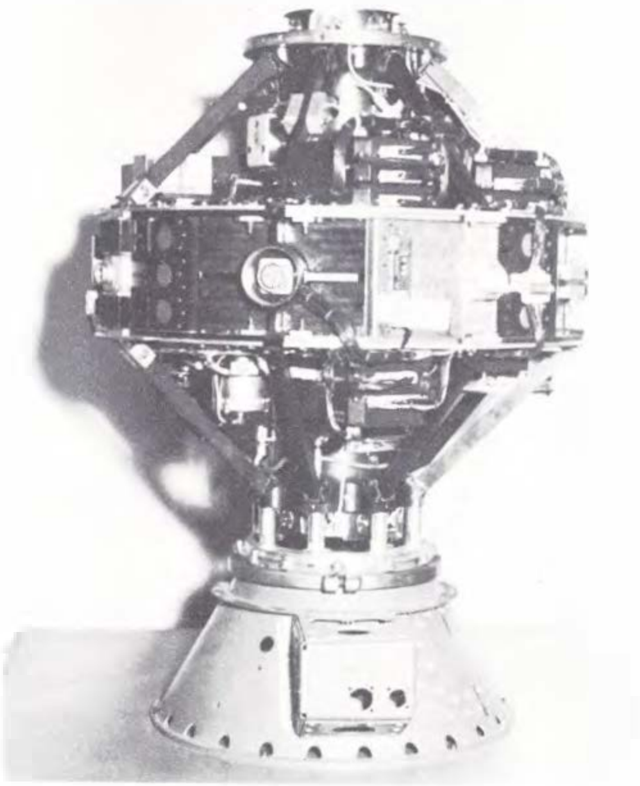
Italy is conducting two satellite programmes simultaneously:

— the San Marco scientific satellites programme, directed by Professor Luigi Broglio of Rome University's CRA (four satellites have already been launched);

— the Sirio telecommunications satellite programme, run by the National Research Council.

In September 1962 the Italian government signed an agreement with the US government under which NASA was to launch a series of scientific satellites for studying the earth's ionosphere and upper atmosphere. These satellites are ingeniously conceived to enable the density of the residual atmosphere at the orbiting altitude to be measured. They consist of two concentric spheres of different mass joined by three flexible arms, as a result of which the drag exerted on the outer sphere by the residual atmosphere can be measured. The third San Marco satellite also carried two American experiment packages.

With the exception of the first in the series, the San Marco satellites have been launched from a floating base anchored off the coast of Kenya, just below the equator. This base, which comprises the San Marco launching platform and a smaller Santa Rita platform on which the operations and control centre is installed, became operational at the end of 1966. Intended as an international facility, it was used to launch small US astronomical satellites in 1970 and 1972 (Explorer 42 and Explorer 48) and another American satellite in 1971. Britain's UK-5 satellite



Italian satellite SAN MARCO-1.

EXPERIMENTS ABOARD ITALIAN SATELLITES

SATELLITE LAUNCH DATE LAUNCH VEHICLE AND SITE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
San Marco-1 15-12-1964 Scout Wallops Island 114 kg San Marco-2 26-4-1967 Scout San Marco platform 128 kg	205 km 816 km 37.6° 216 km 797 km 2.9°	*Study of the upper atmosphere and of the earth ionosphere* Two similar experiments on each of two satellites: — measurement of the density of the upper atmosphere by studying the braking effect on the satellite (L. Broglio, CRA, Rome) — measurement of the degree of ionisation of the upper atmosphere and of the ionosphere by studying the characteristics of radio waves (20 MHz) emitted by the satellite (N. Carrara, National Microwave Institute, Florence)
San Marco-3 24-4-1971 Scout San Marco platform 164 kg	222 km 723 km 3.23°	*Study of the upper atmosphere* — measurement of the density by atmospheric braking (L. Broglio, CRA, Rome) — measurement of the temperature and distribution of molecular nitrogen (Goddard Space Flight Center and Univ. of Michigan) — measurement of the density of neutral components in the upper atmosphere, nitrogen, oxygen, argon, helium (Goddard Space Flight Center)
San Marco-4 18-2-1974 Scout San Marco platform 165 kg	228 km 850 km 2.9°	*Study of the upper atmosphere*
Sirio 1st half 1975 Thor Delta Cape Kennedy 220.5 kg	geostationary orbit	*Experimental communications satellite* Transmission of sounds and images on 12 and 18 GHz frequencies. Study of the degradation of signals (reduction, phase distortion, etc.) during their passage through the ionosphere and the atmosphere

is also due to be launched from it. The platform is equipped with a launching ramp for American Scout rockets and with a ramp for US Nike-Apache and Nike-Tomahawk sounding rockets.

The Sirio programme began in 1967. With a total weight of 398 kg at lift-off (220 kg in geostationary orbit), this satellite should have a life expectancy of two years and will enable experiments in sound and image transmission (telephony and TV) to be conducted on hitherto little-used and unfamiliar frequencies. The earth-to-satellite link will be in the 18 GHz band, the down link in the 12 GHz band.

Experiments will be concerned alike with multiple-axis telephone links in a narrow frequency band (1.5 MHz) and wide-band TV transmissions (26 MHz). A telemetry and telecommand station and an SHF antenna are to be installed at Fucino, the location of the Italian station for communicating with Intelsat satellites. Development of the Sirio satellite has been entrusted to the Compagnia Industriale Aerospaziale (CIA). Two scientific experiments on trapped protons and electrons, planned initially, have been abandoned.

EXPERIMENTS BY ITALIAN LABORATORIES ABOARD ESRO AND NASA SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
University of Rome			
A. Egidi	HEOS-A2 31-1-1972 117 kg	359 km 238 199 km 90°	Fluxes and directions of electrons and protons (20 EV - 50 keV) inside and outside the polar magnetosphere
M. Candidi	GEOS mid-1976 180 kg	geostationary orbit	Measurement of the very low frequency (up to 5 Hz) DC magnetic field
Universities of Florence and Rome			
A. Bonnetti and G. Pizzela	HEOS-1 5-12-1968 108 kg	424 km 223 428 km 28.3°	Energy spectrum and angular distribution of solar [1] wind protons (0.15 - 15 keV)
Institut de Physique de l'Université de Milan			
G. Occhialini	HEOS-1 5-12-1968 108 kg	424 km 223428 km 28.3°	Flux and energy spectrum of primary cosmic radiation [1] electrons (50 - 600 MeV)
"	HEOS-A2 31-1-1972 117 kg	4 059 km 238 199 km 9.0°	Flux and energy spectrum of primary cosmic radiation [2] electrons (7 - 500 MeV)
"	TD-1A 12-3-1972 472 kg	533 km 545 km 97.6°	1. Solar gamma ray (50 - 500 MeV) spectrometry during eruptions 2. Intensity of galactic [3] gamma radiation (70 - 300 MeV)
Institute of Physics of Universities of Milan and Palermo			
G. Occhialini	COS-B February 1973 280 kg	350 km 100 000 km 25°	Energy spectrum and direction of arrival of cosmic [4] gamma rays (20 MeV - 5 GeV)
University of Bologna			
D. Brini	OSO-6 9-8-1969 288 kg	550 km 550 km 33°	Solar and cosmic X-rays (20 - 200 keV)

(1) Conducted in collaboration with the University of Brussels (M. Coutrez).

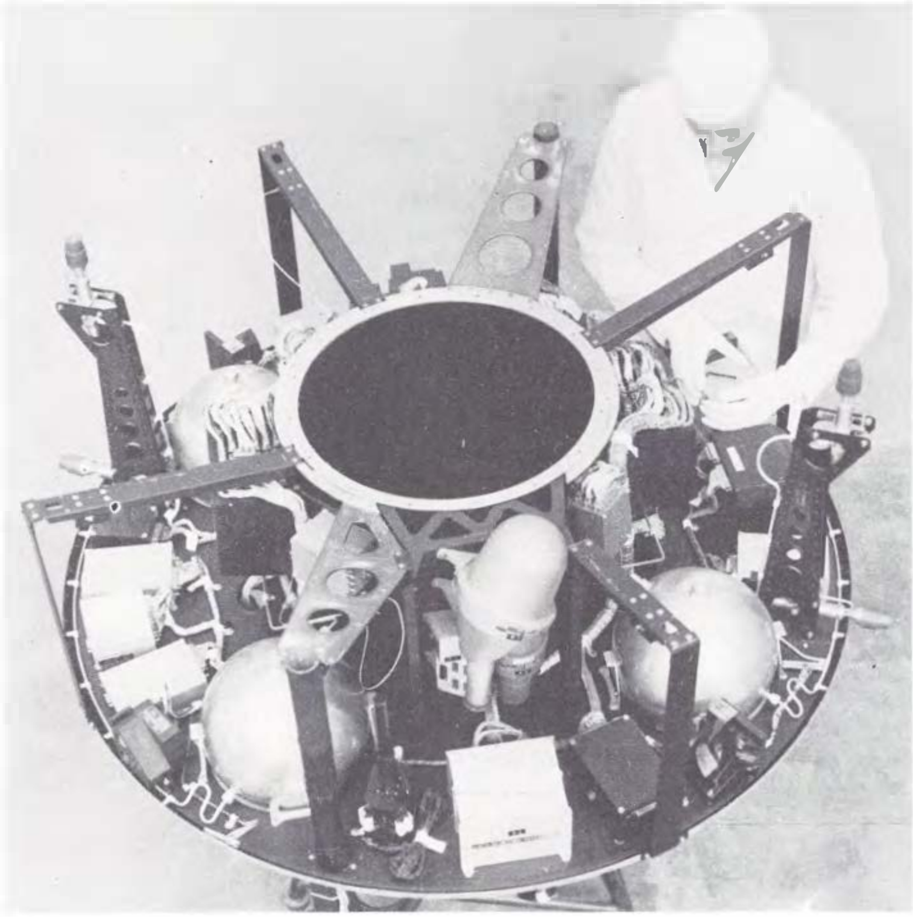
(2) Conducted in collaboration with the Service d'électronique physique of the Centre d'études nucléaires, Saclay (J. Labeyrie).

(3) Conducted in collaboration with the Max Planck Institute for Extraterrestrial Physics, Garching, the Service d'électronique physique du Centre d'études nucléaires, Saclay.

(4) Conducted in collaboration with other European laboratories: the Max Planck Institute for Extraterrestrial Physics, Garching (K. Pinkau), the Service d'électronique physique du Centre d'études nucléaires, Saclay (J. Labeyrie), the Space Science Department of ESTEC, the Kamerlingh Onnes Laboratory of the University of Leiden (H. C. van de Hulst).

NB. Rome University cooperated with the Goddard Space Flight Center in an experiment to measure the interplanetary field on board the US Pioneer-3 probe (1967) and is to collaborate with this Center in a further experiment to measure the interplanetary field aboard the German Helios probes (1974 and 1976).

From 1968 onwards Italian laboratories conducted experiments aboard ESRO or foreign satellites, usually in collaboration with laboratories in other countries. The University of Milan in particular has cooperated with the Nuclear Research Centre at Saclay (France) on many occasions and is continuing to do so in connection with instrument packages on board the COS-B satellite to study cosmic radiation and gamma-ray sources.



Electrical model of Italian experimental communications satellite, SIRIO.

These laboratories also carry out research using sounding rockets and balloons. Moreover Italy operates a sounding rocket range at Salto di Quirra in Sardinia, and an average of six sounding rockets have been launched annually since 1960 as part of the national space programme. Other sounding rockets have been launched from this range by ESRO and NASA (e.g. Skylark and Centaure rockets) under cooperative programmes. A number of experiments have been conducted aboard balloons, some of them in collaboration with France.

Netherlands

Up to 1970 all of the Netherlands' space projects were implemented within ESRO or in cooperation with non-European countries. Experiments were placed notably on board ESRO and NASA satellites and sounding rockets. In 1971 the Netherlands decided to build its first national satellite, the ANS (Astronomical Netherlands Satellite), which is scheduled for launch by NASA in 1974. The Netherlands has no national satellite project other than this for the time being. It does not build sounding rockets, satellite launchers, nor balloons.

The ANS project was initiated in 1971 when the Ministry of Economic Affairs awarded a Dutch industrial consortium a contract for the construction of a 136 kg satellite for studying stellar UV and x-ray emission. The ANS has been defined and determined jointly by Netherlands industry and scientific experimenters. Its development and the cooperation with NASA have been agreed by the Government. Costing approximately 76 million guilders, this project is funded by the Ministry of Economic Affairs and the Ministry of Education and Science. A second flight model may be launched subsequently.

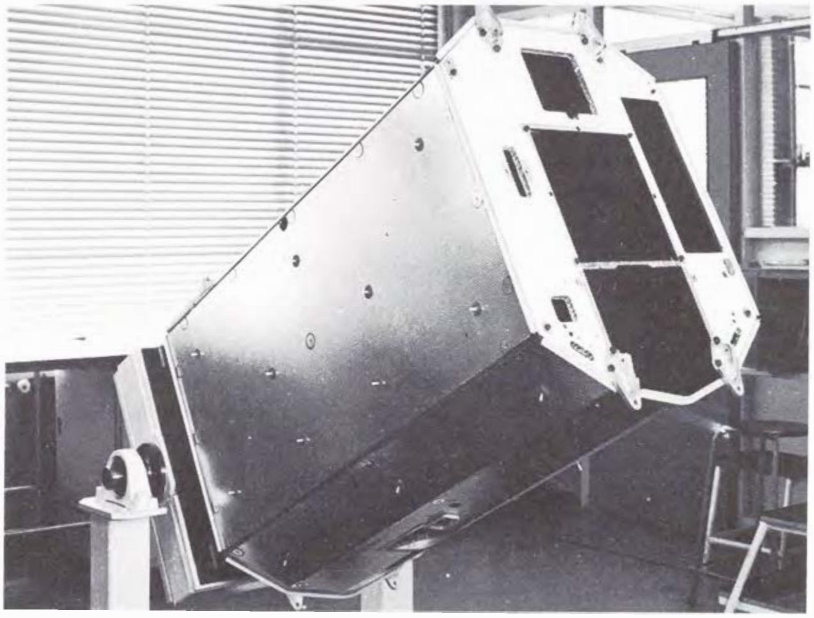
The ANS satellite will have several sun and star sensors on board, enabling it to be aimed and stabilised to within one minute of arc. A small on-board computer will be used to store a continuous twelve-hour stellar observation programme. A special facility for processing scientific data from the ANS will be set up at the University of Utrecht and will be linked to ESRO's operations centre (ESOC) at Darmstadt.

THE ANS SATELLITE

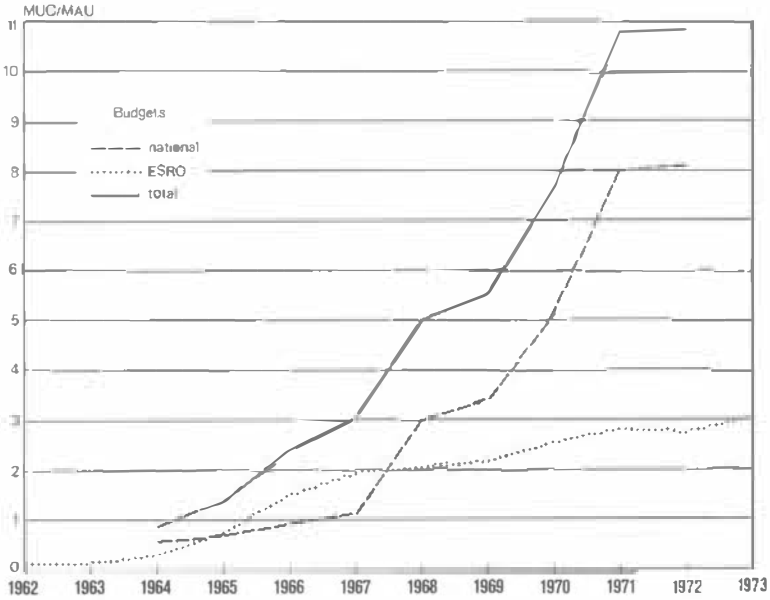
total weight	136 kg
dimensions	height : 123 cm width : 61 cm with folded solar panels 144 cm with deployed solar panels length : 73 cm
launch date	August 1974
rocket	Scout
launching base	Vandenberg
orbit	circular at 500 km sun synchronous
scientific mission	Study of UV spectrum (1 500 - 3 295 Å) of young hot stars up to 10th magnitude, using a Cassegrain telescope (Kapteyn Observatory, University of Groningen) Observation of soft X-rays from cosmic sources, using small area (44 - 70 Å) and large area (2 - 16 and 27 - 35 Å) proportional counters (Space Research Laboratory, University of Utrecht) Observation of hard X-rays (2 - 40 keV) from cosmic sources, using two proportional counters (American Science & Engineering Inc. and Massachussetts Institute of Technology, Cambridge, U.S.A.)

Dutch laboratories have carried out scientific experiments on board ESRO sounding rockets, in cooperation with NASA and Japan (four in 1965 and one in 1967, one in 1971 and one in 1972, respectively). Delft University participated in the Western European Satellite Triangulation (WEST), the American National Geodetic Satellite Programme (NGSP) and the International Satellite Geodesy Experiment (ISAGEX).

In recent years experiments have also been conducted with balloons. On an average, two balloons have been sent up yearly to study IR, UV and hard X-ray solar radiation, to prepare for the TD-1A satellite's onboard experiments, and to measure diffuse background radiation in the 20 - 220 keV range, x-ray emission from the pulsar in the Crab nebula and broadband infrared emission from the galactic centre.



ANS, *Dutch astronomical satellite to be launched in 1974 (VFW-Philips photo).*



Netherlands' space budget.

EXPERIMENTS BY NETHERLANDS LABORATORIES ABOARD ESRO AND NASA SATELLITES

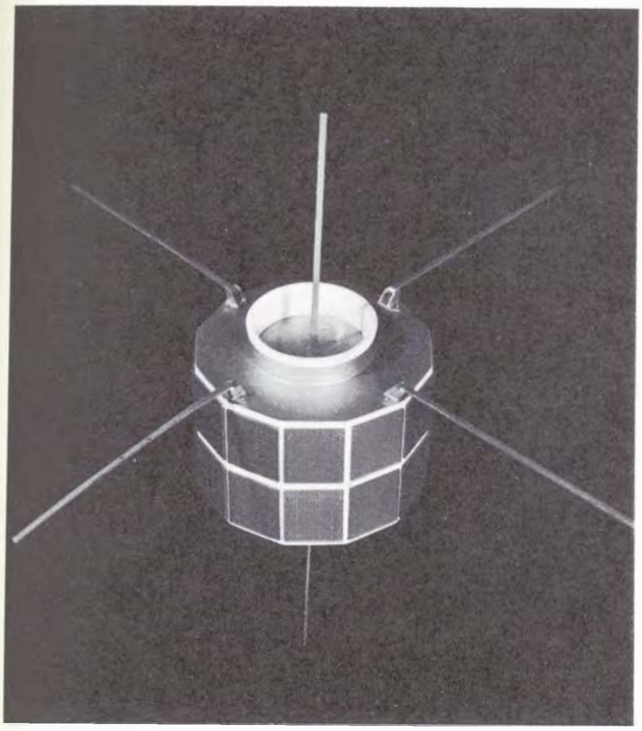
LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Space Research Lab., Univ. of Utrecht C. de Jager	ESRO-II 17-5-1968 75 kg	332 km 1 094 km 97.2°	Soft solar X-ray fluxes (44 - 60 A)
H. F. van Beck C. de Jager	TD-1A 12-3-1972 472 kg	533 km 545 km 97.6°	1. Solar X-ray measurements (20 - 900 keV) 2. Ultraviolet (2 000 - 3 000 A) star spectrometry
C. de Jager	ESRO-IV 22-11-1972 113 kg	280 km 1 100 km 90°	Detection of solar protons (2 - 100 MeV) and alpha particles (4 - 240 MeV) above the polar regions
Kamerlingh Onnes Cosmic Ray Lab., Leiden Univ. H. C. van de Hulst	COS-B 1975 280 kg	350 km 100 000 km 25°	Energy and direction of arrival of cosmic (1) gamma rays (20 MeV - 5 GeV)
Kamerlingh Onnes Lab., Leiden University H. C. van de Hulst	OGO-5 4-3-1968	278 km 148 160 km 31°	Energy fluxes and spectra of cosmic radiation electrons

(1) Experiment conducted in collaboration with other European laboratories: Max Planck Institute for Extraterrestrial Physics, Garching (K. Pinkau), the Service d'électronique physique of the Centre d'études nucléaires, Saclay (J. Labeyrie), the Universities of Milan and Palermo (G. Occhialini) and the Space Science Department of ESTEC.

Spain

Up to now space research in Spain has been carried out with sounding rockets and balloons. The sounding rockets have been launched by the National Commission for Space Research (CONIE), by ESRO, or on a cooperative basis with other countries. In 1967 Spain undertook the design and development of a first sounding rocket, the Inta-250, with the help of Britain's Hawker Siddeley Dynamics. The Inta-250 was flight-tested for the first time in December 1969. In 1971 the Instituto Nacional de Tecnica Aerospacial (INTA) completed the definition phase on a more powerful sounding rocket, the Inta-300. That same year the Spanish government approved a project for a first Spanish satellite, the Intasat.

Initial studies on a satellite project by the National Commission for Space Research (CONIE) began at the end of 1968, and the definition phase took place in 1969 and 1970 in collaboration with Hawker Siddeley Dynamics. From June 1970 onwards the work was pursued in Spain and project management for the Intasat ionospheric satellite was turned over to INTA. This satellite is due to be launched in 1974 by a NASA Delta rocket together with the US Itos-F meteorological satellite.



The first Spanish satellite, INTASAT (HSD photo).

INTASAT SATELLITE	
total weight	24.5 kg
height	450 mm
width	445 mm
launch date	July 1974
launcher	Delta
launch site	Vandenberg (USA)
orbit	circular at 500 km sun synchronous
scientific mission	study of the density of the ionosphere by means of a balloon which will transmit polarised signals linearly on 40 and 41 MHz

Spanish laboratories have so far conducted their experiments by means of ESRO and foreign sounding rockets, either directly through CONIE or in collaboration with Federal Germany, Belgium, the United States, France and Switzerland, but chiefly with the United Kingdom. Their main area of interest has been the ionosphere. Between 1966 and 1973, 294 sounding rockets were launched from the El Arenosillo facility, many of them in cooperation with foreign institutions. These launches included a large number of American Judi Dart meteorological rockets, and British Skua, American Nike and French Centaure rockets.

Other experiments relating to the density and composition of cosmic radiation and to the sun's photospheric granulation and infrared radiation were conducted in 1969, 1970, 1971 and 1972 aboard balloons sent up from France or the United States. The stabilized nacelle developed by the University of Liège (Belgium) was used for some of the astronomical experiments.

While many of the industrial aspects of space activities in Spain are in the development stage, the following Spanish concerns should be noted as having collaborated most significantly with INTA on the Intasat satellite and other programmes:

— CASA (Construcciones Aeronauticas, S.A.)

— ITT Spanish Laboratories

— SENER

— IBM

SOUNDING ROCKETS LAUNCHED FROM THE EL ARENOSILLO LAUNCH BASE (outside ESRO programme)

1966	14
1967	
1968	32
1969	32
1970	82
1971	42
1972	49
1973	40
total	291

These sounding rockets are of the type Judi, Skua, Nike and Centaure. Three Spanish Inta-255 sounding rockets have also been launched since the end of 1969.

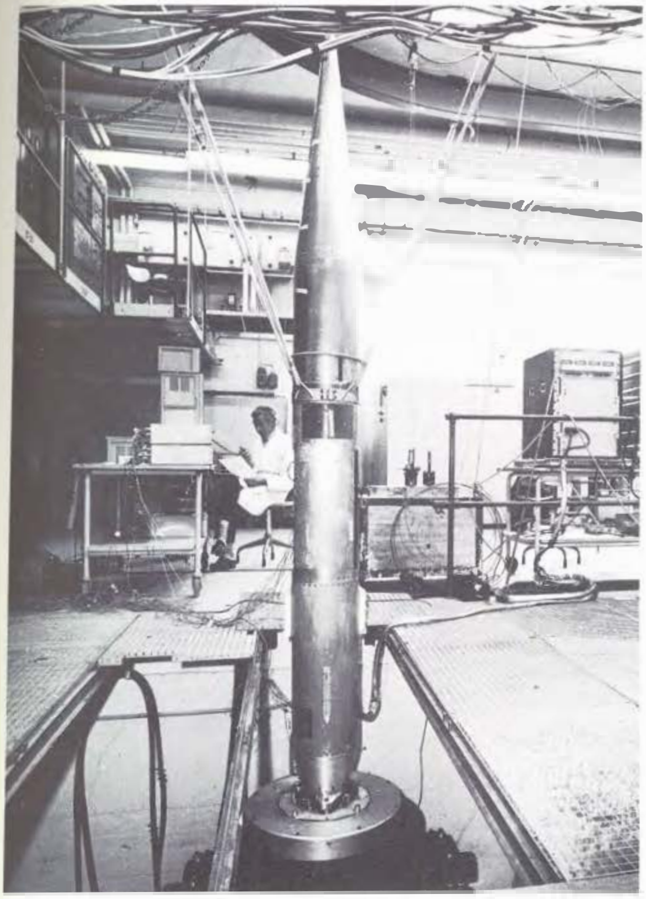
Sweden

So far space research has been conducted by means of instrumentation packages placed on board ESRO satellites and on board sounding rockets and balloons. Sounding rockets have been launched in collaboration with ESRO, in collaboration with other countries, or as part of the national programme. In 1967-70 Sweden contemplated the construction of a first scientific satellite but the project never materialised. A sounding rocket construction project was also abandoned. Sweden is due to place an experiment on board a Russian Intercosmos satellite in 1975.

Sounding rocket launches began in 1961. Sweden has collaborated notably with NASA, the German Federal Republic's DFVLR and the UK's Science Research Council.

SWEDISH EXPERIMENTS LAUNCHED BY SOUNDING ROCKET

	NATIONAL PROGRAMME	ESRO PROGRAMME	JOINT PROGRAMMES
1961	1	—	—
1962	5	—	—
1963	7	—	—
1964	9	—	1
1965	4	—	6
1966	—	2	1
1967	—	2	1
1968	1	6	4
1969	6	6	2
1970	6	6	3
1971	—	5	2
1972	4	—	—
Total = 90	43	27	20



Preparation of a sounding rocket payload (photo SAAB-Scania).

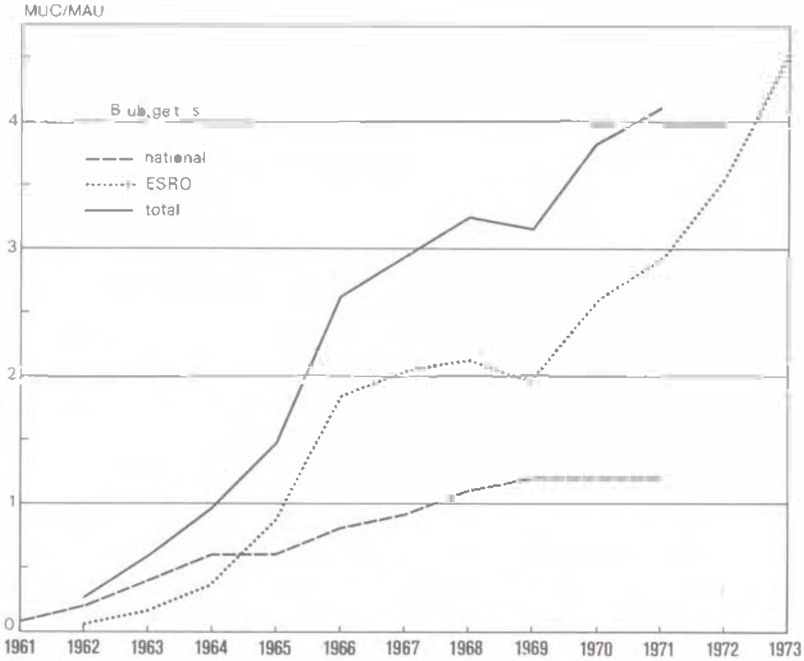
Several balloon release campaigns have been conducted jointly by Sweden and the Federal Republic of Germany, using balloons purchased in France. Five to ten balloons have been launched each year from Kiruna. These balloons have an average capacity of 5 000 m^3 and carry a payload of about 20 kg.

There are about 10 laboratories interested in space in Sweden: the Kiruna Geophysical Institute (Kiruna); the Space Physics Group, Department of Plasma Physics, Royal Institute of Technology (Stockholm); the Geodetic Institute (University of Uppsala); the Ionospheric Observatory (Uppsala); the Section for Atmospheric Physics, Institute of Meteorology (University of Stockholm); the Astronomical Observatory (University of Lund); the Stockholm Observatory; the Cosmic High Energy Physics Group, Department of Physics (University of Lund); the Cosmic Ray Group (University of Uppsala); Onsala Space Observatory, Chalmers Institute of Technology (Gothenburg).

The Kiruna sounding rocket range, ESRANGE, was set up by ESRO, and became operational in November 1966. In 1971 the member countries of ESRO decided to transfer the range to Sweden on 1st July 1972. The launching range is used by ESRO member countries under an agreement running for five years and constituting a Special Project within ESRO.

EXPERIMENTS BY SWEDISH LABORATORIES ABOARD ESRO SATELLITES

LABORATORY EXPERIMENT	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Kiruna Geophysical Observ. B. Hultqvist	ESRO-I 3-10-1968 86 kg	253 km 1 534 km 93.8°	Fluxes of electrons and protons precipitated or trapped in the northern auroral zones (1 - 13 keV)
»	ESRO-IV 22-11-1972 113 kg	280 km 1 100 km 90°	Pitch angles and energy spectrum (0.5 - 150 keV) of electrons and protons precipitated in the auroral zones
»	GEOS mid-1976 180 kg	geostationary orbit	Pitch-angle distribution of incidence of electrons and protons (0.2 - 20 keV)



Sweden's space budget.

Switzerland

Switzerland has no national space programme, all projects being implemented either on a bilateral cooperation basis or in collaboration with other countries within ESRO. Experiment packages have been placed on board ESRO and NASA satellites and sounding rockets. Switzerland built Zenit sounding rockets but has not developed a satellite of its own so far.

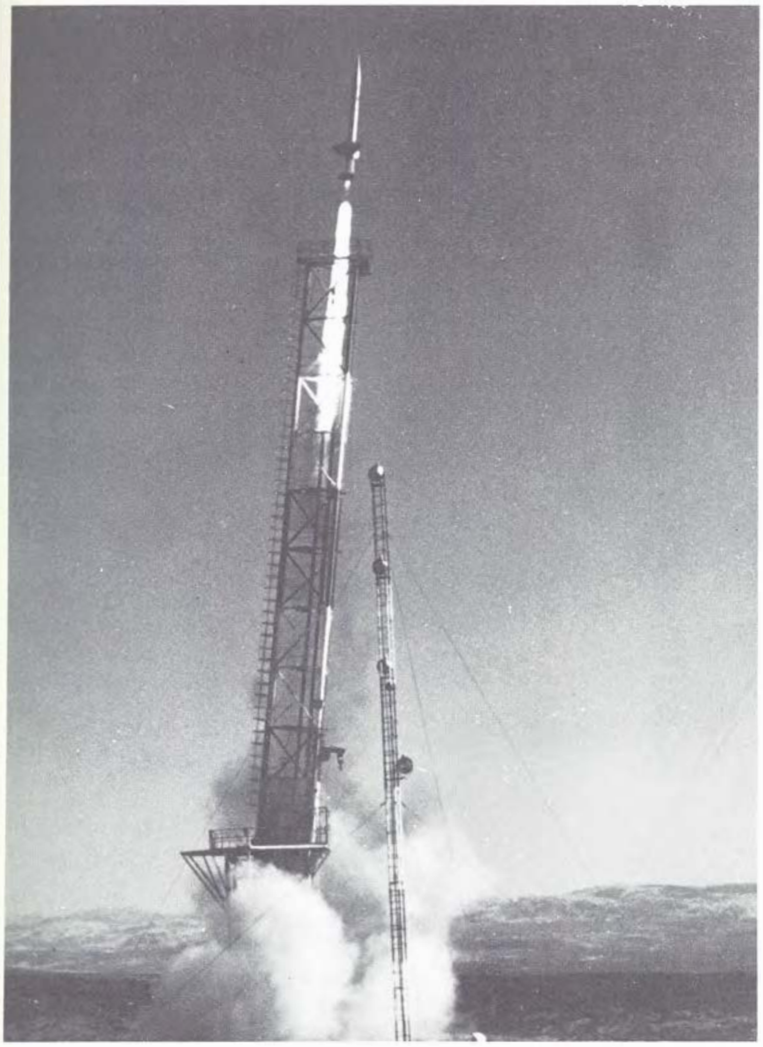
The Physics Institute of the University of Berne will be placing Switzerland's first experiment on an European satellite in connection with the GEOS programme. Previous to this, the Physics Institute has had an instrumentation package aboard each Apollo flight, as well as on board Skylab. Experiments on board sounding rockets began in 1970 when ESRO launched two rockets to study the composition of the atmosphere and neutral and ionized particles. This experiment was repeated with two-more firings in 1971. In 1972 and 1973 sounding rockets were launched to study atmospheric pressure.

In 1972, in collaboration with Federal Germany's DFVLR, the Physics Institute of Berne University conducted a further sounding rocket experiment on the composition of the upper atmosphere. This study is to be pursued through 1974 and 1975 in collaboration with Spain. In 1971 the Institute also had aurora borealis experiments on two American Nike-Tomahawk sounding rockets, in collaboration with the University of San Diego.

SWISS EXPERIMENTS ON BOARD SOUNDING ROCKETS AND BALLOONS

	ROCKET LAUNCHES (1)	BALLOON LAUNCHES
1970	2	2-3 launches per year, including:
1971	5	7 balloons of 50,000 cu. m capacity
1972	2	2 balloons of 100,000 cu. m capacity 1 balloon of 300,000 cu. m capacity
1973	2	1 balloon of 600,000 cu. m capacity

(1) Including ESRO souding rockets.



Launch of a Zenith sounding rocket (Contravès photo).

Meanwhile the Geneva Observatory and the Physical Chemistry Laboratory of the Federal Polytechnic School of Zurich have helped to study the data picked up by the American OAO astronomical satellite, jointly with the Madison Astronomy Department.

Two earth resources research programmes by the Geography Institute of the University of Zurich are under way, on the basis of images of the earth taken by America's ERTS-1 earth resources technology satellite and Skylab orbiting laboratory (the EREP experiment).

The sounding rocket built by the Contraves concern in Switzerland in collaboration with the German Dornier concern has been flight-tested three times since 1967.

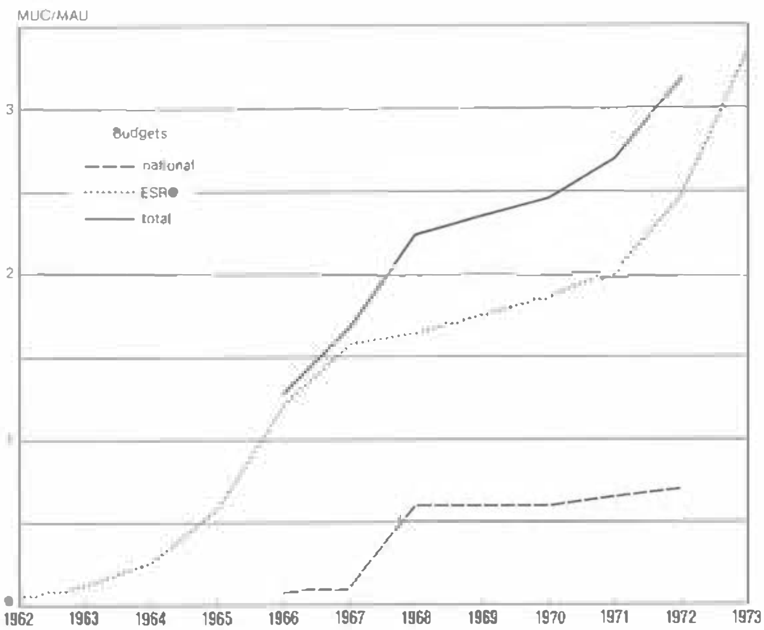
Other experiments connected with the ozone in the atmosphere, the atmosphere's transparency, and solar infrared and stellar ultraviolet radiation are conducted with balloons. The latter are purchased in France or the United States and their capacities range from 50 000 to 600 000 m³. The payload is a 250 kg observation nacelle designed and built by Geneva Observatory that can be aimed with an accuracy of to within one minute of arc. An onboard computer programs the experiments and provides onboard control.

The Physics Institute of the University of Berne, the Crystallography and Petrography Institute of the Federal Polytechnic School of Zurich, and the Mineralogy and Petrography Institute of the University of Basle are helping to analyse the moon samples brought back by the Apollo astronauts and the Soviet Luna probes.

EXPERIMENTS BY SWISS LABORATORIES ABOARD ESRO AND NASA SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
Bern University			
J. Geiss and P. Eberhardt	GEOS mid-1976 180 kg	geostationary orbit	Composition, energy spectrum and angular distribution (1) of magnetospheric plasma particles
J. Geiss	Apollo-11 16-7-1969 Apollo-12 14-11-1969 Apollo-14 31-1-1971 Apollo-15 26-7-1971 Apollo-16 16-4-1972	lunar trajectory	Investigating solar wind composition by means a sheet of aluminium set up on the moon and exposed to the solar wind during the astronauts' stay on the moon
»	Skylab 14-5-1973	435 km 435 km 50°	Content of heavy ions notably noble gases, in the magnetosphere (2)

(1) Conducted in collaboration with the Max Planck Institute for Extraterrestrial Physics, Garching (H. J. Völk).
(2) Conducted in collaboration with the astronaut Don Lind, Manned Spacecraft Center, Houston.



Switzerland's space budget.

United Kingdom

The United Kingdom's initial space projects go back to before the 1960s. To date these include four scientific satellites, a technology satellite and two military communications satellites, and the UK has launched several hundred sounding rockets and dozens of balloons. It has built a successful satellite launcher, the Black Arrow (a programme which was terminated at the end of 1971), and produces several families of sounding rockets (Skua, Petrel and Skylark).

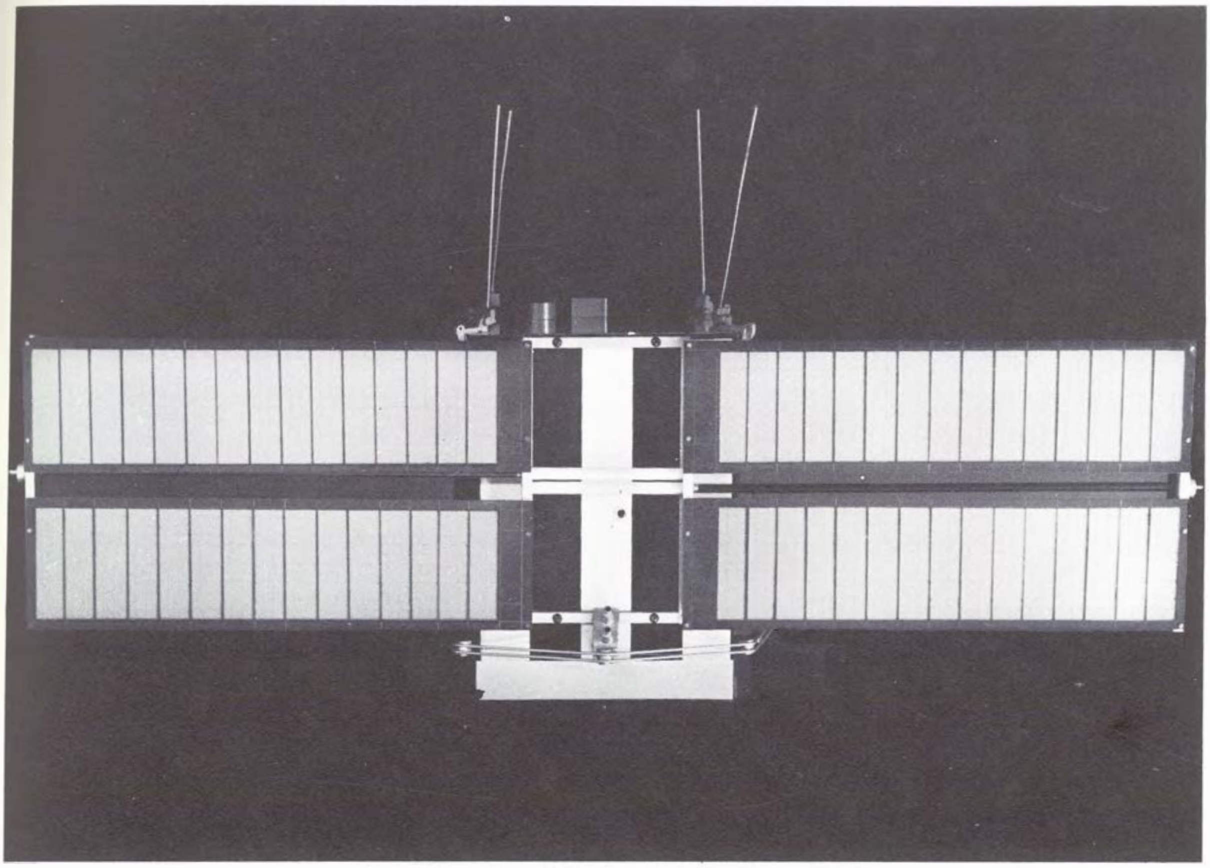
The UK does not have a special-purpose national space technical centre nor a network of telemetry and command stations. The satellite and sounding rocket integration and test facilities are distributed among government establishments and companies in charge of the production side. Early in the 1960s, a rocket launching range was built at Woomera in Australia, from which launches of the Black Arrow and the European Europa-2 launch vehicles took place. The Woomera facility is also used for launching sounding rockets.

As responsibility for preparing, running and financing space projects falls to several government departments and agencies it is difficult to speak of any single British space programme. The technological research and satellite programme and the industrial development projects are prepared by DTI and the space science programme is run by SRC. The military communications satellite programme is defined by MOD.

1. R & D Programme

DTI continues to follow the practice of the Ministries which preceded it by providing funds for R & D in industry and in a number of goverment laboratories, such as the Royal Aircraft Establishment.

British technology satellite X-4, launched in 1974 (HSD photo).



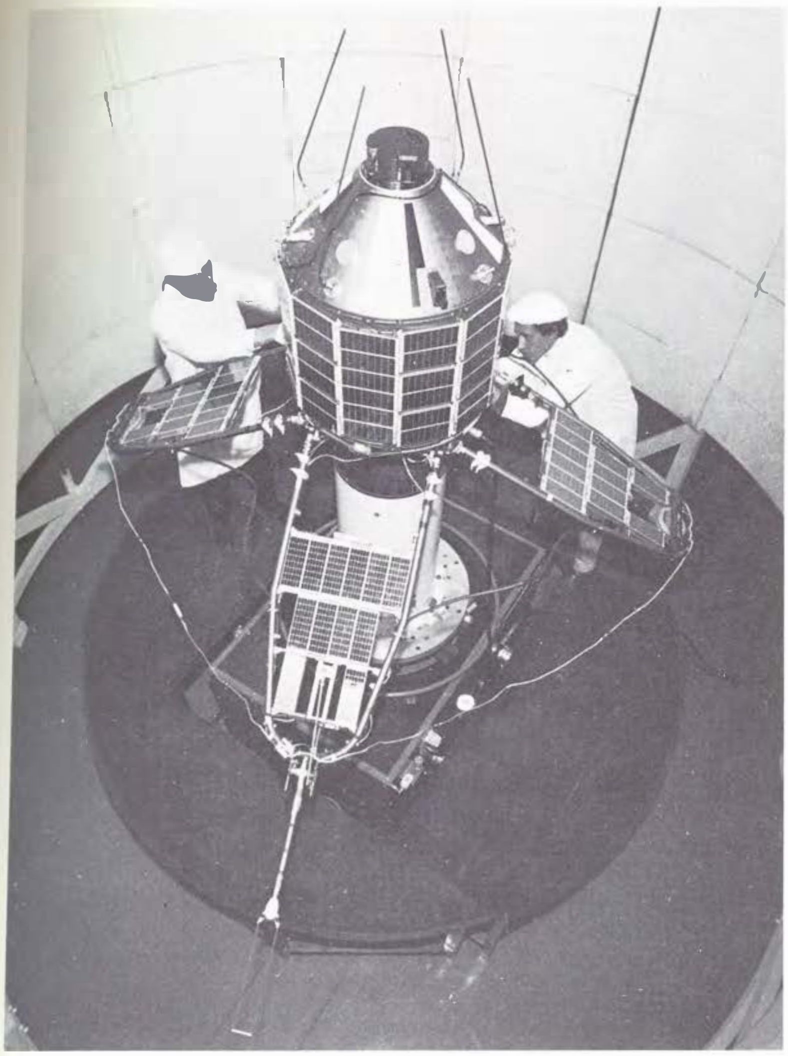
CHARACTERISTICS OF BLACK ARROW LAUNCHER			
	1st STAGE	2nd STAGE	3rd STAGE
Thrust (kN)	227	70	21.9
Number of engines	8	2	1
propellants	hydrogen peroxide and kerosene	hydrogen peroxide and kerosene	solid propellant
total mass at lift-off (metric tons)	14.2	3.5	0.353
mass of propellants (metric tons)	13.2	3.18	0.318
dry mass (metric tons)	1,015	0.37	0.035
height (metres)	5.7		
diameter (metres)	2	1.37	1.26
burn time (seconds)	125	121	40
specific impulse (seconds)	217-250	265	276
attitude control	swivelling nozzles	swivelling nozzles	rotation

With a view to testing new equipment and components, the UK decided in October 1964 to build Black Arrow, a vehicle intended to launch a series of technology satellites, and the first of which known as Prospero (previously X3) was successfully launched from Woomera before the Black Arrow programme was abandoned in 1971. Another technology satellite, the X-4, was launched by an American rocket early in 1974 at a total cost of £ 6 million (including the launch).

A monitoring centre was installed at the Royal Aircraft Establishment for the Prospero satellite, from which the latter received command signals throughout its life from September 1971 to October 1972. The same facility is being used for the X-4 satellite. A telemetry and command station at Lasham (Hants) is linked to the Farnborough monitoring centre.

DTI has undertaken a programme of sounding rocket launches in collaboration with certain other countries, the aim being to experiment with Skylark sounding rockets equipped for the detection of earth resources. This cooperative programme began with Argentina, from whose

X-3, British satellite launched in 1971 for meteorology and the study of micro-meteorites (Marconi SDS photo).



British satellite ARIEL-4, *launched in 1971 to study the ionosphere* (BAC *photo).*

territory two Skylarks were launched in March 1973, and is currently being pursued with Federal Germany's DFVLR and the Swedish Space Corporation. DTI also backs several groups of British experimenters engaged in studying the images transmitted by NASA's ERTS-1 earth resources satellite.

2. Space Science Programme

British research teams have conducted numerous experiments using UK, ESRO and US satellites as well as using national and foreign sounding rockets.

The UK's scientific satellite programme began many years ago when, at a March 1959 meeting of COSPAR (Committee on Space Research of the International Council of Scientific Unions), NASA offered to launch foreign scientific payloads or satellites. An agreement was accordingly negotiated in 1959-1960 between NASA and the British National Committee on Space Research for three satellites carrying British instrumentation packages to be launched over a five-year period. These were the Ariel-1, Ariel-2 and Ariel-3 satellites.

The Ariel-1 and Ariel-2 satellites were built in the United States and only the instrumentation payloads were developed by the United Kingdom. On the other hand, the Ariel-3 satellite launched in 1967 was built entirely in the UK. On each occasion the US supplied the launch vehicle free of charge and undertook the satellite tracking function.

In 1969 the SRC signed a further Memorandum of Understanding with NASA, as a result of which an American rocket was used to launch Britain's Ariel-4 which carried four British and one American instrument packages. A fifth scientific satellite (UK-5), designed to study X-ray sources, is due to be launched in the first half of 1974 from the San Marco international platform off the coast of Kenya. This satellite will have five British experiments and one US instrument on board.

EXPERIMENTS ABOARD BRITISH SATELLITES

SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	LABORATORY EXPERIMENTER	EXPERIMENT
UK-1 (Ariel-1) 26-4-1962 60 kg	387 km 1 206 km 53.9°	University College, London R. F. Boyd and A. P. Willmore	*Studies of the ionosphère and the sun* 1. Electron temperature, density and composition (Langmuir probe) 2. Temperature, mass and composition of ions in the ionosphere (mass spectrometer)
		J. A. Bowles and A. P. Willmore	3. Solar Lyman alpha radiation (1 100 - 1 350 Å)
		University College, London and Univ. of Leicester R. F. Boyd and K. A. Pounds	Solar X-ray radiation (3 - 12 Å)
		Univ. of Birmingham J. Sayers	Electron density in the ionosphere
		Imperial College, London H. Elliott and J.J. Ouenby	Energy spectrum of primary cosmic radiation
UK-2 (Ariel-2) 27-3-1964 75 kg	288 km 1 349 km 51.6°	Meteorol. Office, Bracknell R. Frith and K. H. Stewart	*Studies of atmospheric and interplanetary space* Vertical distribution of ozone in the earth's atmosphere (2 500 - 4 000 Å)
		Mullard Radio and Astronomy, Univ. of Cambridge F. Graham-Smith	Intensity of galactic radio noise (0.75 - 3 MHz)
		Nuffield Radio and Astronomy and Univ. of Manchester (Jodrell Bank) R. C. Jennison	Micrometeorite fluxes
UK-3 (Ariel-3) 5-5-1967 90 kg	489 km 595 km 80.2°	Meteorol. Office, Bracknell R. Frith and K. H. Stewart	*Study of ionosphere and radio-astronomy observations* Vertical distribution of molecular oxygen
		Univ. of Birmingham J. Sayers	Electronic density and temperature
		Radio and Space Research Station, Slough J. A. Saxton	Intensity of terrestrial radio noise and geographical distribution of noise sources
		Univ. of Sheffield K. Bullough	Intensity and variation of very-low-frequency radio noise (3.2, 9.6 and 16 kHz)
		Univ. of Manchester (Jodrell Bank) F. G. Smith	Galactic radio noise (2 - 5 MHz)

SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	LABORATORY EXPERIMENTER	EXPERIMENT
UK-4 (Ariel-4) 11-12-1971 100 kg	474 km 589 km 83°	Univ. of Manchester F. G. Smith	*Radio astronomy* Intensity of galactic radio noise [1]
		Univ. of Sheffield K. Bullough	Emission of very low and extremely low frequency radio noise ; VLF pulses
		Univ. of Birmingham J. Sayers	Electron temperature and density
UK-5 (Ariel-5) 1974	equatorial orbit at 500 km	Univ. of Leicester K. A. Pounds	*X-ray astronomy* 1. Celestial map of X sources (1.5 - 20 keV) and diffuse X radiation sources 2. Polarization of X sources and energy spectrum of sources (1 - 8 keV)
		Mullard Space Science Lab. R. L. F. Boyd	1. Celestial map of X sources (0.3 - 30 keV) 2. Energy spectrum of X sources (2 - 10 keV)
		Imperial College, London	Energy spectrum of X sources (20 keV - 2 MeV) and study of pulsed X-radiation
X-3 (Prospero) 28-10-1971 66 kg	544 km 1 573 km 82.06°	Univ. of Birmingham	*Technology satellite* Testing a new type of solar cell and thermal coating Micrometeorite fluxes
X-4 Feb.-March 1974 93 kg	750 km 750 km 98.4°		*Technology satellite* Tests of a three-axis stabilization system, unfurlable solar panels, and solar, stellar and albedo sensors

1. Experiment conducted in collaboration with the Radio and Space Research Station, Slough.
N.B. The University of Iowa (Dr. L. A. Franck) had an experiment aboard UK-4 for measuring low-energy (5 eV - 50 keV) charged particles. The Goddard Space Flight Center placed an experiment aboard UK-5 to study variable X-ray sources.

A telemetry and tracking station, which forms part of NASA's STADAN network, has been set up at Winkfield and is run by SRC. A monitoring centre for the UK-5 satellite is being completed at the Appleton Laboratory and will be linked to NASA's STADAN and NASCOM networks.

Many universities are interested in space exploration: these include the Mullard Space Science Laboratory of University College London, the Imperial College of Science and Technology in London, the Universities of Birmingham, Southampton, Leicester, Oxford, Reading, Bristol and Sussex, and Queen's University (Belfast).

Twelve experiments provided by UK laboratories have already been launched as part of the payloads on board American satellites in the Explorer, OSO, OGO, OAO and Nimbus series.

Three types of sounding rockets are built in the UK and are used for scientific purposes in the national programme. The Skua rocket is used for launching small payloads, the more powerful Petrel rockets for launching larger payloads and the much larger Skylark rockets for lifting widely differing payloads to various altitudes. Over 350 British sounding rockets have been launched from various ranges (Woomera, South Uist, Andoya, etc.) since 1960 as part of the national programme. Well over half of these were the well-tried Skylark rocket. Most aspects of space research have been and are being covered in the national programme by the use of these rockets.

EXPERIMENTS BY BRITISH LABORATORIES ABOARD ESRO SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
University of Leeds			
M. Wilson and P. Marsden	ESRO-II 17-5-1968 75 kg	332 km 1 094 km 97.2°	Flux and energy spectrum of primary cosmic radiation electrons (1 - 13 GeV)
Imperial College, London			
H. Elliott and J. J. Quenby	ESRO-II 17-5-1968 75 kg	332 km 1 094 km 97.2°	1. Time variations of particle fluxes in the Van Allen radiation belts
H. Elliott and Y. Hynds			2. Energy spectrum of solar protons (1 - 100 MeV) and Van Allen Belt protons after solar eruptions
H. Elliott and J.J. Quenby			3. Solar and galactic proton and alpha particle radiation fluxes (0.4 — 0.8 GeV)
H. Elliott and M. Engel	HEOS1 5-12-1968 108 kg	424 km 228 428 km 28.3°	1. Directional anisotropy of solar proton fluxes (E > 350 MeV) and correlation with interplanetary magnetic fields
H. Elliott and M. Hedgecock			2. Interplanetary magnetic field measurements ± 64 gammas) inside and outside the magnetosphere and close to the shockwave 3. Energy spectrum (1 — 20 MeV) and direction of arrival of solar protons
H. Elliott	HEOSA2 31-1-1972 117 kg	359 km 238 199 km 90°	Intensity (± 144 gammas) of the Interplanetary and magnetospheric magnetic fields
Royal Observ. of Edinburgh			
H. Butler	TD-1 A 12-3-1972 472 kg	533 km 545 km 97.6°	Map of the sky and of celestial objects up to magnitude 9 (1 350 — 3 000 Å)
University College, London			
R. L. F. Boyd	ESRO-II 17-5-1968 75 kg	332 km 1 094 km 97.2°	Flux and spectrum of hard solar X-rays (1 — 20 Å) (2)
"	ESRO-1 3-10-1968 86 kg	306 km 393 km 85.1°	1. Electron temperature and density in the ionosphere 2. Ion composition and temperature in the ionosphere
"	ESRO-IV 22-11-1972 113 kg	280 km 1 100 km 90°	Nature, energy spectrum and rate of drift of ions; electron temperature and density
Radio and Space Research Station, Slough			
R. Dalziel	ESROI 3-10-1968 86 kg	306 km 393 km 85.1°	1. Flux and energy spectrum (50 — 400 keV) of precipitated and trapped electrons 2. Flux an energy spectrum of protons produced during solar absorption phenomena (1 — 30 MeV)
Mullard Space Science Lab.			
M. Raitt	GEOS mid-1976 180 kg	geostationary orbit	Study of superthermal plasma

1. Experiment conducted in collaboration with the Institut d'astrophysique of the University of Liège (L. Houziaux, A. Monfils).
2. Experiment conducted in collaboration with the University of Leicester.

EXPERIMENTS BY BRITISH LABORATORIES ABOARD NASA SATELLITES

LABORATORY EXPERIMENTER	SATELLITE LAUNCH DATE WEIGHT	ORBIT PERIGEE APOGEE INCLINATION	EXPERIMENT
University College, London			
R.L.F. Boyd and A.P. Willmore	Explorer-20 25-8-1964	866 km 1 019 km	Ion concentration and temperature in the atmosphere
A.P. Willmore	Explorer-31 29-11-1965	500 km 3 000 km 80°	1. Distribution of positive ions in the ionosphere 2. Electron temperature
R.L.F. Boyd	OSO-4 18-10-1967	circular at 550 km 33°	Solar X-ray detection (1 - 20 and 44 - 75 Å)
•	OSO-4 18-10-1967	circular at 550 km 33°	Radiations emitted by solar hydrogen (1 216 Å) and helium-II (304 Å)
•	OGO-5 4-3-1968	278 km 148 160 km 31°	Electron temperature and density; interactions between solar wind and magnetospheric plasma
•	OSO-5 22-1-1969	circular at 550 km 33°	Intensity and variation of solar X-rays (3 - 9 Å and 8 - 18 Å) (1)
•	OSO-6 9-8-1969	circular at 550 km 33°	Solar spectrum lines in the helium-I (584 Å), helium-II (304 Å), oxygen-II (833 Å), oxygen-IV (790 Å) and nitrogen-III (922 Å) ultraviolet
•	OAO-3 21-8-1972	circular at 740 km 35°	Study of X-ray sources up to 70 Å (1)
University of Southampton			
G. Hutchinson	OGO-5 4-3-1968	278 km 148 160 km 31°	Cosmic gamma ray detection
University of Oxford (Clarendon Lab.)			
J.T. Houghton	Nimbus-4 8-4-1970	circular at 1 100 km 80°	Determination of the atmosphere's temperature profile, from the cloud cover up to an altitude of 65 km (2)
•	Nimbus-5 10-12-1972	99.94°	As for Nimbus-4
•	Nimbus-F 1974	circular	Temperature profile of the atmosphere

1. Experiment conducted in collaboration with the University of Leicester.
2. Experiment conducted in collaboration with Thomson Physics Laboratory of Reading (D. Smith).

N.B. London University is to be co-experimenter with the Jet Propulsion Laboratory in exploiting the TV pictures from the Mariner Venus/Mercury interplanetary probe (1973). The University of York is to be co-experimenter with the University of Michigan in an experiment aboard the Atmospheric Explorer E satellite (1975). The Jodrell Bank Laboratory is to be co-experimenter with the Langley Research Center in the study of radio signals from the Viking Mars probes (1975).

The SRC also undertakes sounding rocket launching programmes in collaboration with other countries and in particular the Commonwealth Collaborative Programme provides for rocket launches jointly with India and with Pakistan. Under this programme three Skua rockets were launched in February 1970 from the TERLS launch facility in India, in November 1971 two Petrel rockets were launched from the Pakistani range at Sonmiani and eight Petrel and three Skua rockets were launched from TERLS in January-February 1972.

SRC has collaborated with NASA and the Swedish Science Research Council in the launching of two Nike-Cajun rockets in January 1969, and with the Pakistan Upper Atmosphere Research Committee and NASA in the launching of four Nike-Cajun rockets in October 1969.

Various collaborative payloads have been flown from Woomera in Skylark rockets and in recent years these have included cooperative launches with Australian and American experimenters for the study of UV and X-ray emissions from celestial objects, usually at the rate of one or two launches per year. Two launches from Woomera are planned for 1974, one of which will be in collaboration with the Saclay Centre of Nuclear Studies and the other with the University of Adelaide and others are planned for 1975 and 1976. These will cover studies of the Crab Nebula, the upper atmosphere and the sun.

Other collaborative payloads have recently been included in Skylarks launched from Andoya and others are planned.

In 1976, the International Ultraviolet Explorer satellite is scheduled to be launched to study the ultraviolet spectra of the stars and galaxies as a joint NASA, ESRO and UK project.

Observations of celestial objects emitting gamma rays, X-rays, UV and IR radiation have been made since 1971 with balloons whose volumes range from 50 000 to 900 000 cubic metres. These have been used mostly by Bristol University, Southampton University and University College London. Nineteen balloon launches were achieved in 1973, and 26 are scheduled for 1974.

The majority of United Kingdom balloon flights are launched by the American National Commission for Atmospheric Research either from their base at Palestine, Texas, or as part of Southern Hemisphere campaigns from Parana in the Argentine. Other launches are made from Australia and a few from Cardington in the United Kingdom.

The MOD firing range on South Uist in the Hebrides is used to launch Petrel and Skua rockets for scientific or meteorological purposes. Skua rockets can also be fired from Aberporth, Cardiganshire, but the base is little used for this purpose. Skylark rockets launched as part of the national programme are fired from the Woomera facility in Australia.

SOUNDING ROCKETS AND BALLOONS LAUNCHED AS PART OF THE UK NATIONAL SPACE PROGRAMME

	SOUNDING ROCKETS				BALLOONS
	SKYLARK	PETREL	SKUA	TOTAL	
1960	8			8	
1961	17			17	
1962	18			18	
1963	19			19	
1964	17			17	
1965	23			23	
1966	18			18	
1967	14		2	16	
1968	12	12	11	35	
1969	19	20	2	41	
1970	14	11	24	49	
1971	9	27	5	41	13
1972	8	24	9	41	14
Total	196	94	53	343	27

BALLOON-FLOWN UK EXPERIMENT PACKAGES 1971-1973

VOLUME OF BALLOON (In thousands of m³)	NUMBER RELEASED	EXPERIMENTER	EXPERIMENT
1971			
270	2	Belfast University	UV astronomy
54	2	University College, London	IR astronomy
40	1		Cosmic ray studies
540	3		Studying very heavy nuclei in cosmic radiation
840	1	Bristol University	Studying very heavy nuclei in cosmic radiation
54	1		X-ray astronomy
290	1		
300	1	Southampton University	Gamma astronomy
560	1		
1972			
400	1	Belfast University/University College, London	UV astronomy
540	1		
81	2	University College, London	IR astronomy
54	2		
840	1		Studying very heavy nuclei in cosmic radiation
300	3	Bristol University	
54	1		X-ray astronomy
400	1		
300	1	Southampton University	Gamma astronomy
81	1		
1973			
540	2	Belfast University/University College, London	UV astronomy
81	6	University College, London	IR astronomy
165	2	Imperial College, London	Gamma astronomy
81	2	Queen Mary College, London	Studying sub-mm waves
300	1		Studying cosmic radiation
135	2		Studying supernovae
840	1	Bristol University	Studying very heavy nuclei in cosmic radiation
300	2		
54	2		
540	2	Bristol/Southampton Univ.	X-ray astronomy
400	2		
81	2	Southampton University	Gamma astronomy
300	2	Leeds University	IR astronomy

VI - EUROPEAN SCIENTIFIC RESEARCH BY SATELLITE

In the space of 12 years approximately 75 European laboratories have placed experiments aboard some 30 satellites built in Europe. Compared to the number of laboratories, the number of satellites is smaller than in the United States or the Soviet Union; also, the number of European laboratories interested in space has tended to remain stationary for several years.

The laboratories in countries which had a national space programme were fortunate in being able to place instrumentation aboard national as well as ESRO satellites. The skills which they acquired in the process enabled them to put forward new ideas and techniques for subsequent European satellites and to take advantage in many cases of opportunities for experiments provided by certain NASA, and to a lesser extent Soviet, programmes.

This collaboration with the two major space powers is still continuing. Having placed experiments aboard foreign satellites in orbit round the earth, European laboratories are now proposing experiments for American and Soviet planetary probes. Such opportunities are limited, however.

With the annual number of scientific satellites fairly constant and likely to remain so in the coming years, ESRO has initiated a slight change of policy. In the early 1960s the goal was to build satellites that would enable member States which had no national programmes to take part in the exploration of space on an equal footing with countries which had a national programme. Each of these satellites carried many instruments and thus provided experiment opportunities for several laboratories. Henceforth the scientific mission of some of ESRO's future satellites will be more specific, implying cooperation by different laboratories in a common experiment, such as on the COS-B satellite. Similarly, national satellites are tending to have more clearly delineated missions.

Yet even with a comparatively limited number of satellites, the European countries have succeeded in conducting experiments in a considerable number of fields, as shown in the tables opposite. On the other hand, there have been some areas from which Europe has been conspicuously absent—notably planetary exploration and earth resources. ESA will therefore endeavour to fill this gap, mainly by collaborating with NASA and with other countries.

Whereas exploration of the planets calls for spacecraft built for the purpose, it will be possible for terrestrial and astronomical observations to be extended and multiplied from 1980 onwards aboard the manned orbiting laboratory. The Spacelab project is indeed timely in that it will give experiments a new dimension, for it will enable widely differing missions to be undertaken and above all enable heavy and complex apparatus to be used.

It will thus be possible, with a large amount of instrumentation, to conduct more wide-ranging experiments in solar, stellar and high-energy astronomy as well as in fields hitherto unexplored in Europe such as biology, earth resources and the manufacture of crystals or metal parts—all under zero-gravity conditions. It will also be the first time, or almost, that European experiments will have the advantage of researchers and scientists aboard the spacecraft, and the ability to adapt to observations which this implies. Space exploration will also be made easier, since the instruments will be the same as those used on earth rather than instruments specially designed to be carried into space aboard satellites.

IONOSPHERIC STUDIES

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
State of ionisation (radio studies)			
16.8 and 24 kHz waves transmitted from the ground and received by the satellite	FR-1		Groupe de recherches ionosphériques L. R. O. Storey
Characteristics of radio waves (20 MHz) transmitted by the satellite	San-Marco-1 and San Marco-2		National Microwave Institute, Florence N. Carrara
Electron temperature, density and composition			
	UK-1	Langmuir probe	University College, London R. L. F. Boyd and A. P. Willmore
	UK-1	Sayers probe	University of Birmingham J. Sayers
temperature	Explorer-31		University College, London A. P. Willmore
temperature and density	FR-1 UK-3	Sayers probe	University of Birmingham J. Sayers
temperature and density temperature and density	OGO-5 ESRO-1	Langmuir probe	University College, London R. L. F. Boyd
temperature and density	UK-4		University of Birmingham J. Sayers
density	Wika	variable impedance probe	Max Planck Inst. for Extraterrestrial Physics, Garching F. Melzner
energy spectrum and density	Aeros		Groupe de physique spatiale de Fribourg K. Spenner and E. Neske
Ion temperature, density and composition	UK-1 Explorer-20	mass spectrometer	University College, London R. L. F. Boyd and A. P. Willmore
	Explorer-31		A. P. Willmore
temperature and composition	ESRO-1	Langmuir probe	R. L. F. Boyd
nature, energy spectrum and drift rate	ESRO-IV		
ion density and composition	Aeros		Max Planck Inst., Heidelberg D. Krankowsky
energy spectrum	Aeros		Groupe de physique spatiale de Fribourg K. Spenner
Terrestrial radio noise			
very low frequency radio noise (3, 2, 9, 6 and 16 kHz)	UK-3		University of Sheffield K. Bullough
very low and extremely low frequency radio noise (3, 2, 9, 6 and 7 kHz)	UK-4		

METEOROLOGICAL AND UPPER ATMOSPHERE STUDIES

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Measurement of atmospheric density			Aerospace Research Centre, Rome
Satellite specially designed for study of atmospheric drag	San Marco-1 San Marco-2 San Marco-3		L. Broglio
			Astrophysics and Extraterrestrial Research Institute of Univ. of Bonn
	Aeros		M. Roemer
			Space Geodesy Research Group
	D-5B	microaccelerometer	F. Barlier
Neutral particle density and composition			Max Planck Inst., Heidelberg
	Aeros	mass spectrometer	D. Krankowsky
			Physics Inst. of Univ. of Bonn
in the F region of the ionosphere	ESRO-IV	mass spectrometer	U. von Zahn
Study of neutral constituents			Meteorological Office of Bracknell
vertical distribution of ozone (2 500 - 4 000 Å)	UK-2	prism spectrometer	R. Frith and K. H. Stewart
vertical distribution of molecular oxygen	UK-3		
Temperature profile of the atmosphere			Univ. of Oxford (Clarendon Lab.)
	Nimbus-4 Nimbus-5 Nimbus-F	radiometers	J. T. Houghton
Temperature, pressure and wind			Aeronomy Service
velocity of wind	Gemini-12	release of a sodium cloud between 60 and 160 km	J. E. Blamont
			Lab. of Dynamic Meteorology
velocity of wind	Eole	500 ballons drifting at an altitude of 12 000 m	P. Morel
Radio noise in the atmosphere			Radio and Space Research Station, Slough
distribution and intensity of terrestrial noise sources (lightning)	UK-3		J. A. Saxton

MAGNETOSPHERIC STUDIES

A. Particle Physics

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Energetic particles			Service d'électronique physique, Centre d'études nucléaires, Saclay
protons (35 MeV - 16 GeV) and alpha particles (140 - 1 200 MeV)	ESRO-II	3 semi-conductor detectors	J. Labeyrie
electrons, protons and alpha particles	HEOS-1	semi-conductor detectors	Mme L. Koch and M. Engelmann
protons (> 350 MeV)	HEOS-1		Imperial College, London H. Elliott and M. Engel
protons (1 - 20 MeV)	HEOS-1		Imperial College, London H. Elliott and M. Hynds
protons and alpha particles	ESRO-II	2 scintillators, 2 proportional counters, 1 Cerenkov detector	Imperial College, London H. Elliott and J. J. Quenby
			Nuclear Physics Institute of Kiel Univ.
protons (0.25 - 2 MeV)	Azur-1	semi-conductor detectors	J. Moritz
protons (5 - 40 MeV), electrons (> 1.3 MeV) alpha particles (5 - 40 MeV)	Wika	semi-conductor detectors	H. Fischer
			Max Planck Inst. for Aeronomy, Lindau
protons (40 keV - 1.4 MeV) and electrons (20 - 300 keV)	GEOS	semi-conductor detectors	J. W. Münch
Magnetospheric plasma			Univ. of Florence, Rome and Brussels
protons (0.15 - 15 keV)	HEOS-1	electrostatic analyser and Faraday collector	A. Bonetti, G. Pizzela and M. Coutrez
			ESTEC Space Science Department
electrons (0.5 - 3 MeV); protons (9 - 36 MeV) and alpha particles (36 - 142 MeV)	HEOS-A2	semi-conductor detectors	D. E. Page
			Univ. of Rome
electrons and protons (20 eV - 50 keV)	HEOS-A2	scintillators, electrostatic analyser	A. Egidi

EXPERIMENT	SATELLITE		
			Max Planck Inst. for Extraterrestrial Physics, Garching
protons (0.23 - 16 keV)	HEOS-A2	2 electrostatic analysers	H. Rosenbauer
protons and electrons (100 eV - 50 keV)	HEOS-A2	electrostatic analysers	*
			Centre d'étude spatiale des Rayonnements, Univ. of Toulouse
protons and electrons (200 eV - 15 keV)	Oreol-1		F. Cambou
protons and electrons (200 eV - 15 keV)	Prognoz-2		*
			Max Planck Inst. for Extraterrestrial Physics, Garching, and Univ. of Bern
composition, energy spectrum and angular distribution	GEOS	electrostatic and magnetic analyser	H.J. Völk, J. Geiss and P. Eberhardt
			Mullard Space Science Lab.
suprathermal plasma	GEOS	2 electrostatic analysers	M. Raitt
			Kiruna Geophysical Observ.
electrons and protons (0.2 - 20 keV)	GEOS	10 electrostatic analysers	B. Hultqvist
			Univ. of Bern
heavy ions and noble gases	Skylab		J. Geiss
Auroral particles			
			Radio and Space Research Station, Slough
trapped and precipitated electrons (50 - 400 keV)	ESRO-I	scintillator	R. Dalziel
protons (1 - 30 MeV)	ESRO-I	semi-conductor detector and scintillator	
			Danish Space Research Inst., Lyngby, Norwegian Defense Research Establishment and ESTEC Space Science Department
electrons (> 40 keV) and protons (> 500 keV)	ESRO-I	Geiger counters	B. Peters, B. Landwark and D. E. Page
			Danish Space Research Inst., Lyngby, and Univ. of Bergen
protons (100 keV - 6 MeV)	ESRO-I	semi-conductor detectors	B. Peters and B. Trumpy
			Kiruna Geophysical Observ.
trapped and precipitated electrons and protons (1 - 13 keV)	ESRO-I	electrostatic analysers	B. Hultqvist
precipitated electrons and protons (0.5 - 150 keV)	ESRO-IV	electrostatic analysers and Geiger counters	

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
			Space Research Lab. of Utrecht Univ.
solar protons (2 - 100 MeV) and alpha particles (4 - 240 MeV)	ESRO-IV	semi-conductor detectors	C. de Jager
			Max Planck Inst. for Extraterrestrial Physics, Garching
protons (0.2 - 90 MeV) and alpha particles (2.5 - 360 MeV)	ESRO-IV	semi-conductor detectors	R. Lüst
Van Allen belts			
			Imperial College, London
time variations of the particle population	ESRO-II	2 Geiger counters	H. Elliott, J. J. Quenby
solar protons (1 - 100 MeV) and Van Allen belt protons after bursts	ESRO-II	4 semi-conductor detectors	H. Elliott, J. J. Hynds
			Radio and Space Research Station, Slough
trapped and precipitated electrons (50 - 400 keV)	ESRO-I	scintillators	R. Dalziel
protons (1 - 30 MeV)	ESRO-I	semi-conductor detectors and scintillator	
			Danish Space Research Inst., Lyngby, and Univ. of Bergen
protons (100 keV - 6 MeV)	ESRO-I	semi-conductor detectors	B. Peters and B. Trumpy
			Max Planck Inst. for Extraterrestrial Physics, Garching
protons (1.4 - 100 MeV), alpha particles (6.5 - 19 MeV)	Azur-1	scintillator	D. Hovestadt
protons (20 - 45 MeV et 40 - 80 MeV), electrons (1.55 - 4.2 MeV)	Azur-1		
			Max Planck Inst., Lindau
protons (> 30 MeV)	Azur-1	4 Geiger-Müller counters	E. Kirsch
electrons	Azur-1	4 Geiger-Müller counters	L. Rossberg

B. Field Physics		
EXPERIMENT	SATELLITE	LABORATORY AND EXPERIMENTER
Magnetic, electric, magnetospheric and interplanetary fields		Geophysics and Meteorological Institute of Braunschweig
Magnetic field (5 kHz) 2 axis threshold	Azur-1	G. Musmann
Magnetic field due to magnetometer equatorial electrojet	Wika	
		Imperial College, London
± 64 gammas (triaxial magnetometer)	HEOS-1	H. Elliott and M. Hedgecock
± 144 gammas	HEOS-A2	H. Elliott
		Danish Space Research Institute of Copenhagen
Magnetic and electric fields between 20 Hz and 236 Hz	HEOS-A2	B. Peters
		University of Rome
Magnetic field contained up to 5 Hz	GEOS	M. Candidi
		Danish Space Research Institute of Lyngby, Ionospheric Research Group of CNET [1] and ESTEC Space Science Department
Plasma electric fields and resonance up to 77 kHz; magnetic fields up to 5 kHz	GEOS	E. Ungstrup, M. Petit and A. Pedersen
Shape of magnetospheric field (from clouds or radio studies)		Ionospheric Research Group
Very-low-frequency wave guidance by field lines	FR-1	L. R. O. Storey
		Max Planck Inst. for Extraterrestrial Physics, Garching
Barium and copper oxide cloud (at altitude of 75 000 km)	HEOS-1	R. Lüst and M. Gollnitz

1. Centre National d'Etude des Télécommunications.

RADIATION PHYSICS

FIELD OR RESEARCH	EXPERIMENT	SATELLITE	LABORATORY AND EXPERIMENTER
Geocorona radiation			Inst. of Atmospheric Physics, Oberpfaffenhofen (DFVLR)
lyman alpha radiation	1 100 - 1 350 Å band	Wika	H. D. Schlichter
	density and temperature	OGO-5	Service d'aéronomie J. E. Blamont
	2 experiments: shape of the emission line and rate of polarisation	D-2A	
other radiations	6 563 Å	D-2A	
other hydrogen radiation	atomic oxygen (1 302, 1 304 and 1 306 Å)	D-2A	
Auroral luminosity			Service d'aéronomie
	6 300, 5 577 and 3 914 Å	OGO-2	J.E. Blamont
	2 630, 3 914, 5 577, 5 890, 6 225 and 6 300 Å 6 300 and 3 914 Å	OGO-4 OGO-6	Inst. of Atmospheric Physics, Oberpfaffenhofen (DFVLR)
	3 914 and 5 577 Å	Azur-1	A. Rossbach

INTERPLANETARY STUDIES

A. Particle Physics

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Interplanetary plasma (solar wind)			Univ. of Florence, Rome and Brussels
protons (0.15 - 15 keV)	HEOS-1	electrostatic analyser and Faraday collector	A. Bonneti, G. Pizzela and M. Coutrez
solar wind composition	Apollo-11, 12, 14, 15, 16	sheet of aluminium exposed on the moon	Univ. of Bern J. Geiss
protons (0.23 - 16 keV)	HEOS-A2	2 electrostatic analysers	Max Planck Inst. for Extraterrestrial Physics, Garching H. Rosenbauer
particle density and energy along Earth-Jupiter trajectory	Pioneer-10 and 11		Max Planck Inst. for Extraterrestrial Physics, Garching R. Lüst
protons (180 eV - 15 keV), electrons (0.5 eV - 1.2 keV)	Helios	electrostatic and electrodynamic analysers	Max Planck Inst. for Extraterrestrial Physics, Garching H. Rosenbaer and H. Pelkoffer
protons and electrons (200 eV - 15 keV)	Oreol-1		Centre d'étude spatiale des rayonnements, Univ. of Toulouse F. Cambou
protons and electrons (200 eV - 15 keV)	Prognoz-2		•
temperature and composition	Mars-6 and 7		•
Medium energy particles			Max Planck Inst., Lindau
electrons (30 keV - 1 MeV) protons (40 keV - 2.5 MeV) and positrons (50 - 215 keV)	Helios		E. Keppler and B. Wilken

B. Field Physics

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Interplanetary magnetic field			Inst. of Geophysics and Meteorology, Braunschweig
	Helios	3 axis fluxgate magnetometer	F. M. Neubaer and A. Maier
	Helios	induction fluxgate magnetometer	F. M. Neubaer and G. Dehmel

C. Radiation Physics

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Hydrogen and helium radiation	Mars-5, 6, 7 and 8		Service d'Aéronomie J.-E. Blamont
Zodiacal light			Univ. of Heidelberg
photometer	Helios		C. Leinert and E. Pitz
optical isodensity spots of the galaxy: 800, 1 216, 1 600, 2 200 and 3 075 Å (concave grating and optical baffle)	D-2B		Lab. d'astronomie spatiale, Marseille G. Courtès

D. Micrometeorites

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Micrometeorite fluxes			Nuffield Lab. of Radioastronomy of Univ. of Manchester (Jodrell Bank)
	UK-2		R. C. Jennison
	X-3		Univ. of Birmingham
			Max Planck Inst., Heidelberg
flux, velocity, mass	HEOS-A2		H. Fechtig
			Office national d'études et de recherches aérospatiales (ONERA)
flux and velocity	D-5B		M. Marec
			Max Planck Inst. for Extraterrestrial Physics, Garching
	Helios		H. Fechtig and M. Kissel

SOLAR STUDIES

EXPERIMENT	SATELLITE	LABORATORY AND EXPERIMENTER
Ultraviolet radiation		University College, London
spectral band 1 100 - 1 350 Å	UK-1	J. A. Bowles, A. P. Willmore
lines 1 216 and 304 Å	OSO-4	R. L. F. Boyd
lines 584, 304, 833, 790 and 922 Å	OSO-6	
Lyman alpha radiation	OSO-5	Service d'aéronomie J. E. Blamont
structure of the chromosphere: 1 216, 1 025, 3 933 - 3 968 and 2 803 - 2 795 Å	OSO-1	Lab. de physique stellaire et planétaire R. Bonnet
Lyman alpha and deuterium radiation	D-2A	Service d'aéronomie J. E. Blamont
15 lines of emission from the chromosphere and the corona (170 - 1 216 Å)	D-2B	Lab. de physique stellaire et planétaire J.-P. de Laboudinière
155 1 602 Å	Aeros	Groupe de physique spatiale de Fribourg G. Schmidtke
X radiation		University College, London, and Univ. of Leicester
3 - 12 Å (proportional counters)	UK-1	R. L. F. Boyd and K A. Pounds
1 - 20 and 44 - 75 Å	OSO-4	R. L. F Boyd
1 - 20 Å	ESRO-II	
3 - 9 and 8 - 18 Å	OSO-5	
44 - 60 Å	ESRO-II	Univ. d'Utrecht C. de Jager
20 - 700 keV (scintillator)	TD-1A	H. F. Van Beck
solar and galactic radiation: 20 - 200 keV	OSO-6	Univ. of Bologna D. Brini
Gamma radiation		Univ. of Milan
50 - 500 MeV (scintillator)	TD-1A	G. Occhialini
300 keV - 9 MeV, 1 - 16 MeV	Prognoz-2	Centre d'étude spatiale de rayonnements, Univ. of Toulouse F. Cambou
Radio bursts		Meudon Observ.
169 MHz	Mars-3	J.-L. Steinberg
30 and 60 MHz	Mars-6 - Mars-7	

STELLAR, GALACTIC AND EXTRAGALACTIC ASTRONOMY

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Stellar ultraviolet radiation			
			Inst. d'astrophysique de Liège and Royal Observ., Edinburgh
map of the sky 1 330 - 3 000 Å	TD-1A	telescope spectrometer and 4 multiplier phototubes	L. Houziaux, A. Monfils and H. Butler
			Space Research Lab. of Univ. of Utrecht
Star spectrum 2 100, 2 500 et 2 800 Å	TD-1A	Cassegrain telescope, spectrometer and pointing system	C. de Jager
star spectrum 1 500 - 3 295 Å	ANS	Cassegrain telescope, spectrograph and multiplier phototube	Kapteyn Observ. of the Univ. of Groningen
			Lab. d'astronomie spatiale de Marseille
star spectrum 1 800 - 3 100 Å	Skylab		G. Courtès
stellar photometry in the UBV bands	D-2B	Kern telescope and electronically scanning image dissector	
star spectrum 800 - 3 500 Å	D-2B	2 spectrophotometers	
Stellar and galactic ultraviolet hydrogen radiation			
			Service d'aéronomie
two experiments 1 216 et 6 563 Å	D-2A	photometers and absorption cell	J. E. Blamont
Galactic and extragalactic X radiation			
			Univ. of Bologna and Service d'électronique physique du Centre d'études nucléaires de Saclay
			D. Brini
solar and galactic radiation 20 - 200 keV	OSO-6		
			Mme Koch
source spectra 20 keV - 2 MeV	TD-1A	2 anti-coincident proportional counters plus collimator	
			University College, London, and Univ. of Leicester
stars and nebulae from 70 Å upwards	OAO-3		R. L. F. Boyd
			University College, London
source spectra 2 - 10 keV	UK-5		R. L. F. Boyd
source spectra 20 ke-V - 2 MeV	UK-5		Imperial College, London
map of the sky 1.5 - 20 keV	UK-5		Univ. of Leicester
detection of source emission lines 1 - 8 keV	UK-5		K. A. Pounds
map of the sky 0.3 - 30 keV	UK-5		Mullard Space Science Laboratory
source spectra 44 - 70, 2 - 16 et 27 - 35 Å	ANS	proportional counters	Space Research Lab. of Univ. of Utrecht

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
Galactic gamma radiation			
			Service d'électronique physique du Centre d'Etudes nucléaires de Saclay, Max Planck Inst. for Extraterrestrial Physics, Garching, and Physics Inst. of Milan
source detection 70 - 300 MeV	TD-1A	spark chamber, counters	Y. Kœchlin, R. Lüst and G. Occhialini
			Univ. of Milan and of Palermo, Max Planck Inst. for Extraterrial Physics, Garching, Service d'électronique physique de Saclay, Kamerlingh Onnes Cosmic Ray Lab. of Leiden and ESTEC Space Science Dept.
source spectra 20 MeV - 5 GeV	COS-B	spark chamber, scintillation counters, Cerenkov counter	G. Occhialini, K. Pinkau, J. Labeyrie
			Southampton Univ.
	OGO-5		G. W. Hutchinson
Galactic noise			
			Mullard Radioastronomy Observ. of Cambridge University
0.75 - 3 MHz	UK-2		F. G. Smith
			Manchester Univ. (Jodrell Bank)
2 - 5 MHz	UK-3		F. G. Smith
			Univ. Manchester and Radio and Space Research Station, Slough
	UK-4		F. G. Smith
Cosmic, solar and galactic radiation			
			Imperial College, London
primary cosmic radiation	UK-1		H. Elliott and J. J. Quenby

EXPERIMENT	SATELLITE	INSTRUMENT	LABORATORY AND EXPERIMENTER
electrons 1 - 5 GeV	ESRO-II	Cerenkov detector and scintillator	Univ. of Leeds M. Wilson and P. Marsden
electrons 50 - 600 MeV	HEOS-1 and HEOS-A2	Cerenkov detectors	Service d'électronique physique du Centre d'études nucléaires de Saclay and Univ. of Milan J. Labeyrie and G. Occhialini
charged particles between Z = 2 et Z = 28 (>220 MeV)	TD-1A	semiconductor-type detectors and Cerenkov detector	Service d'électronique physique du Centre d'études nucléaires de Saclay Mme L. Koch
electrons	OGO-5		Kamerlingh Onnes Lab. of Univ. of Leyden H.C. van de Hulst
heliocentric gradient	Mars-6 and Mars-7		Service d'électronique physique du Commissariat à l'énergie atomique J. Labeyrie
energy spectra of solar and galactic protons, alpha particles and heavy ions	Helios		Univ. of Kiel H. G. Hasler and H. Kunow

BIOLOGY STUDIES

EXPERIMENT	SATELLITE	LABORATORY AND EXPERIMENTER
Biostack experiment: effect of the bombardment by heavy ions of primary cosmic rays on biological tissues	Apollo-16 and 17	Lab. de biologie spatiale, Toulouse and Univ. of Frankfurt M. Planel and H. Bucker
Effect of the space environment on 5 bacterial growths	Apollo-16	Univ. of Frankfurt

GEODESY STUDIES

EXPERIMENT	SATELLITE	LABORATORY	EXPERIMENT COORDINATOR
Laser ranging			
Measuring the distance between 3 earth stations and the satellite	D-1C and D-1D	Bureau des longitudes, Observ. de Paris, Inst. géographique nat., Service d'aéronomie, Office nat. d'études et de recherches aérospatiales (ONERA) and Marine nationale	J. Kovalevsky
Satellite used for the 16 nation Isagex international campaign	Péole	Observ. de Paris-Meudon	F. Barlier
	Luna-17 and Luna-21	Groupe de recherche de géodésie spatiale and Observ. du Pic du Midi	L. Orszag
	Starlette	Groupe de recherche de géodésie spatiale	Mme Cazenave
	D-5B	Groupe de recherche de géodésie spatiale and Observ. de Paris-Meudon	F. Barlier
Doppler effect			
Signals emitted: 150 - 400 MHz ; 2 receiving stations	D-1A	Bureau des longitudes, Observ. de Paris, Inst. géographique nat. and Marine nationale	J. Kovalevsky
Signals emitted: 150 - 400 MHz ; 3 receiving stations	D-1C and D-1D	Bureau des longitudes, Observ. de Paris, Inst. géographique nat. Service d'aéronomie, ONERA and Marine nationale	
Photographing the satellite			
	D-1A	Bureau des longitudes, Observ. de Paris, Inst. géographique nat. and Marine nationale	J. Kovalevsky and P. Muller
	D-1C and D-1D	Bureau des longitudes, Observ. de Paris, Inst. géographique nat. Service d'aéronomie, ONERA and Marine nationale	J. Kovalevsky
	Starlette	Groupe de recherche de géodésie spatiale	Mme Cazenave
Baker-Nunn ground cameras at the Smithsonian Astrophysical Observatory	D-5B	Groupe de recherche de géodésie spatiale and Observ. de Paris Meudon	F. Barlier

RELATIVITY STUDIES

EXPERIMENT	SATELLITE	LABORATORY AND EXPERIMENTER
The sun's quadrupole moment and improvement of the ephemerides of the inner planets	Helios	Univ. of Hamburg W. Kundt

TECHNOLOGICAL STUDIES

EXPERIMENT	SATELLITE
Onboard power	
thin silicon solar cells	X-3
thin-film cadmium sulphide and cadmium telluride solar cells	SRET-1
solar panels	X-4
Thermal control	
thermal cooling system of a radiometer on a meteorological satellite	SRET-2
thermal blanket	X-3
Stabilisation	
gravity gradient	Péole
hydrazine microthruster (2,5 N of thrust)	D-5A
ultra-sensitive three-axis microaccelerometer (10^{-5} - 10^{-9} g)	D-5B
3-axis stabilisation system	X-4
nutation damper	SRET-2
Tracking	
Eole satellite's transponder	Péole
Attitude measurement	
solar, stellar and albedo sensors	X-4
infrared sensor	ESRO-IV
Lubrification	
fluid lubrification in a fluid device	SRET-2

VII - THE EUROPEAN MARKET

The research undertaken for this Guide shows that in 1972 the European space industry represented a potential workforce of about 12 000 people and had a global turnover of 250 MAU in the civil sector.

These are approximate figures, of course, especially inasmuch as they relate to approximately 60 firms only whereas, in addition to these leading companies having a permanent space department, there are many others engaging occasionally in space activities, either on a specific project or as subcontractors to a leading company. Moreover, the total manpower and turnover estimates for the space industry were obtained by adding the figures provided by the companies themselves, not all of which could be checked out.

In what follows, we have endeavoured to present Europe's space industry, its skills and its achievements. Each major area of activity (satellites, launchers, sounding rockets, balloons, infrastructure) is consequently dealt with individually in the form of tables indicating the different companies' participation in past or current projects. A monograph on the leading companies has been included (Annex IV).

Although, in order to be complete, the areas of activity mentioned above should have included technological research and development, this particular activity is very widely dispersed and generally involves only small contracts in the region of 20 000 to 30 000 accounting units. It was felt therefore that it would be unrealistic to attempt to include these activities within the framework of this Survey. However, an inventory of them has been made and is the subject of another ESRO publication (European Activities in Space Technology, ESRO SP-91).

In the second part of this publication certain features of the European space industry are clearly evident. The companies which produce space hardware range from very large multiple-activity concerns to firms which are much smaller and more specialised. In other words, space activities have not produced a strictly space-oriented industry, the firms engaged in them being aviation or electronics concerns. These companies' turnover on space activities is more often than not only marginal—a few percent of the total turnover at the most, with a few rare exceptions. In other words, space activities have not represented a significant market, although industrial consortia have frequently asked their respective governments to be bolder and to increase their efforts. This is what happened in 1973.

Moreover, space activities do not have commercial outlets in the usual sense, i.e. a huge market and many customers, nor will they in the immediate future. The only customers in Europe are the governments or the international organisations, whether for scientific or application satellites (telephony, radio and TV broadcasting, air and maritime navigation, meteorology, earth resources, etc.). The public utilities have hitherto adopted a reserved attitude towards space, and have yet to organise themselves into customer consortia for the purchase of satellites. And yet the number of applications satellites in use through the 1980s in Europe is thought likely to be in the region of 30 to 40. In the United States private companies are already having satellites built and launched, with the aim of placing them at the disposal of private customers and exploiting them commercially.

Owing to the fact that varying degrees of importance have been attached to space research in the European countries, the support received for space activities has also varied greatly from country to country. Nations which ran a national programme in addition to participating in the European programme derived advantage from this situation on the international level, for at first virtually all ESRO contracts awarded on the basis of tenders went to companies in the countries which had a national programme, since the other countries were not in a position to submit satisfactory proposals. However, thanks to subcontracts issued by the prime contractors, the industries of these countries were subsequently able to take part in the development of satellite systems, the aim being that eventually each member country would receive a share of industrial contracts proportional to its financial contribution to the Organisation.

EUROPEAN INDUSTRIAL CONSORTIA

	PERMANENT CONSORTIA			TEMPORARY CONSORTIUM
	COSMOS (1)	MESH	STAR	CIFAS (2)
AEG Telefunken (Germany)			X	X
Aeritalia (Italy)		X		
BAC (UK)			X	
CGE-Fiar (Italy)			X	
Contraves (Switzerland)			X	
Dornier (Germany)			X	
ERNO (Germany)		X		
ETCA (Belgium)	X			
Fokker VFW (Netherlands)		X		
GEC-Marconi (UK)	X			
HSD (UK)		X		
L.M. Ericsson (Sweden)			X	
Matra (France)		X		
MBB (Germany)	X			X
Montedel (Italy)			X	
SAAB-Scania (Sweden)		X		
SABCA (Belgium)			X	
SAT (France)	X			X
Selenia (Italy)	X			
Siemens (Germany)	X			
SNIAS (France)	X			X
Thomson-CSF (France)			X	X

1. The COSMOS consortium was formerly known as the César consortium. BAC was a member at the time but has since been replaced by GEC-Marconi.
2. CIFAS is the Franco-German industrial consortium formed to develop the Symphonie satellite.

This policy of « fair return » brought certain constraints to bear on the awarding of contracts and did not always operate in favour of an optimum restructuring of Europe's space industry. It also helped to produce an undue dispersion of technical skills. The « fair return » principle was not the only reason for this dispersal, however; other contributory factors were the absence of initial coordination of national programmes, and the fact that many firms were anxious to join the « space club » for reasons of prestige. This led to the present situation, in which the number of firms which have sprung up in certain technological areas is too big for the limited market. As a result, efforts have overlapped and men and money have been wasted. But without this principle it would be difficult to ensure adequate workloads for the industrial teams.

At the same time, there can be no question under our economic system of requiring the industry to restructure itself; this must come of its own accord. This is not to say, of course, that public utilities or national or international organisations may not provide the appropriate inducement. In fact, the MESH, STAR and COSMOS consortia were formed in response to a clause contained in ESRO invitations to tender for large satellite contracts to the effect that only bids from properly balanced multinational groups would be considered. Industry met this requirement by organising itself accordingly. ESRO made no stipulations as to the number or composition of such groups, nor did it require them to remain stable from one project to the next.

In any event it would not be advisable to carry this structuring process too far as this could lead to situations of monopoly in certain technical fields. The spur which a measure of competition could provide is essential in order to enhance competitiveness on the world level, which must remain one of the European space industry's priority goals. ESA's problem will be to ascertain ways and means of prompting industry to reorganise to a greater extent in order to avoid duplication, and to do so whithout eliminating competition and without hindering application of the principle of « fair return ».

NOTE: The aggregate contributions of ESRO member states are not all redistributed in the form of industrial contracts in the states concerned. Part of them is used to cover the Organisation's operating costs, another part goes towards financing contracts placed in non-member states, in particular for the purchase of American launchers. The remainder is redistributed, on a « fair return » basis, in the form of industrial contracts in the member states.

The « fair return » is the ratio between each country's percentage share of the industrial contracts awarded and its percentage contributions to the Organisation, bearing in mind the information given above regarding that part of the contracts and contributions that is taken into account for this purpose, and the fact that the contracts are « weighted » on the basis of their technical value.

VIII - SATELLITE DEVELOPMENT

It would be difficult to say which of the 30 or so European or strictly national satellites built by Europe since 1962 have brought most know-how to its industry. Each undoubtedly made a contribution. The actual lifetime of European satellites has more often than not exceeded the nominal lifetime. Reliability has been of a high order and has remained at a constant level even though the complexity of satellites has increased from year to year. Europe's industry is unquestionably now fully capable of coping with more numerous and more ambitious programs of the kind decided in July 1973.

After relying during the very first years of its existence on the industrial skills of countries having already initiated national projects, ESRO later had to promote the industries of countries whose competence in space matters had barely developed yet. A glance at the tables which follow will suffice to show that this mission has been successfully accomplished. From 1969-1970 onwards, industrial concerns which had hitherto never secured contracts for complete items of equipment are seen to be responsible for developing subsystems for the latest European or national satellites. Both technically and financially moreover, their tenders are today on a level with those of their more experienced competitors.

At ESRO's instigation, European companies grouped themselves into three permanent industrial consortia, which helped to promote the involvement of additional firms. Formed from 1966-1967 onwards, the COSMOS, MESH and STAR consortia were restructured in 1970 and have remained stable since. The prime contractor in each consortium varies from one programme to another. The consortium then takes on subcontractors, an arrangement which usually ensures the required geographical distribution of contracts.

Because of the lead gained by some countries in the early 1960s, it has not always been possible to apportion contracts among the member States on a pro-rata basis with financial contributions to ESRO. However, the goal set for 1971 was met: each member country was allotted a share of the overall contract figure representing 70 % of its « fair share », the technically most interesting contracts being weighted accordingly. The figure set for 1972 was 80 %, but ESRO has to apply this rule sufficiently flexibly for it to remain consistent with sound project management.

One advantage which the stability and coherence of the consortia have had is to permit uninhibited trading of information and to make it easier to initiate certain companies to new technologies. Another is that they have undoubtedly sparked a spirit of rivalry and competition among the consortia.

The procedure for awarding satellite development contracts is as follows: after an open call for tenders, to which the COSMOS, MESH and STAR consortia usually respond three or four months later, two of these consortia are selected for a detailed study phase lasting approximately nine months. This is funded by ESRO and results in technical and financial tenders for the development phase. The two tenders are examined by panels of experts who compare the solutions proposed for each subsystem. A Tender Evaluation Board then appraises each tender—this time introducing the cost and time aspects—and recommends a choice which is submitted first to the Adjudication Committee (a group which comes under the Secretariat), then to the Administration and Finance Committe for the final decision. The selected consortium then develops and builds the satellite.

This method, which applied in 1972 for the GEOS and in 1973 for the Meteosat and OTS satellites, ensures more accurate development costing and fewer technical hitches. It has a number of drawbacks, however. The fact that uncertainty about the final choice prevails throughout the detailed studies phase may prevent optimization of the interfaces between the scientific experiments and the space vehicle. Moreover, discussions between ESTEC and the competing consortia are subject to restrictions imposed by the need to maintain strict fairness during the competitive phase. ESRO is therefore anxious to retain some flexibility in this procedure.

Another way of ensuring a more competitive European industry is to arrive at some measure of specialization by the different companies through the medium of research and development contracts. Since 1972 ESRO has striven to achieve some degree of coordination between the R and D programmes of member States in connection with future satellites. This has been one of its preoccupations in the preparation of R and D programmes.

The following tables show the technical competences of the various industrial firms as regards satellites. They have been drawn up on the basis of information collected by ESRO and supplied by each of the firms concerned. The information has been carefully checked and, in certain cases, corrected. We hope that all contestable points have been eliminated.

In each table the industrial firms are listed, not by country, but in alphabetical order. The list of satellites for which each firm has supplied the equipment or sub-system concerned has been compiled according to the order in which the satellites were launched, or are planned to be launched.

For the purpose of these tables, only those firms that have manufactured the equipment or sub-systems have been taken into account. Thus no reference is made to the special competence of the firms that have merely assembled or integrated, but not manufactured, them.

PRIME CONTRACTORS, INTEGRATION AND TESTING

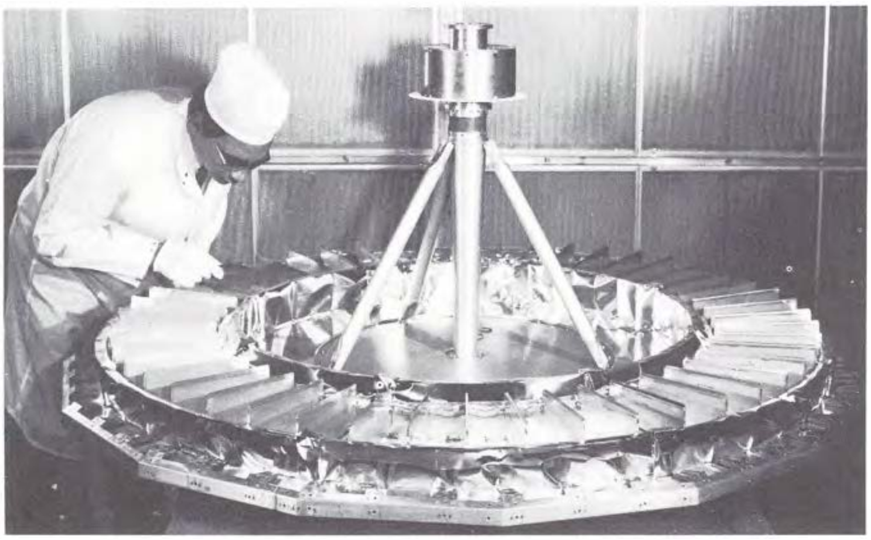
BAC	: UK-3, X-3 (1), UK-4 and GEOS
CIA	: Sirio
CIFAS	: Symphonie
Dornier	: Aeros
Fokker-VFW	: ANS
HSD	: ESRO-II, ESRO-IV, X-4 and GTS
INTA	: Intasat
LCT	: ESRO-1
Marconi-SDS	: X-3 (1), UK-5 and Skynet
Matra	: TD-1A and D-2B
MBB	: HEOS-1 (2), Azur-1, Dial, HEOS-A2, Helios and COS-B
SNIAS	: Meteosat

1. Integration and testing of the X-3 satellite was carried out by both BAC and Marconi. Properly speaking, there was no prime contractor.
2. Prime contractor for the HEOS-1 satellite was actually the Junkers concern, which had not yet merged with MBB.

NB. a) In the case of two series of satellites, the prime contractors were not industrial concerns but organisations which do not appear in this table. Cases in point are the French space agency CNES, which has acted as prime contractor for all French satellites launched to date (FR-1, D-1A, D-1C, D-1D, Péole, D-2A, Eole, SRET-1, D-5A and D-5B) and the Centro Ricerche Aerospaziale which was the prime contractor for Italy's San Marco satellites (San Marco-1, San Marco-2, San Marco-3).

b) In most instances the industrial concerns acting as prime contractors for the satellites also handled satellite integration and developed the satellite checkout equipment. (In most cases, development of the test racks for checking out the telemetry, telecommand, onboard power, stabilisation, attitude measurement and control systems was handled by subcontractors.) However, there were a few exceptions: CASA integrated the Spanish Intasat satellite, and Marconi should be responsible for integration and testing of the GTS satellite.

c) Two industrial concerns participated in integration and/or testing of certain of the Intelsat satellite flight models: BAC handled integration of one Intelsat-IV flight model and participated in the testing of two others. Thomson-CSF took part in the integration and partial testing of four Intelsat-IV flight models.



Thermal control system of German probe HELIOS.

STRUCTURES AND THERMAL CONTROL

Aeritalia	: Sirio and OTS [1]
BAC	: UK-3, X-3, Intelsat-IV (6 flight models) and Intelsat-IV A (3 flight models)
CASA	: HEOS-A2 (partly) [2], Intasat and COS-B (partly)
Contraves	: ESRO-I and GEOS (partly) [2]
Dornier	: Aeros and GEOS (partly) [2]
ERNO	: Azur-1 [2], TD-1A, Helios and OTS [1]
Fokker-VFW	: ANS
HSD	: ESRO-II, ESRO-IV, X-4, Marots, Intelsat-III (2 flight models)
Marconi-SDS	: Skynet-3 and UK-5
Matra	: D-1A, D-1B, D-1C [2]
MBB	: HEOS-1 [2, 3], Dial, HEOS-A2 (partly) [2] and Meteosat
SNIAS	: FR-1 [2], Péole [2], D-2A, Eole, D-5A, D-5B, D-2B, Symphonie and COS-B

1. ERNO is responsible for the design and integration of the OTS structure, for which Aeritalia is fabricating the components.
2. The companies responsible for satellite structures are also responsible for thermal control except in the following cases: SEP was responsible for thermal control on HEOS-1, MBB/SEP on HEOS-A2, Dornier on Azur-1, Fokker-VFW on GEOS, and the French space agency CNES on FR-1, D-1A, D-1C, D-1D and Péole.
3. Prime contractorship on HEOS-1 was actually assumed by Junkers, which later merged with MBB.

TELECOMMUNICATIONS

A. Prime contractors

AEG Telefunken	: Helios
ITT (Spain)	: Intasat
LCT	: Eole [1]
Marconi-SDS	: UK-3, Skynet-2, X-3, UK-4, UK-5 and X-4
Matra	: D-2B
Philips	: ANS
SAAB-Scania	: TD-1A and OTS
Selenia	: COS-B and Meteosat
Thomson-CSF	: Eole [1], Symphonie and GEOS

1. LCT was prime contractor for the UHF communications system between the satellite and the balloons, Thomson-CSF for VHF communications between the satellite and the earth stations.

NB. ESTEC was prime contractor for the ESRO-II, ESRO-1A, HEOS-1, HEOS-A2 and ESRO-IV satellite communications systems.

Telemetry encoders of the ESRO COS-B *satellite (Montedel photo, the Franco-German* SYMPHONIE *satellite (*SAT *photo) and the French* D-2B *satellite (Intertechnique photo).*

B. Telemetry

	ENCODER	TRANSMITTER
AEG-Telefunken		Azur-1, Dial, Aeros and Intelsat-IVA (2 satellites)
BTM		Intelsat-III (2 flight models)
Crouzet	D-5A [1] and SRET-2	
Intertechnique	ESRO-II, D-2A, Eole, D-5A [1], D-5B and D-2B	
ITT (Spain)	Intasat	Intasat
LCT		OTS [4]
Marconi-SDS	UK-3, Skynet-2, X-3, UK-4, UK-5 and X-4	UK-3, Synet-2, X-3, UK-4, UK-5 and X-4
Montedel	HEOS-A2, ESRO-IV, COS-B, Sirio and GEOS	Sirio
Philips	ANS	ANS
SAAB-Scania	OTS	
SAT	ESRO-I, HEOS-I, TD-1A, Symphonie and Meteosat	D-2A [5], SRET-1, D-5A and D-2B
Schlumberger [3]	D-1A, D-1C and D-1D	
SEL	Azur-1, Dial, Aeros, Helios and Intelsat-III (4 flight models)	
Selenia		ESRO-IV, COS-B and Meteosat [4]
SNIAS		D-1A, D-1C and D-1D [5, 6] and ESRO-1
SRA		TD-1A
Thomson-CSF	Intelsat-IV (6 flight models)	ESRO-II, HEOS-1 [7], Eole, HEOS-A2 [7], D-5B, Helios [8], Symphonie, GEOS, Intelsat-III (4 flight models) and Intelsat-IV (3 flight models)

1. In the case of the D-5A satellite, Crouzet developed the on-line telemetry encoder and Intertechnique the off-line telemetry encoder.
2. The Montedel company's space equipment is produced by the Laben division.
3. Schlumberger's American subsidiary, EMR, developed the telemetry encoders for the D-1A, D-1C and D-1D satellites.
4. OTS and Meteosat have SHF transmitters; both satellites also have VHF transponders which operate only during the transfer phase. Selenia is responsible for the Meteosat transmitter and transponder, and LCT for those of OTS.
5. The SNIAS department which manufactured the telemetry transmitters for the D-1A, D-1C and D-1D was absorbed by SAT in November 1970, which thereafter produced the transmitter for D-2A.
6. In the case of the D-1A, D-1C and D-1D satellites, Thomson-CFS also supplied 150 MHz and 400 MHz Doppler measurement transmitters and ultra-stable oscillators for the geodesy experiment.
7. Thomson-CSF also supplied the telemetry transponders for HEOS-1 and HEOS-A2.
8. An SHF transmitter is used for the Helios probe.

C. Telecommand

	DECODER	RECEIVER
AEG-Telefunken		Azur-1, Aeros, Helios, Intelsat-IVA (2 satellites)
BTM		OTS [1]
Contraves	Intelsat-III (3 flight models)	
ITT (Spain)	Intasat	Intasat
LCT	D-2A, Eole, D-5B, D-2B, Intelsat-III (4 flight models)	D-2B
Marconi-SDS	UK-3, Skynet-2, X-3, UK-4, UK-5 and X-4	UK-3, Skynet-2, X-3, UK-4, UK-5 and X-4
Montedel		Sirio
Philips	ANS	ANS
SAAB-Scania	TD-1A and OTS [1]	
SEL	Azur-1, Aeros and Helios	
Selenia	ESRO-IV, COS-B, Sirio and Meteosat [1]	ESRO-IV, COS-B and Meteosat [1]
SRA		TD-1A
Thomson-CSF	D-1A, D-1C, D-1D, ESRO-II, ESRO-I, HEOS-1, HEOS-A2, Symphonie, GEOS and Intelsat-IV (6 flight models)	D-1A, D-1C, D-1D, ESRO-II, ESRO-I, HEOS-1, D-2A, Eole, HEOS-A2, D-5B, Symphonie, GEOS and Intelsat-IV (3 flight models)

1. The Meteosat and OTS telecommand equipment operates on UHF.

NB. Péole's telemetry and telecommand equipment was recovered from a model of the FR-1 satellite.

D. Antennae

	VHF ANTENNA	UHF ANTENNA	SHF ANTENNA
Aeritalia	Sirio		
L.M. Ericsson	GEOS	GEOS	
ETCA	HEOS-1 and HEOS-A2		
Fokker-VFW	ANS[1]		
HSD	X-4		
Marconi-SDS	UK-3, X-3, UK-4 and UK-5		
Matra	D-1A, D-1C, D-1D, ESRO-II and TD-1A	D-1A, D-1C and D-1D	
MBB	Dial and Helios		
Philips	ANS[1]		
Selenia	ESRO-IV, COS-B and Meteosat[2]	Meteosat[2]	Meteosat[2] and OTS[3]
Siemens	Azur-1 and Aeros		
SNIAS	FR-1, Péole, Eole, D-2A D-5A, D-5B and D-2B		
Starec	Symphonie	Péole and Eole	
STC	ESRO-I		
Thomson-CSF			Helios

1. The VHF antennae for the ANS satellite were designed by Philips and produced by Fokker-VFW.
2. The Meteosat VHF antennae are linked to the transponder which operates only during the transfer phase; the UHF and SHF antennae which transmit and receive meteorological data are also used for telemetry and telecommand.
3. The OTS UHF and SHF antennae provide for telemetry and telecommand once the satellite is in position. OTS also has VHF antennae (supplied by INTA) linked to the transponder which operates only during the transfer phase.

NB. 1. The VHF antennae for Intasat were produced in INTA's laboratories.
2. Contraves supplied the electronic equipment for antenna de-spinning and positioning.

E. Communications systems

	REPEATER					ANTENNA
	PRIME CONTRACTOR	INPUT STAGES AND AMPLIFICATION STAGES	TRAVELLING WAVE TUBES	CONVERTER OSCILLATOR	FILTER	
AEG Telefunken	OTS and Intelsat-IV[1]		Symphonie, Sirio[2] and OTS	Symphonie	OTS	
CGE-Fiar				Sirio		
GTE		Canadian technology satellite and OTS[3]				
L.M. Ericsson			OTS		OTS	
Marconi SDS					OTS	
Selenia	Sirio			OTS	Sirio	Sirio, Meteosat, OTS and Intelsat-IV[4]
Siemens	Symphonie	Symphonie				
SNIAS						Symphonie
STS		Sirio				
Thomson-CSF		OTS[3]	OTS	Symphonie		Intelsat-IV

1. AEG-Telefunken assembled the complete responder for Intelsat-IV and 4 receivers for 2 other satellites.
2. The travelling wave tube for Sirio will be supplied by either AEG-Telefunken or Hughes Aircraft (USA).
3. GTE is supplying the parametric amplifiers for the CTS an OTS satellites, and Thomson-CSF the OTS wide-band amplifiers.
4. Selenia supplied the SHF antennae for 6 Intelsat-IV flight models. Thomson-CSF also supplied antennae for 6 Intelsat-IV flight models.

F. Systems for transmitting Meteosat images and data
Marconi SDS: UHF transmitter-receiver unit Selenia: Toroidal antennae for SHF and UHF; electronically de-spun antenna for the S band Siemens: SHF transmitter-receiver unit

N.B. Meteosat is equipped with two transmitter-receiver units. The links between the satellite and the data collection platforms operate in the UHF band: the satellite interrogates the platforms and the latter send back information to it, using a toroidal UHF antenna. The links between the satellite and the central station operate in the S band: the satellite receives signals for interrogating the platforms from the central station by means of a toroidal antenna, which is also used for sending data from the platforms back to the central station. A third antenna, electronically de-spun and operating in the S band, is only used for transmission and serves to send the visible and infrared images from the satellite to the central station. The 2 UHF and SHF toroidal antennae serve also to transmit telemetry signals and to receive telecommand signals.

ONBOARD POWER SUPPLY

A. **Prime contractors**

AEG Telefunken: Azur-1 and Symphonie
CASA: Intasat
CGE-Fiar: ESRO-IV, Sirio and GEOS
Dornier: Aeros
ETCA: HEOS-A2 and COS-B
HSD: ESRO-II, TD-1A, X-4 and OTS
Marconi SDS: UK-3, Skynet-2, X-3, UK-4 and UK-5
Matra: D-2B
MBB: Dial and Meteosat
Philips: ANS
SNIAS: Péole and Eole

B. **Solar cells**

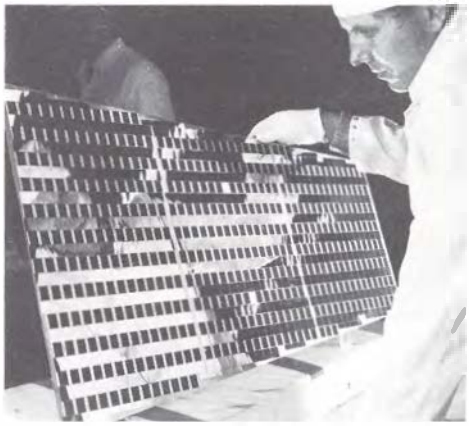
AEG-Telefunken: Azur-1, ESRO-IV, Helios, GEOS, OTS, Intelsat-IV (3 flight models) and the Canadian technological satellite CTS
Ferranti: UK-3, ESRO-II, X-3, UK-4, TD-1A, UK-5, X-4, Intasat, COS-B and Intelsat-IV (6 flight models)
La Radiotechnique: Péole, Eole (1), SRET (1) and ANS
SAT: D-1A, D-1C, D-1D, ESRO-I, HEOS-1, D-2A, HEOS-A2, D-5A, D-5B, D-2B, Symphonie, Meteosat, Intelsat-III (3 flight models) and Intelsat-IV (2 flight models)
Selenia: Sirio
Siemens: Dial and Aeros

C. **Solar panels**

1. *Solar cell assembly and glueing*
   - Four solar cell suppliers (AEG-Telefunken, la Radiotechnique, SAT and Selenia) assemble solar cells into panels.
   - Ferranti and Siemens do not assemble solar cells. In the case of the UK-3, UK-4, UK-5, X-3, X-4 and Intasat satellites, the Ferranti-made cells were assembled by Turner, while those which Ferranti produced for the Intelsat-IV satellites were assembled by BAC. MBB assembled the solar cells produced by Siemens for the Dial and Aeros satellites.
2. *Structural panels (substrates)*
   - Some satellites are equipped with solar panels attached to the satellite's central body. These panels have invariably been manufactured by the company responsible for the satellite structure: Matra for the D-1A, D-1C and D-1D ; BAC for tthe UK-3 and UK-4; Erno for the TD-1A; Fokker-VFW for the ANS ; SNIAS for the D-2A, D-2B and Symphonie; and HSD for the X-4 satellite.
   - The other satellites had the solar cell aways attached directly to the central body, and in such cases the cell-supporting substrates are an integral part of the satellite structure and are usually manufactured by the concern responsible for the structure. However there are a few exceptions to this rule: in the case of the ESRO-II, Aeros, ESRO-IV and COS-B satellites, the substrates were manufactured by HSD, MBB, Fokker-VFW and BAC respectively. The substrates for the British UK-3, UK-4 and UK-5 satellites were made by various concerns, including CIBA in Switzerland.

Model of folding solar panel; this 10 m² panel produces 1 kW (1 kg for 48 watts) (photo AEG-Telefunken).

Solar panel of German probe HELIOS, showing solar cells and secondary surface mirrors (ERNO photo).



D. Rechargeable batteries

SAFT is the only supplier of satellite batteries in Europe. It supplied the batteries for the following satellites: D-1A, D-1C, D-1D, Peole, SRET-1, ESRO-4, D-5A, D-5B, D-2B, ANS, Intasat, Symphonie, Sirio, COS-B, Meteosat and OTS.

NB. 1. The batteries for the ESRO-IV and Sirio satellites were supplied by SAFT and assembled by CGE-Fiar. Those for the Sirio satellite were assembled by V.d. Heem, a member of the Philips group. The Symphonie satellite's batteries were supplied by SAFT and assembled by AEG-Telefunken.
2. The batteries for ESRO-II, ESRO-1A, TD-1A and Aeros were supplied by the Gulton concern in the US. This concern also supplied the batteries for most of the British satellites.
3. The batteries for FR-1, HEOS-1, Eole, HEOS-A2 and GEOS were supplied by Yardney, the US concern. CGE-Fiar assembles the batteries for GEOS.

E. Converters-regulators

AEG-Telefunken: Azur-1 and Symphonie (1)
BTM: ESRO-I and OTS (2)
CASA: Intasat
CGE-Fiar: ESRO-IV, Sirio and GEOS
Crouzet: FR-1, D-1A, D-1C, D-1D, Péole (3), SRET-1, SRET-2 and D-5A
EMD: D-2A (4), Eole (5) and D-2B
ETCA: HEOS-1, HEOS-A2, Helios, COS-B, Symphonie (1), Meteosat (6) and Intelsat-IV (6 flight models) (6)
HSD: TD-1A
Marconi SDS: UK-3, Skynet-2, X-3, UK-4 and UK-5
Matra: ESRO-II, Péole (3), Eole (5) and D-5B (4)
Philips: ANS (7)
Terma: COS-B

1. For the Symphonie satellite, AEG-Telefunken supplied the charge regulating system and ETCA the converters. The only converter not made by ETCA is that of the repeater, which was supplied by Siemens.
2. For OTS, van der Heem/Philips supplied the battery charge regulating system.
3. In the case of the Péole satellite, Crouzet developed the main converter and Matra the converter used to power the transponder's transmitter.
4. For the D-2A and D-5B satellites, Crouzet supplied the regulators, while EMD and Matra produced the converters.
5. In the case of the Eole satellite, the main converters and regulators were supplied by EMD and the power supply converters for the satellite-balloon link were manufactured by Matra.
6. The battery monitoring system for the Intelsat-IV satellites was supplied by ETCA.
7. The converters and regulators were supplied by V.d. Heem, a member of the Philips group.

ATTITUDE MEASUREMENT

A. Prime contractors

Air Equipement: D-2A
BAC: HEOS-1, HEOS-A2 and COS-B
CIA: Sirio
Dornier: Azur-1, Aeros and GEOS
HSD: ESRO-IV [1] and X-4
LCT: ESRO-I
Marconi SDS: Skynet-2, X-3, UK-5 and Meteosat
Matra: ESRO-II, TD-1A, D-2B and OTS
MBB: Helios and Symphonie
Philips: ANS [2]
SNIAS: Péole and Eole

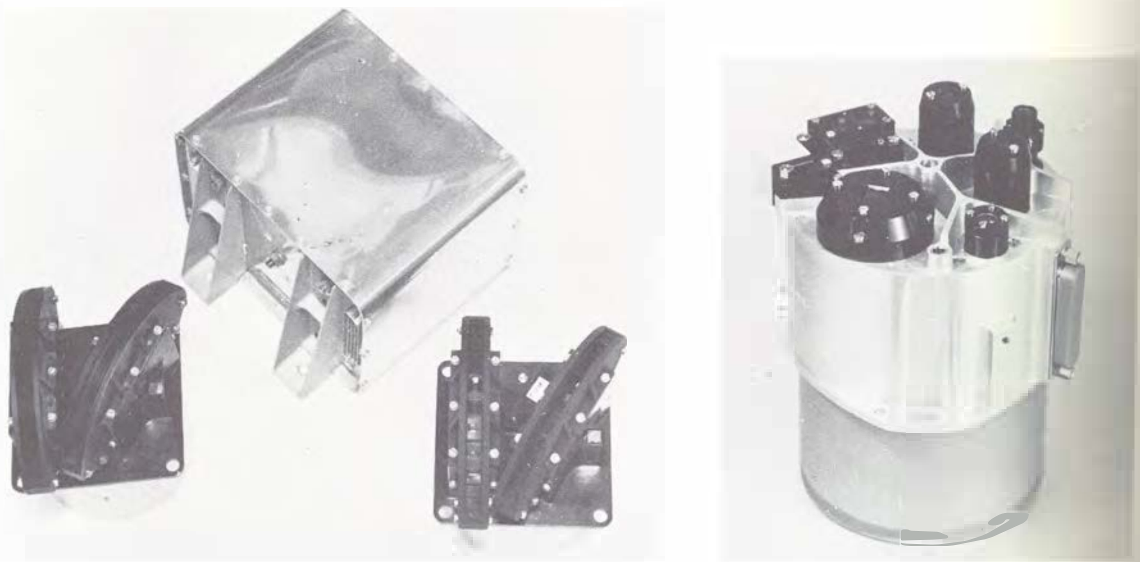
B. Sun sensors

BAC: COS-B and Intelsat-IV (3 flight models)
HSD: X-4 [1]
Leitz: Symphonie
Marconi: X-3, TD-1A [2], UK-4, UK-5, X-4 [1] and Meteosat
MATRA: TD-1A [2]
Officine Galileo: Sirio and GEOS
Philips: ANS [3]
SODERN [4]: ESRO-II, D-2A, TD-1A [2], D-2B and SRET-2

A. 1. Adcole (U.S.A.) shared prime contractorship with HSD on the ESRO-IV satellite's attitude measuring system.
2. For ANS, part of the pointing system was developed with the help of items purchased in the U.S.A. (the infrared horizon sensor and the star sensors). The star pointing system was supplied by Ball Brothers.

B. 1. Marconi supplied the fine sun sensor and HSD the coarse and intermediate sensors for X-4.
2. Elliot Brothers of the Marconi group developed the fine solar sensors for TD-1A. The intermediate sensors were supplied by Air Equipment (Sodern) and the coarse sensors by Matra.
3. Aquisition of the sun by the ANS satellite is by means of coarse sensors (solar cells), intermediate sensors and fine sensors, all manufactured within the Philips group.
4. Air Equipment developed the D-2A satellite's analog solar sensor and Schlumberger the Symphonie satellite's digital sensor. Sodern has since taken over both these tasks and has supplied the analog sensor for D-2B and the modified digital sensor for SRET-2.

NB. a) La Radiotechnique supplied solar cell arrays for attitude sensing aboard the D-1C, D-1D, D-2A, Péole, Eole, D-5B, ANS, D-2B and Symphonie satellites.
b) Adcole (U.S.A.) developed the solar sensors for ESRO-1A, HEOS-1, Azur, HEOS-A2, ESRO-IV and Aeros.
c) The Helios probe's solar sensors were supplied by an American firm.
d) The solar sensors for OTS were supplied by the Dutch TNO (Institute of Applied Physics).



Left: attitude measurement system of ESRO's HEOS-1 and HEOS-2 satellites (BAC photo); right: central unit of solar detectors of French D-2 series of satellites (Sodern photo).

C. Infrared horizon sensors

Leitz: Symphonie
Officine Galileo: ESRO-IV, Sirio, GEOS and OTS
SODERN: COS-B, Symphonie [1], Meteosat and OTS

D. Albedo sensors

BAC: HEOS-1, HEOS-A2 and COS-B
HSD: X-4 [2]
Integrated Photomatrix: X-4 [2]
Marconi: UK-5 and Meteosat

E. Star sensors

There are few star sensor manufacturers in Europe. Integrated Photomatrix supplied an experimental sensor for the X-4 satellite that had been designed by the Royal Aircraft Establishment. Philips developed a plumbicon tube for the ANS satellite. The latter's reference star sensors and the Helios probe's star sensor were supplied by American companies.

F. Magnetometers

CIT-Alcatel: D-5B
Forster: Azur-1 and Aeros
HSD: ESRO-IV and D-2B
Schlumberger [3]: ESRO-I, Péole, D-2A and Eole.

G. Gyroscopes

The gyroscopes for the TD-1A satellite were supplied by Nortronics (USA) and integrated by HSD. The rate gyros were supplied by Honeywell and integrated by Matra. Ferranti manufactured the X-4 satellite's gyroscopes.

H. Nutation sensors

The nutation sensor for Meteosat was supplied by the U.S. Company System Donner.

1. Sodern supplied the Symphonie satellite's infrared sensor used during the transfer phase and the static infrared sensor that operates after the satellite is in orbit.
2. For the X-4 satellite, HSD supplied two pulse-type albedo sensors set at 10 degrees to each other. Integrated Photomatrix produced another experimental albedo sensor designed by the Royal Aircraft Establishment.
3. The magnetometers for ESRO-1A, Péole, Eole and D-2A were developed by Compagnie des Compteurs, whose activities were later taken over by Schlumberger. In 1970 Schlumberger in turn transferred its magnetometer department to Thomson-CSF.

NB. a) Marconi supplied two infrared sensors for X-3, but they were not used in the end because of a change in the launch date. Marconi is to produce them again for the Skynet-3 satellite.
b) The ANS satellite's horizon sensor consists of a bolometer procured in the U.S.A. and a movable mirror. The lenses were made by Sodern.
c) Barnes (U.S.A.) supplied the horizon sensors for the HEOS-1, Azur, TD-1A and Aeros satellites.
d) The magnetometer for ESRO-II was supplied by Sperry (U.S.A.).
e) The magnetometer for the ANS satellite was purchased in the U.S.A.

Infra-red horizon sensor of Franco-German satellite SYHPHONIE *(Sodern photo).*

STABILISATION AND ATTITUDE CONTROL

A. Prime contractors

BAC: UK-4, COS-B and GEOS
CASA: Intasat
CIA: Sirio
Contraves: ESRO-I
Dornier: Azur-1 and Aeros
ERNO: Intelsat-III (4 flight models)
HSD: ESRO-IV and X-4
Marconi SDS: Skynet-2, UK-5 and Meteosat
Matra: D-1C, D-1D, TD-1A, D-2B and OTS
MBB: HEOS-1, HEOS-A2, Helios [1] and Symphonie
Philips: ANS
SNIAS: Péole and Eole [2]

B. Despin and yo-yo systems

BAC: UK-3 and UK-4
Contraves: ESRO-I
Dornier: Aeros
EMD: D-1A, D-1C and D-1D
ERNO: Azur-1
Fokker VFW: ANS
HSD: X-4
Matra: ESRO-II
SNIAS: FR-1, Péole, D-2A, Eole and Symphonie

C. Nutations dampers

Air Equipement: FR-1, ESRO-II, HEOS-1, HEOS-A2, ESRO-IV and OTS
BAC: Intelsat-IV (6 flight models)
Elsag: Sirio
Fokker-VFW: UK-5, COS-B and GEOS
Matra: X-3 and ESRO-IV
SAGEM: SRET-2
SNIAS: Symphonie and Meteosat

D. Magnetic bars and coils

	MAGNETIC BARS	MAGNETIC COILS
BAC		UK-4
Contraves	ESRO-I	
Dornier		Aeros
HSD		ESRO-IV
Marconi SDS		UK-5
Matra	ESRO-II	
Philips		ANS
SNIAS	Péole, Eole and D-5B	

E. Momentum wheels

Air Equipement: TD-1A
Philips: ANS and OTS
SAGEM: D-5B
Teldix: Symphonie

1. Part of the stabilisation system for the German Helios probe was supplied by the U.S. firm Ball Brothers, notably the antenna de-spinning system.
2. The Péole and Eole satellites are stabilised by gravity gradient. The boom roll-out systems were supplied by the U.S. firm Fairchild Hiller.

The momentum wheels of D-5B were of a special kind and formed part of an experimental system. D5B carried a highly sensitive micro-accelerometer: 2 small wheels and 3 metal weights enabled the satellite to be centred aroud the sensitive point of the accelerometer. The prime contractor for the whole experiment was l'Office National d'Etudes et de Recherches Aérospatiales (ONERA).

Casing, ball and electrodes of CACTUS *accelerometer core from French satellite* D-5B *(*ONERA *photo).*

F. Gas jets

	HYDRAZINE SYSTEM	COLD GASES (NITROGEN)	HOT GASES
BAC	Intelsat-IV (3 flight models) (1)		
ERNO	Aeros (orbit control) OTS (attitude and orbit control) (2)	TD-1A	
HSD		X-4 (3)	
Marconi		UK-5 and X-4	
MBB		Helios	Symphonie (4)
Oto Melara	Sirio		
SEP	D-5A (5) and GEOS	ESRO-II	
SNIAS		D-2A (6), D-2B (6) and Symphonie	

1. For the Intelsat-IV, BAC used small American thrusters.
2. For OTS ERNO will supply 8 small motors of 2 newtons thrust and the U.S. firm TRW 4 motors of 0.5 newtons thrust.
3. For X-4, HSD was responsible for the cold gas system but the system's components were supplied by Hymatics Engineering, Marston Excelsior and Marconi, who fabricated tubes identical to those of UK-5.
4. Symphonie has a double stabilisation system: station-keeping of the satellite in orbit is effected by means of 7 small engines burning nitrogen peroxide and mono-methylhydrazine, fabricated by MBB; attitude control is effected by a pneumatic system supplied to MBB by SNIAS.
5. The D-5A hydrazine micro-thruster was an experimental system intended for flight qualification and subsequent use as a stabilisation and attitude command system.
6. Crouzet developped the electronics of the pneumatic system of D-2A and D-5B.

N.B. Certain components of the cold gas pneumatic systems of the satellites HEOS-1, HEOS-A2, TD-1A and COS-B were supplied by the U.S. firm Sterer. Crouzet fabricated the electronics of the HEOS-1 and HEOS-2 pneumatic system. The hydrazine system for Meteosat will be supplied be Rocket Research (U.S.), and the tank by the U.S. firm ARDE.

DATA RECORDING AND PROCESSING

	MAGNETIC TAPE RECORDERS	CORE MEMORIES	WIRE MEMORIES	ONBOARD COMPUTER
AEG-Telefunken	Azur-1			
Crouzet			Meteosat	
EMD		D-2A (1)		
IER	ESRO-II, ESRO-I, D-2A, TD-1A, ESRO-IV, Aeros and D-2B			
LCT		Eole, D-5A and D-5B		
Marconi	X-4 (4)	UK-5		
Philips				
Plessey		Intasat Aeros (3) and Helios (4)		ANS

1. For the D-2A satellite, EMD supplied the buffer memories required for a scientific experiment and IER the main recorder.
2. The buffer memories for the Aeros satellite were supplied by SEL.
3. The magnetic recorders for the UK-3, X-3 and UK-4 satellites were designed by the Royal Aircraft Establishment and manufactured by the Aldermaston establishment of the United Kingdom Atomic Energy Authority (UKAEA). Marconi subsequently developed the X-4's magnetic recorder on the basis of the Aldermaston product.
4. Dornier also manufactures the core memories for three of the experiments on the Helios satellite.

APOGEE MOTOR
MBB: Symphonie [1] SEP/SNIA Viscosa/MAN: Meteosat, OTS and Marots SNIA Viscosa/SEP: GEOS [2] SNIA Viscosa: Sirio [3]

1. The apogee motor for Symphonie is a liquid fuel one; the main tank was manufactured by Fokker-VFW.
2. The GEOS and Sirio apogee motors are solid fuel.
3. For Meteosat, OTS and MAROTS, ESRO is financing the development of a solid apogee motor. Should it not be ready in time, an American replacement will be purchased.

RADIOMETER
The Meteosat radiometer is being fabricated by Matra.

IX - LAUNCHER DEVELOPMENT

From 1960 onwards the European countries developed several satellite launchers. France built a family of small operational launchers in the Diamant series, the three successive versions of which (Diamant-A, Diamant-B, Diamant-BP4) were steadily improved. The Diamant-BP4 version is comparable in power to the American Scout rocket. The United Kingdom built the black Arrow rocket and ELDO the Europa-2 rocket, both of which have since been abandoned.

This early work made it possible to contemplate developing a much more powerful launcher—Ariane—capable of placing about 1 500 kg in transfer orbit or 750 kg in earth-synchronous orbit. The French space agency (CNES) is acting as project manager for this launcher.

Overall integration of the Ariane launcher has been entrusted to France's SNIAS, which is also prime contractor for all three stages. Details of past or future work on launch vehicles by European companies are given in the following pages.

A. PRIME CONTRACTORS FOR ROCKET STAGES

ASAT (MBB-ERNO consortium): third stage of Europa-2

British Hovercraft Corporation (Westland Aircraft Division): first, second and third stages of the Black Arrow

Hawker Siddeley Dynamics: first stage of Europa-2

Société Nationale Industrielle Aérospatiale [1]: first, second and third stages of Diamant-A, Diamant-B and Diamant-BP 4; second and fourth stages of Europa-2 [2]; first, second and third stages of Ariane[3]

1. At the time of the Diamant-A and Diamant-B, Nord-Aviation was prime contractor for the first two stages and Sud-Aviation for the third stage. These two companies, together with SEREB, which was prime contractor for the entire Diamant-A rocket, later merged to form SNIAS (Aerospatiale).
2. The Europa-2's fourth stage was similar to the third stages of Diamant-B and Diamant-BP 4.
3. SNIAS also integrates the first and third stages of Ariane. ERNO is responsible for integration of the second stage.

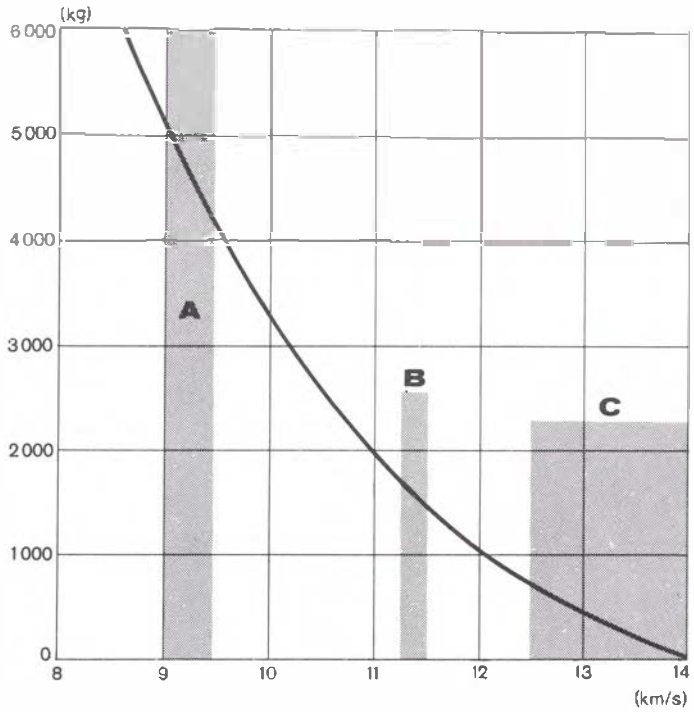
B. STRUCTURE OF STAGES

1. Tanks and structures

Air Liquide: tanks for Ariane third stage
BHC: tanks for Black Arrow first and second stages
Dornier: tanks for Ariane second stage
ERNO: tanks for Europa-2 third stage
HSD: tanks for Europa-2 first stage
MAN: water tank for Ariane first stage
Rocket Propulsion Establishment: structure of Black Arrow's third stage
SNIAS: tanks for first and second stages of Diamant-A and Diamant-B and for first stage of Diamant-BP 4; tanks for Europe-2 second stage; glass-fibre structures for third stage of Diamant-A, Diamant-B and Diamant-BP-4 and for second stage of Diamant-BP 4; structure of Europa-2 fourth stage; structures of first and second stages of Ariane ; tank for Ariane first stage

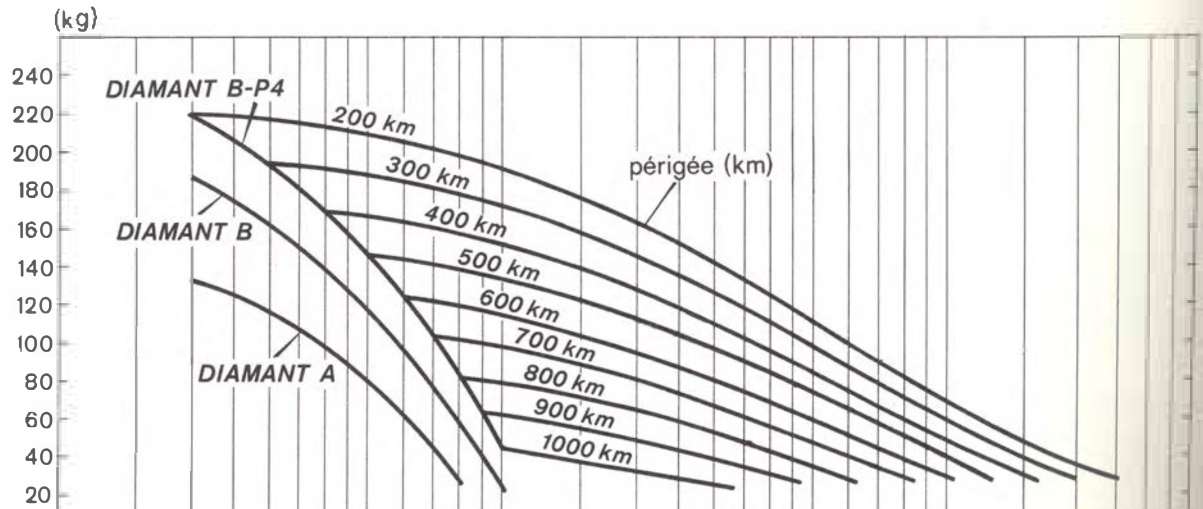
2. Ring Sections

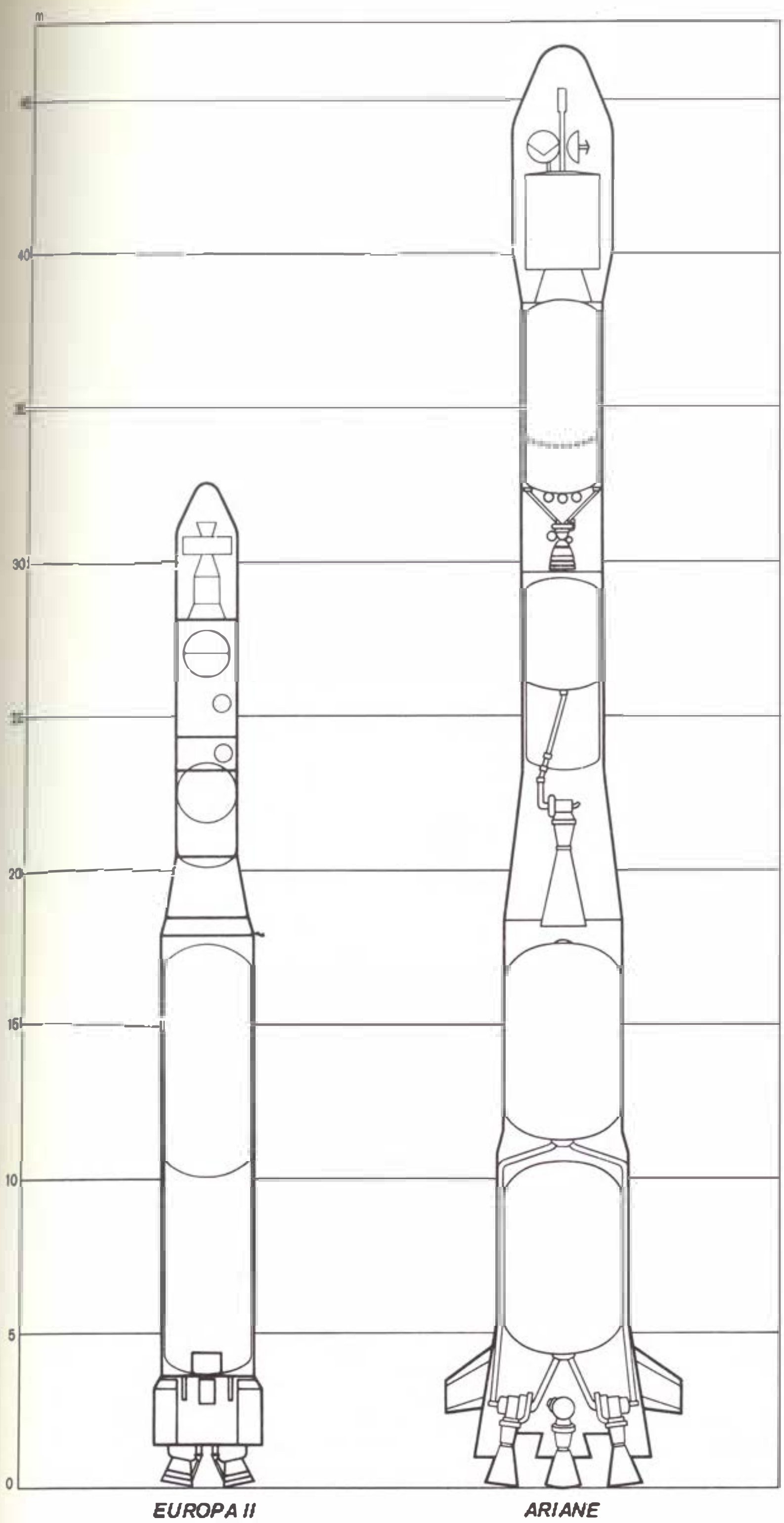
BHC (Westland Aircraft Division): interstage rings (Black Arrow first/second and second/third stages)
CASA: upper and intermediate rings for Ariane first stage
ERNO: interstage ring for Europa-2 second/third stages; forward and aft ring sections for Ariane second stage
Fokker: interstage rings for Ariane first/second and third stages
SNIAS: interstage rings for Europa-2 first-second and third/fourth stages; interstage rings for Diamant-BP 4 first/second and second/third stages



Performances of Ariane launcher: A — low equatorial orbits; B — 200/3 600 km transfer orbits; C — escape.

Performances of DIAMANT-BP-4 *launcher for equatorial orbits inclined at 5.23°.*



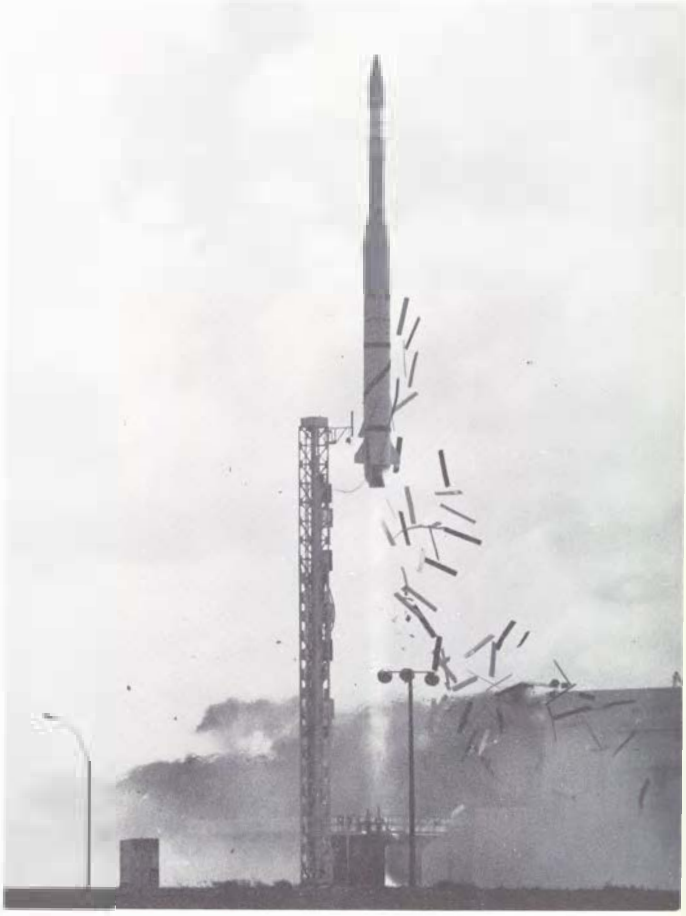


European launchers.

C. SHROUDS

Aeritalia [1]: Europa-2
BHC: Black Arrow and Diamant-BP 4
Contraves: Ariane
SNIAS: Diamant-A and Diamant-B

1. At the time this shroud was produced by FIAT, which had not yet combined with other companies to form Aeritalia.



Launch of French satellite D-2A by DIAMANT-B rocket in 1971 from Guiana Space Centre (CNES photo).

D. MOTORS

1. Prime Contractors

ERNO: Europa-2 third stage
LRBA/Tarbes facility: Europa-2 second stage
LRBA: Diamant-A first stage
MBB: thrusters for Europa-2 third stage
Rocket Propulsion Establishment: Black Arrow third stage
Rolls-Royce: Europa-2 first stage; Black Arrow first and second stages
SEP: Diamant-BP 4 first, second and third stages; Europa-2 fourth stage; Ariane first, second and third stages
SNIA Viscosa: Ariane first/second and second/third stage separation rockets

2. Combustion Chambers and Nozzles

LRBA/Tarbes facility: Diamant-B and Diamant-BP 4 first stages; Europa-2 second stage
ERNO: Europa-2 third stage
MBB: thrusters for Europa-2 third stage; Ariane third stage (liquid oxygen and hydrogen)
Rocket Propulsion Establishment: Black Arrow third stage
Rolls-Royce: Black Arrow first and second stages: Europa-2 first stage
SEP: Diamant-BP 4 second and third stages; Europa-2 fourth stage
Volvo: Ariane first and second stages

3. Turbopumps

MAN: Ariane first and second stages
Rolls-Royce: Black Arrow first and second stages; Europa-2 first stage
SEP: Ariane third stage

Third stage of Europa-1 and Europa-2 launchers (MBB photo).

E. EQUIPMENT COMMON TO ALL THE STAGES OF THE SAME LAUNCHER

1. **Prime contractors for instrumentation pack and structure**
Matra: Diamant-A, Diamant-B and Diamant-BP 4; Ariane

2. **Guidance and control system**

a. Prime contractors
Marconi SDS: Europa-2
Matra: Diamant-BP 4

b. Reference unit (inertial platform)
Ferranti: Black Arrow; Europa-2; Ariane
SAGEM: Diamant-BP 4 (instrumentation pack)

c. Computer unit
Ferranti: Black Arrow
Marconi SDS: Europa-2
SAAB-Scania/Rovsing: Ariane

d. Control unit
HSD: Ariane

3. **Central programmer (command generator)**
ETCA: Ariane
Matra: Diamant-BP 4

4. **Telemetry**
SAT: Diamant-A, Diamant-B and Diamant-BP 4
SAT or Intertechnique: Ariane

5. **Check-out system**
Matra/ETCA: Ariane

F. STAGE EQUIPMENT

1. Powerpack

Air Equipement: first stage of Diamant-A, Diamant-B and Diamant-BP 4; second stage of Europa-2
Vardel/HSD: first stage of Europa-2
Vickers/Blocher: third stage of Europa-2

2. Actuators (linear actuators or motors)

Air Equipement: second stage of Europa-2
Matra: first stage of Diamant-BP 4
MBB: third stage of Europa-2
SABCA: first stage of Europa-2; first, second and third stages of Ariane

3. Autopilot (control unit)

HSD: first stage of Europa-2
MBB: third stage of Europa-2
SAT: first stage of Diamant-A, Diamant-B and Diamant-BP 4
SFENA: second stage of Europa-2

4. Programmer

HSD: first stage of Europa-2
LCT/Matra: second stage of Europa-2
MBB: third stage of Europa-2; third stage of Diamant-BP 4
RAE: second stage of Black Arrow

5. Telemetry

Philips: first and third stages of Europa-2
SAT: second stage of Europa-2; third stage of Diamant-BP 4
SFIM/CGE: first stage of Diamant-BP 4

6. Test-stand

HSD/ICL: first stage of Europa-2
SNIAS/CII: second stage of Europa-2
MBB/Siemens: third stage of Europa-2

X - SOUNDING ROCKET DEVELOPMENT

Inbetween balloons, which seldom exceed an altitude of 40-45 km, and satellites, which do not orbit below 200 kilometres, sounding rockets make it possible to explore regions of the earth's environment inside which it would otherwise be impossible to make *in situ* measurements. Nevertheless, sounding rockets can reach altitudes of as high as 900 to 1 000 km.

Distinctly less costly than satellites, sounding rockets were the first means used to explore space before the advent of earth satellites in 1958. They are still the preferred means used by countries wishing to familiarise themselves with space before moving on to satellite-borne experiments. The time spent above 100 kilometres and set aside for experiments varies from 1-15 (and sometimes 25) minutes, depending on the rocket's power.

Since 1955 the European countries have launched over a thousand sounding rockets from various ranges. Up to around 1965 studies focused mainly on the ionosphere (from 80 to 300 km) and the exosphere (above 300 km). Since then investigators have been endeavouring more and more to take advantage of the very small residual atmosphere at these altitudes to conduct astronomy and astrophysics experiments in ultraviolet light and to study X-ray sources.

Thus, in addition to the first rockets intended for geophysics experiments, most of them solid-propellant, the European countries have developed more complex rockets with stabilised and recoverable nosecones for astronomical observations. In 1964 the United Kingdom began to launch sun-pointing Skylark rockets, and in 1970 launched the first Skylark equipped with a star sensor which permitted unusually fine pointing to be achieved. For its part, France decided in January 1971 to develop a stabilisation and pointing system—the Cassiopée system —to study celestial ultraviolet radiation sources, for mounting on Véronique 61M rockets. Like the Skylark's system, the Cassiopée system provides initial pointing by means of inertial sensors, followed, if the experiment requires it, by fine pointing by means of a star sensor. The first launch is due to be made in 1974. Meanwhile Germany has designed a similar system called the Astrid. More recently, certain Skylarks have been designed to enable earth resources to be detected.

So far the European countries have developed and built about 50 sounding rockets. Some of them are no longer built today, others are still in the design study stage and are not mentioned here. Nonetheless, the range of sounding rockets now being built is a very wide one and covers the entire performance spectrum required. These rockets have been classified into three groups according to their power. The classification criterion is a simple one, the power being estimated on the basis of the product of peak altitude times payload.

The first group—rockets of limited power—includes a number of small meteorological rockets and a few rockets which peak at around 150 km with a payload of 20 to 45 kg. Time spent above 100 km ranges from 1-4 minutes.

In the second group—medium-power rockets—are to be found many geophysical rockets used very frequently in Europe (the Centaure, Dragon and Skylark) and rockets intended for astronomical observations. They peak at between 200 and 600 km with payloads varying between 300 and 50 kg. Time spent above 100 km ranges from 2-12 minutes. To date, some 150 rockets of the Centaure family and nearly 150 Skylarks have been launched.

The third group—high-power rockets—covers rockets capable of carrying payloads between 1 000 and 100 kg to altitudes of 400-500 km, and in some cases even to 1 000 or 1 500 km. Time spent above 100 km varies from 3-25 minutes.

One of the advantages of sounding rockets is that they lend themselves readily to low-cost industrial or scientific multinational collaboration. The French Centaure and Dragon rockets, for instance, are built under licence in India. Moreover, countless scientific experiments have been conducted on a bilateral cooperation basis. In some cases a country will agree to have a foreign rocket launched from its territory for a specific experiment (such as studying equatorial or polar regions or observing an eclipse or celestial sources in the southern hemisphere) and will often help to analyse the data obtained. Alternatively, experiments of different origin may be placed aboard the same rocket, or else two countries may each decide to fire one or more rockets from the same or different locations in order to conduct mutually complementary experiments. These cooperative experiments have multiplied both in the industrialised and the developing countries.

Many experiments have also been conducted within the framework of ESRO. The 164 sounding rockets launched by ESRO from 1964 to 1972 often carried payloads which included more than one experiment and implied cooperation between scientific groups from many European countries. In the case of several European scientific laboratories, moreover, these launchings were their first experience of experiments in space. Some forty groups participated actively in this programme, which played an important part in setting up a European scientific community in the realm of space research.

SOUNDING-ROCKETS LAUNCHED FROM ESRO RANGES

	LAUNCHES	PAYLOAD		MOTOR		LAUNCH SITE		SUCCESSFUL LAUNCHES	SUCCESSFUL LAUNCHES %
		FAILURE	PARTIAL FAILURE	FAILURE	PARTIAL FAILURE	FAILURE	PARTIAL FAILURE		
1964	3							3	100
1965	8	4	1					3	38
1966	27	4	1	4	4			14	52
1967	18	4		2				12	67
1968	20	1	1	1		1		16	80
1969	26	1		4		1		20	77
1970	26	2		1		1		22	85
1971	28	2		2				24	84
1972	12		1					11	93
Total	168	18	4	14	4	3		125	75 average

This figure for the total number of sounding rockets launched includes launches made under the ESRO program (about 55 % of the total) and launches made on behalf of national space agencies. In 1971, ESRO launched 15 Skua meteorological rockets in addition to the 28 sounding rockets mentioned above.

Breakdown by type of rocket and launch site

Arcas	14
Bélier	2
Centaure	64
Dragon	4
Petrel	1
Skua	15
Skylark	82
Zenit	1

Andoya (Norway)	17
Ile du Levant (France)	1
Kiruna (Sweden)	86
Nissaki (Greece)	9
Salto-di-Quirra (Italy)	63
Woomera (Australia)	7

PRIME CONTRACTORS

BAC [1]: Skylark 1 (Raven VIII)
2 (Cuckoo + Raven VIII)
3 (Cuckoo + Raven IV)
4 (Goldfinch + Raven VIII)
5 (Raven XI)
6 (Goldfinch + Raven VI)
10 (Raven XI + Gosling)
11 (Goldfinch + Raven VI + Cuckoo II)
12 (Goldfinch + Raven XI + Cuckoo II)

BAJ: Skua and Petrel
Contraves: Zenit and Zenit + Cuckoo [2]
INTA: Inta 255 and Inta 300 [3]
ONERA: Tacite [5], Tibère and Titus [5]
SEP: Véronique 61 M and Vesta
SNIAS: Bélier III, Centaure [5], Dragon III, Eridan and Dauphin
Thomson-CSF [4]: Bélisama and Grannos

1. The Skylark 11s (Goldfinch + Raven VI + Cuckoo II) and Skylark 12s (Goldfinch + Raven XI + Cuckoo II) are projects only, and these new versions are not due to fly before 1975. The Skylark 8 (Stonecat and Waxwing is a study which has not yet been funded.
2. Contraves is prime contractor for the Zenit rocket. It mates the Zenit stage to the Cuckoo stage supplied by BAC.
3. The Inta-300 sounding-rocket is still in the development stage.
4. Belisama and Grannos are meteorological rockets.
5. The SNIAS Centaure and the Titus and Tacite rockets are no longer made.

SHROUDS

BAC: Skylark
BAJ: Inta 300, Skua and Petrel
CASA: Centaure [1] and Nike-Cajun
Contraves: Zenit
Dornier [2]: Centaure [1], Skua, Skylark, Zenit, Black-Brant and Nike-Apache
HSD: Centaure [1]
Matra: Eridan and Véronique
MBB: Black-Brant
ONERA: Centaure [1], Tacite [1], Tibère and Titus
SAAB-Scania: Nike-Tomahawk [3]
SNIAS [4]: Bélier III, Centaure [1], Dauphin, Dragon III, Eridan and Véronique

1. The Centaure, Tacite and Titus shrouds are no longer made.
2. The shrouds manufactured by Dornier are of the fixed or opening type.
3. The shroud developed by SAAB-Scania is an ejectable shroud 305 mm in diameter.
4. The shrouds produced by SNIAS are of the fixed, opening or ejectable type. SNIAS is developing ejectable shrouds for the Véronique and Eridan sounding rockets.

RECOVERY SYSTEMS

BAC	CONTRAVES	DORNIER	LATECOERE	SNIAS
land recovery	recovery on land or at sea for Skylark and Zenit	recovery on land or at sea for Skylark and Zenit [1]	recovery at sea with monitoring console and onboard programmer	recovery on land for payloads 305 and 560 mm in diameter

1. Dornier has also tested a recovery system employing a paraglide sail instead of parachutes.

Sounding rocket payload (Dornier photo).

PRIME CONTRACTORS FOR PAYLOADS

BAC	BAJ	CASA	CONTRAVES
26 ESRO sounding rockets and 38 Petrel and Skylark sounding rockets since 1963 (British programme)	several Skua	Centaure [1] and Skylark (ESRO programme) ; Centaure [1] and Nike-Cajun (Spanish programme)	Zenit (Swiss programme)

DORNIER	HSD	MATRA	MBB	SAAB-SCANIA	SNIAS
18 Centaure [1], 9 Skylark and 2 Zenit (ESRO programme); 69 Skua, 3 Black Brant and 2 Nike-Apache between 1968 and 1972	Centaure [1] and Skua	Dragon, Eridan and Véronique	Skylark, Black-Brant, Javelin and Nike-Apache	2 Nike-Tomahawk and 2 Skylark (ESRO programme)	200 sounding rockets (since 1960): Arcas, Bélier, Centaure [1], Dragon, Dauphin, Eridan, Véronique and Vesta

1. The Centaure Rocket is no longer made.
N.B. Elecma, EMD, SABCA used to integrate payloads but have since ceased their activities in this area.

TELECOMMUNICATIONS AND PROGRAMMERS

	TELEMETRY		ANTENNA	PROGRAMMER
	ENCODER	TRANSMITTER		
CGE	Bélier, Centaure [1], Dauphin, Dragon, Eridan and Skylark rockets (PAM, PSM, FM)			
Contraves	Zenit			Zenit
Crouzet [2]	Véronique and Eridan (Faust and Araks experiments) (PCM)			5-channels for French sounding rockets; 10 channels for experiments with Cassiopée sensor; 15 channels for Faust and Araks experiments [3]
Dornier				Skua
Dynatel	Skylark and Petrel			
Elecma		215-260 MHz		
Elektronik-centralen			Dipole for Centaure [1] and Skylark	
EMI	Inta-255, Petrel, Skua and Skylark		Inta-255, Petrel, Skua, Skylark	
Marconi				Skylark
MBB	Black-Brant (Aeros [4] experiments)	27-500 MHz	Skylark and Black-Brant (VHF and UHF)	Details not available
Montedel	Nike-Apache		Centaure [1] and Skylark	
ONERA		Tibère (2.2 GHz)	Bélier, Centaure [1], Tacite, Tibère, Titus	Tibère
SAAB-Scania	for certain ESRO experiments and the Nike-Tomahawk rocket	for certain ESRO experiments and the Nike-Tomahawk rocket		
SAT	for the majority of sounding rockets	for the majority of sounding rockets	Centaure and Dragon	
SFIM	modulators for Bélier, Centaure [1] and Véronique			various sounding rockets
SNIAS			Bélier, Centaure, Dauphin, Eridan, Titus, Véronique	for certain experiments on Véronique and Eridan (Araks experiments)

Sounding rocket programmer (Crouzet photo).

Telecommand

SAT produces telecommand systems for most sounding-rockets.

SNIAS is producing a prototype system at Toulouse which is likely to be quantity-produced ultimately.

Radar Transponders

SAT manufactures radar transponders for most sounding-rockets.

1. The Centaure, Tacite and Titus rockets are no longer made.
2. Crouzet's multiformat encoder (1 Mbits) is compatible with most sounding-rockets, especially the French ones.
3. France's Faust experiments will begin in 1974. Véronique 61 M sounding-rockets equipped with a stabilisation system (Cassiopée) will enable astronomical observations in the ultraviolet to be made. The Araks experiments will be conducted in cooperation with the Soviet Union; Eridan sounding-rockets will carry electron guns which will allow the magnetosphere and ionosphere to be studied.
4. Several Canadian Black-Brant sounding-rockets were launched after the German Aeros satellite had been orbited in order to obtain further low-altitude data.

N.B. BAC is developing an L-band antenna for Skylark and Zenit sounding-rockets. Intertechnique is developing a new PCM encoder. SABCA abandoned its sounding-rockets activities in 1970. SNIAS has turned over its telemetry department to SAT.

ATTITUDE RESTITUTION SYSTEMS

	BAC	BODENSEE-WERK GERATE-TECHNIK	FERRANTI	INTEGRATED PHOTOMATRIX	MARCONI	MBB	SAGEM	THOMSON CSF
Solar sensors	Skylark			details not available	Skylark and Black-Brant	for Aeros launches		
Lunar sensors	Skylark				Skylark			
Magneto-meters						for Aeros launches		(1)
Gyro-scopes		for the Astrid and Dachs systems	Skylark				for the Cassiopée system	

1. Activity ceded by the Compteurs Schlumberger Company.

N.B. SODERN and HSD manufacture sensors for satellites that can be adapted for sounding-rockets. ONERA has developed a solar sensor which measures a sounding-rocket's attitude in 15 half-degree steps and is used also for roll measurements. Several companies (e.g. SFIM, Teldix) manufacture rate gyro units.

ROLL CONTROL	BAC	DORNIER	MARCONI	ONERA	SAGEM	SEP	SNIAS
Yo-yo	details not available			Tibère			carried on rockets 305 and 560 in diameter
Gas jets		Astrid and Dachs systems (cold gas jets)	Skylark (cold gas jets)		Cassiopée system (cold gas jets)	small solid thrusters carried on the Titus[1]	

1. The Titus rocket is no longer made.

CHARACTERISTICS OF STABILISATION AND POINTING SYSTEMS

	STAR POINTING[1]			SUN POINTING	INERTIAL POINTING ONLY
	ASTRID SYSTEM (DORNIER)	SKYLARK SYSTEM (MARCONI)	CASSIOPEE SYSTEM (SAGEM-SODERN)	SKYLARK SYSTEM (MARCONI)	DACHS SYSTEM (DORNIER)
number of axes monitored	2 (3rd axis is spin axis)	3	3	3	3
acquisition time (seconds)	< 60	< 90	30	< 30	
precision of coarse gyro pointing	5 minutes of arc		< 1 minute of arc		< 1 degree
precision of fine pointing	< 5 minutes of arc	30 seconds of arc in yaw and pitch; 1 degree in roll		30 seconds of arc in yaw and pitch; 1 degree in roll	
amplitude of limit cycle					
— in gyro pointing mode (minutes of arc)			6 minutes of arc about the 3 axes		
— in fine pointing mode		< 10 seconds of arc in yaw and pitch; 1 minute of arc in roll	1 minute of arc in yaw and pitch; 6 minutes in roll	< 10 seconds of arc in yaw and pitch; < 10 minutes of arc in roll	
magnitude of star observed	< 2	— 2 + 5	+ 3		
weight of pointing system (kg)	18	85		50	
weight of monitored payload (kg)	75	275	250—450		

1. In the Astrid and Cassiopée systems, coarse pointing controlled by a gyro platform can be followed, if the experiment requires it, by fine acquisition controlled by a star sensor. In the system used on Skylark rockets, initial pointing at the moon is controlled by magnetometers and moon sensors; this is followed by a coarse pointing controlled by integrating rate gyros, followed in turn by fine acquisition controlled by a star sensor.

NB. The Skylark system and the Cassiopée system enable from 1-5 stars to be acquired during the same flight.
The Cassiopée system can be used for sun pointing.

FABRICATION OF STABILISATION AND POINTING SYSTEMS

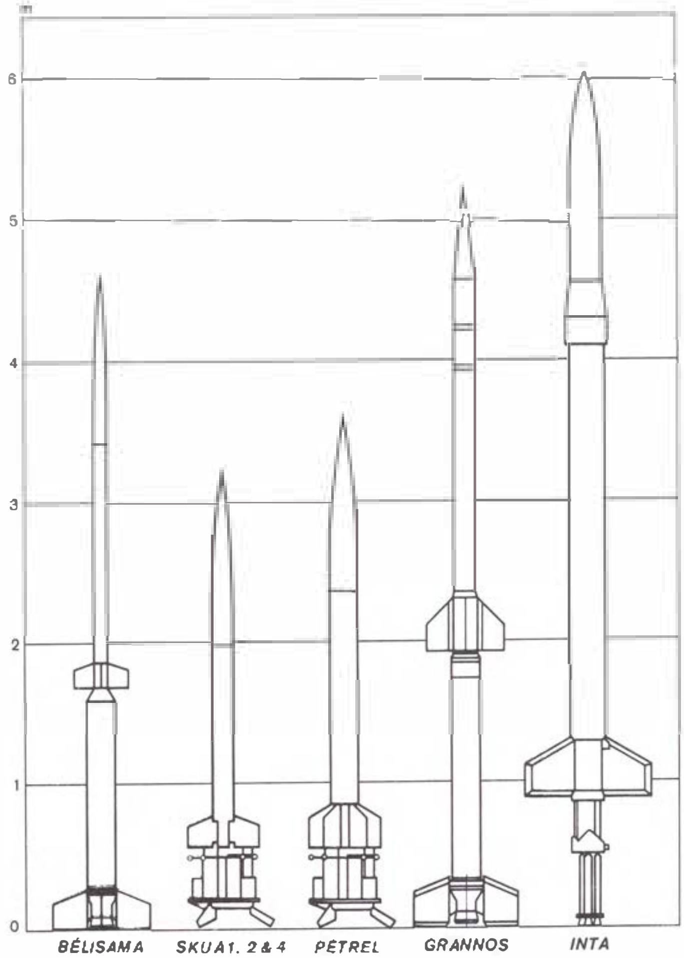
	BAC	DORNIER	MARCONI	MBB	SAGEM
Lunar pointers			Skylark	Black-Brant (Aeros programme)	
Solar pointers			Skylark and other rockets with a diameter of 44 cm [1]	Black-Brant (Aeros programme)	
Stellar pointers		Astrid system for Centaure rocket	Skylark [1]		Cassiopée system for Véronique 61 M rockets [2]
Earth pointers	for Skylark earth resources detecting rockets				
Inertial pointers		Dachs system for Skylark			

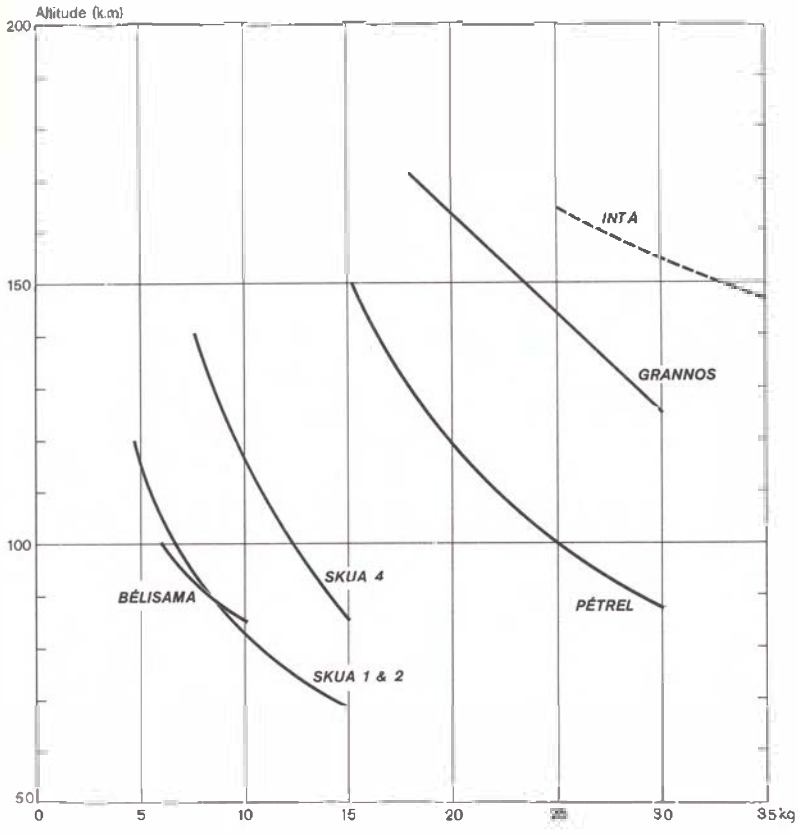
1. Stellar and solar detectors are also manufactured by the Marconi group.
2. SAGEM is responsible for the complete pointing system. The inertial detectors are supplied by SAGEM, the stellar detectors by SODERN. Like the Skylark system, the Cassiopée system is of the universal type and consists of an inertial pointer to which are associated fine detectors, particularly solar detectors.

Sounding rocket integration hall, ESTEC, *Noordwijk.*

CHARACTERISTICS OF SOUNDING-ROCKETS - GROUP I						
PRIME CONTRACTOR	STAGE OF DEVELOPMENT DATE OF FIRST LAUNCH NUMBER OF SUCCESSFUL LAUNCHES AS AT 31-12-1972	NUMBER OF STAGES AND PROPELLANT	LENGTH LESS PAYLOAD LIFT-OFF WEIGHT LESS PAYLOAD	DIAMETER AND HEIGHT OF SHROUD AND VOLUME AVAILABLE	PROPULSION AND FLIGHT TIME ABOVE 100 KM	PERFORMANCE * (85 deg. launch)
Bélisama Thomson-CSF	operational 5-3-1968 40 launches	2 solid	3 395 mm 118 kg	100 and 1 200 mm ≃ 5 dm³	2.5 - 0.9 s	6 kg 100 km 10 kg 85 km
Skua-1 et 2 BAJ	operational 1962 750 launches	2 solid	1 960 mm 76.3 kg	131 mm and 400 - 1 200 mm 2-8 dm³	0.2 - 32.5 s 180 - 0 s (1)	4 kg 120 km 15 kg 68 km (1)
Skua-4 BAJ	flight qualified 1972 2 launches	2 solid	1 960 mm 83.3 kg	131 mm and 400 - 1 200 mm 2-8 dm³	0.2 - 32.5 s 180 - 0 s (1)	7.5 kg 140 km 15 kg 85 km (1)
Petrel (2) BAJ	operational 1967 110 launches	2 solid	2 410 mm 163.3 kg	190.5 mm and 400 - 1 200 mm 4-15 dm³	0.2 - 30/36 s	15 kg 150 km 30 kg 87 km (1)
Grannos Thomson-CSF	operational 9-4-1969 5 launches	2 solid	3 940 mm 163.6 kg	156 and 1 310 mm ≃ 15 dm³	3.15 - 8 s 240 - 145 s	18 kg 172 km 30 kg 124 km
Inta-255 (3) INTA	flight qualified 20-12-1969 3 launches	2 plastic propellant	4 585 mm 306 kg	228.6 mm and 1 538 mm 36 dm³	0.25 - 17 s 164 s	27.6 kg 136 km (with antenne and launch at 82.5 deg)

* Performance figures shown relate to minimum and maximum payloads respectively and the altitudes reached with each.
1. For Skua and Petrel rockets, performance figures apply to 87 degree launches.
2. BAJ is developing more powerful Petrel rockets.
3. For the INTA-255 rocket, performance figures are based on the three launches made.



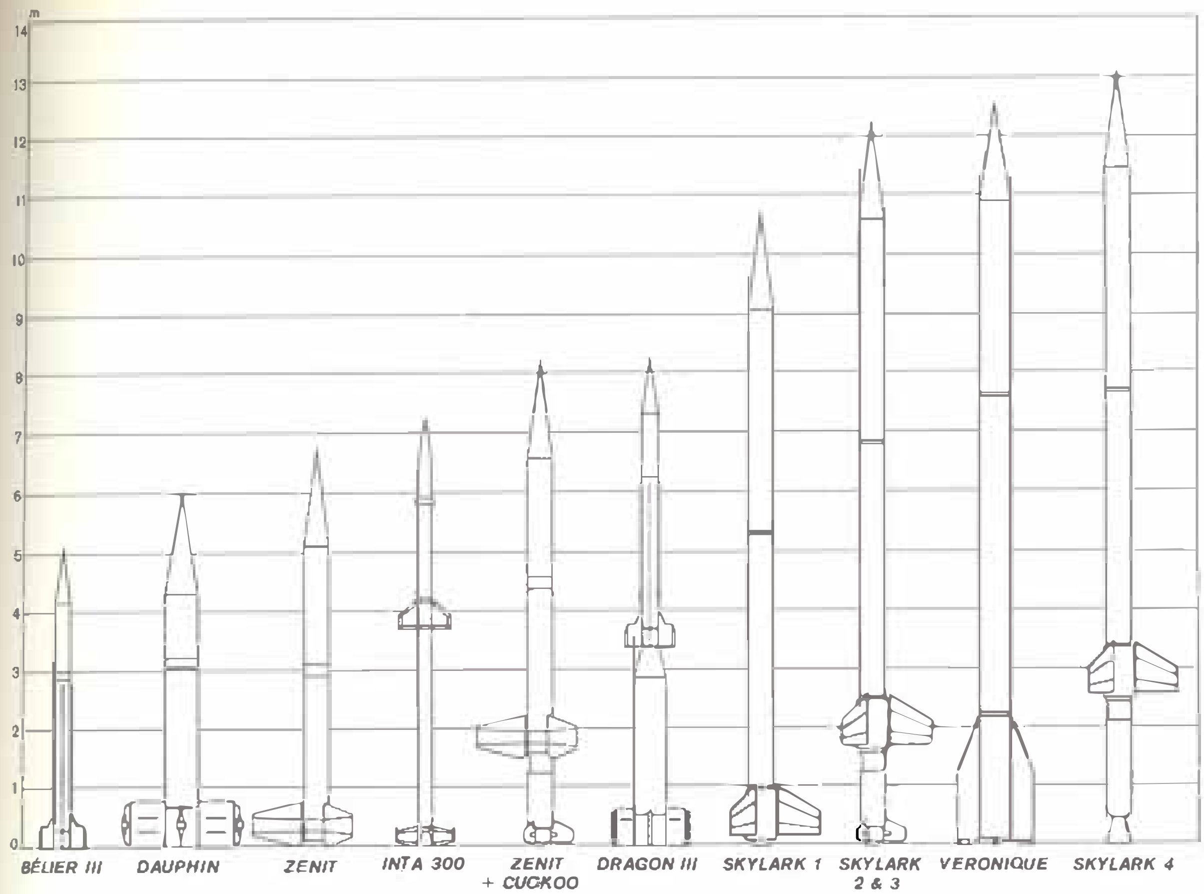


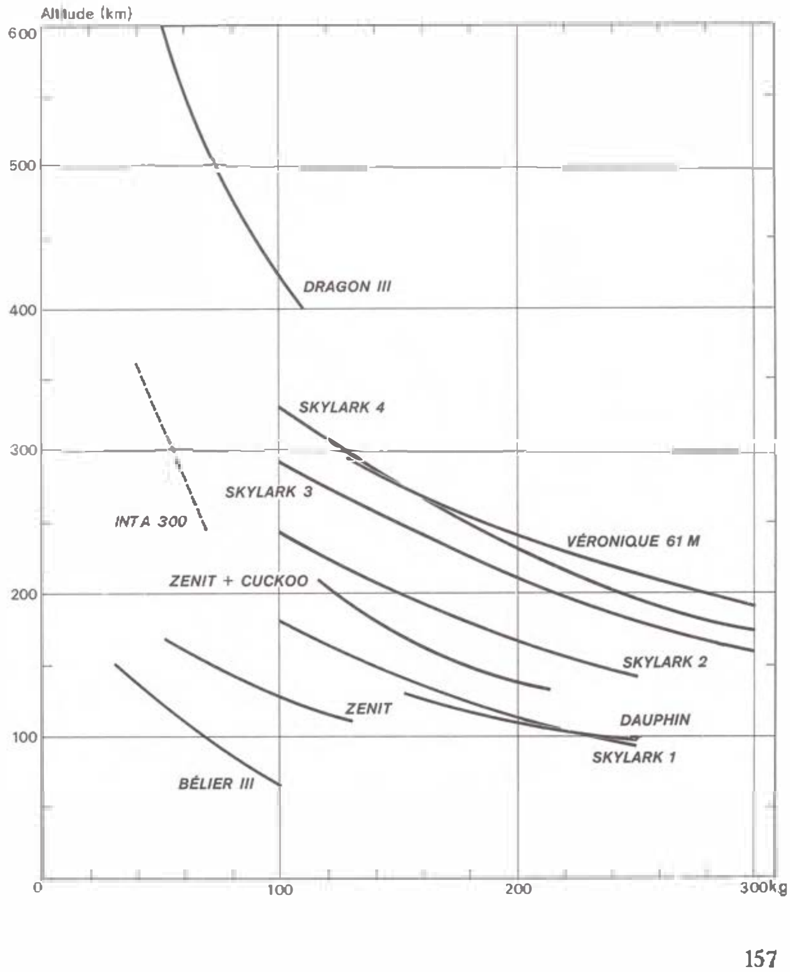
Performances of Group I sounding rockets.

CHARACTERISTICS OF SOUNDING-ROCKETS - GROUP II

PRIME CONTRACTOR	STAGE OF DEVELOPMENT DATE OF FIRST LAUNCH NUMBER OF SUCCESSFUL LAUNCHES AS AT 31-12-1972	NUMBER OF STAGES AND PROPELLANT	LENGTH LESS PAYLOAD LIFT-OFF WEIGHT LESS PAYLOAD	DIAMETER AND HEIGHT OF SHROUD AND VOLUME AVAILABLE	PROPULSION AND FLIGHT TIME ABOVE 100 KM	PERFORMANCE * (85 deg. launch)
Bélier III SNIAS	operational 18-3-1968 4 launches	1 solid	2 862 mm 325 kg	305 and 1 080-2 250 mm (970 if necessary) 30-100 dm³	23.4 s 210 - 0 s	30 kg 150 km 100 kg 70 km
Inta-300 INTA/BAJ	development April 1974	2 plastic propellant	5 794 mm 503 kg	260 and 1 478 mm 35 dm³	4.4 - 17 s 470 s	expected performance: (with antenne)
Zenit Contravès/ Dornier	flight qualified October 1967 2 launches	1 solid	2 847 mm 610 kg	420 and 1 850-3 850 mm 104-356 dm³	31 s 240 - 160 s [1]	52 kg 170 km 130 kg 113 km [1]
Zenit + Cuckoo Contravès/ Dornier	flight qualified July 1971 1 launch	2 solid	4 288 mm 877 kg	420 and 1 850-3 850 mm 104-356 dm³	4 - 31 s 330 - 200 s [1]	115 kg 207 km 215 kg 135 km [1]
Dauphin SNIAS	operational 20-3-1967 4 launches	1 solid	3 028 mm 932 kg	563 and 1 930-3 000 mm 200-500 dm³	16 s 190 - 0 s	150 kg 132 km 250 kg 97 km
Dragon III SNIAS	operational 23-7-1968 7 launches	2 solid	6 242 mm 1 216 kg	305 and 1 080-2 050 mm 30-100 dm³	16 - 23.4 s 690 - 490 s	50 kg 600 km 110 kg 400 km
Skylark 1 BAC	operational 7 October 1966 7 launches	1 solid	5 167 mm 1 079 kg		30 s 250 - 0 s	100 kg 175 km 250 kg 95 km
Skylark 2 BAC	operational April 1966 26 launches	2 solid	6 738 mm 1 334 kg	438 mm 1 489-1 699- 1 985 mm + cylindrical section 500-3 820 mm	4.2 - 30 s 350 - 180 s	100 kg 240 km 250 kg 140 km
Skylark 3 BAC	operational February 1965 60 launches	2 solid	6 738 mm 1 472 kg		4.2 - 30 s 420 - 200 s	100 kg 290 km 300 kg 160 km
Skylark 4 BAC	operational March 1972 2 launches	2 solid	7 649 mm 1 542 kg		3.7 - 30 s 430 - 230 s	100 kg 330 km 300 kg 175 km
Véronique 61 M SEP	operational 18 June 1964 for Véronique and 1966 for Véronique 61 M	1 liquid	7 610 mm 1 950 kg	550 and 1 650-4 490 mm 100-900 dm³	56 s 280 - 430 s	130 kg 292 km 300 kg 185 km

* Performance figures shown relate to minimum and maximum payloads respectively and the altitudes reached with each.
1. For Zenit and Zenit + Cuckoo rockets, performance figures apply to 87.5° launches.



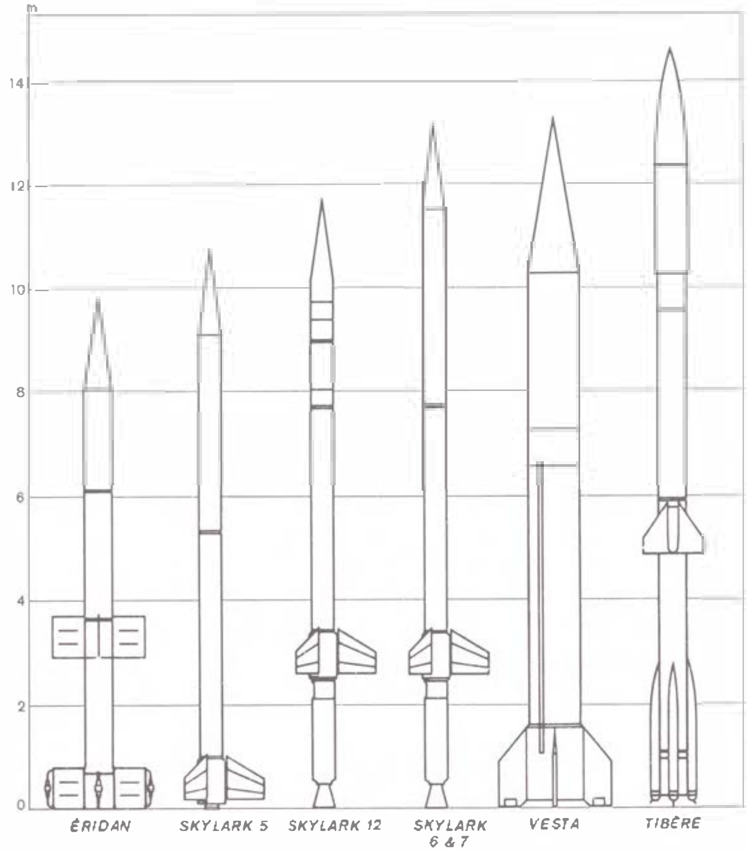


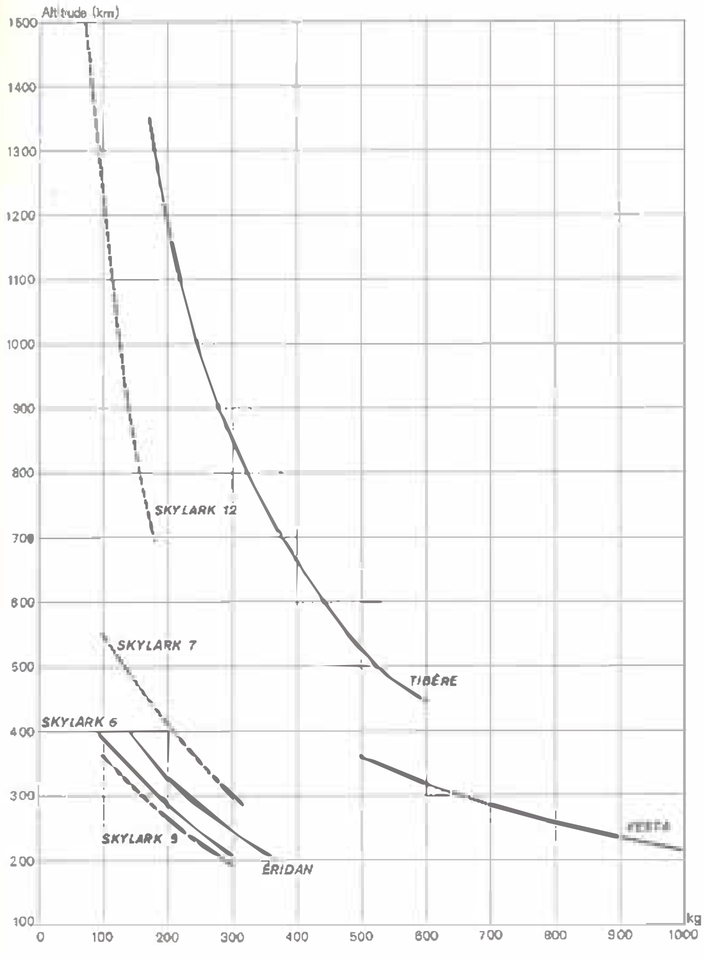
Performances of Group II sounding rockets.

CHARACTERISTICS OF SOUNDING ROCKETS - GROUP III

PRIME CONTRACTOR	STAGE OF DEVELOPMENT DATE OF FIRST LAUNCH NUMBER OF SUCCESSFUL LAUNCHES AS AT 31-12-1972	NUMBER OF STAGES AND PROPELLANT	LENGTH LESS PAYLOAD LIFT-OFF WEIGHT LESS PAYLOAD	DIAMETER AND HEIGHT OF SHROUD AND VOLUME AVAILABLE	PROPULSION AND FLIGHT TIME ABOVE 100 KM	PERFORMANCE * (85 deg. launch)
Eridan SNIAS	operational 26-9-1968 7 launches	2 solid	6 085 mm 1 877 kg	563 and 1 930-3 700 mm 200-670 dm^3	16 and 16 s 415 - 200 s	140 kg 400 km 360 kg 210 km
Skylark 5 BAC	development August 1974 —	1 solid	5 167 mm 1 877 kg		30 s 480 - 280 s	100 kg 365 km 300 kg 210 km
Skylark 6 BAC	operational 8-2-1969 18 launches	2 solid	7 648 mm 1 682 kg	438 mm 1 489-1 690- 1 985 mm + cylindrical section 500-3 820 mm	37 - 30 s 430 - 310 s	100 kg 380 km 300 kg 210 km
Skylark 7 BAC	development October 1973	2 solid	7 648 mm 1 722 kg		37 - 30 s 620 - 460 s	100 kg 550 km 300 kg 300 km
Skylark 12 [1] BAC	development October 1975 2 launches	3 solid	8 896 mm 1 964 kg	1 985 mm + cylindrical section 710 mm	1 200 - 715 s	75 kg 1 500 km 175 kg 700 km
Tibère ONERA	operational February 1971 2 launches	3 solid	12 185 mm 4 420 kg	656 and 2 200 mm 600 dm^3	20 - 20 et 48 s 1 600 - 550 s	170 kg 1 350 km 600 kg 450 km
Vesta SEP	operational 15-10-1965 5 launches	1 liquid	7 207 mm 5 000 kg	1 000- 3 000-6 000 mm 750-2 150 dm^3	56 s 440 - 318 s	500 kg 360 km 1 000 kg 212 km [2]

* Performance figures shown relate to minimum and maximum payloads respectively and the altitudes reached with each.
1. Skylark 11 has a Raven VI first stage; its performance is slightly lower than that of Skylark 12.





Performances of Group III sounding rockets.

XI BALLOON DEVELOPMENT

Seldom used in the early 1960s, balloons began to play a increasingly important role over the years, eventually becoming a select medium for experiments in certain areas—initially for solar observation in ultraviolet or infrared light and bio-astronautics, followed by infrared astronomy and, more recently, Xray and gamma source astronomy and earth resources detection.

Capable of reaching altitudes of 20 to 40 km, balloons rise sufficiently above the dense layers of the atmosphere to permit observation of radiation forms invisible on the ground. Depending on their volume, they can carry payloads ranging from 10-350 kg or more into the stratosphere, enabling experimenters to use heavy instruments like telescopes, cooled infrared detectors, scintillators or spark chambers.

All the ESRO member countries use balloons as a complementary means of research in addition to sounding rockets and satellites, and France and the United Kingdom particularly so. For their astronomy experiments, a number of countries have developed a stabilised nacelle which is pointed at the sun or a star:

— In Belgium the Astrophysics Institute of Liège University has had a stabilised nacelle developed, the attitude control system of which was produced by ETCA.

— In France the French space agency (CNES) had a stabilised nacelle (Astrolab) developed in 1966, the attitude control system being produced by the French Schlumberger Company. This nacelle, which has made dozens of flights, is remote-controlled from the ground and equipped with a PCM telemetry system. The French Atomic Energy Authority and the Space Radiation Research Centre at Toulouse have also developed balloon nacelles, and somewhat less elaborate ones have been developed by other laboratories.

— In Germany the Dornier Company has developed a stabilised nacelle called the Thisbe, along with the necessary onboard equipment (programmer, servo controls, PCM telemetry, remote-control equipment) and ground support facilities. Initial tests of this nacelle were performed in Texas (USA) at the end of 1971.

— Switzerland's Geneva Observatory has had a 250 kg nacelle developed, capable of being pointed accurately to one minute of arc and equipped with an onboard programmer.

Only one company in Europe manufactures balloons: the French Zodiac-Espace concern. The balloons it makes are sold to Belgium, Denmark, Italy, the Netherlands, Switzerland and the United Kingdom and some of these have been launched from the Aire-sur-l'Adour station in France. Zodiac-Espace makes four kinds of balloons:

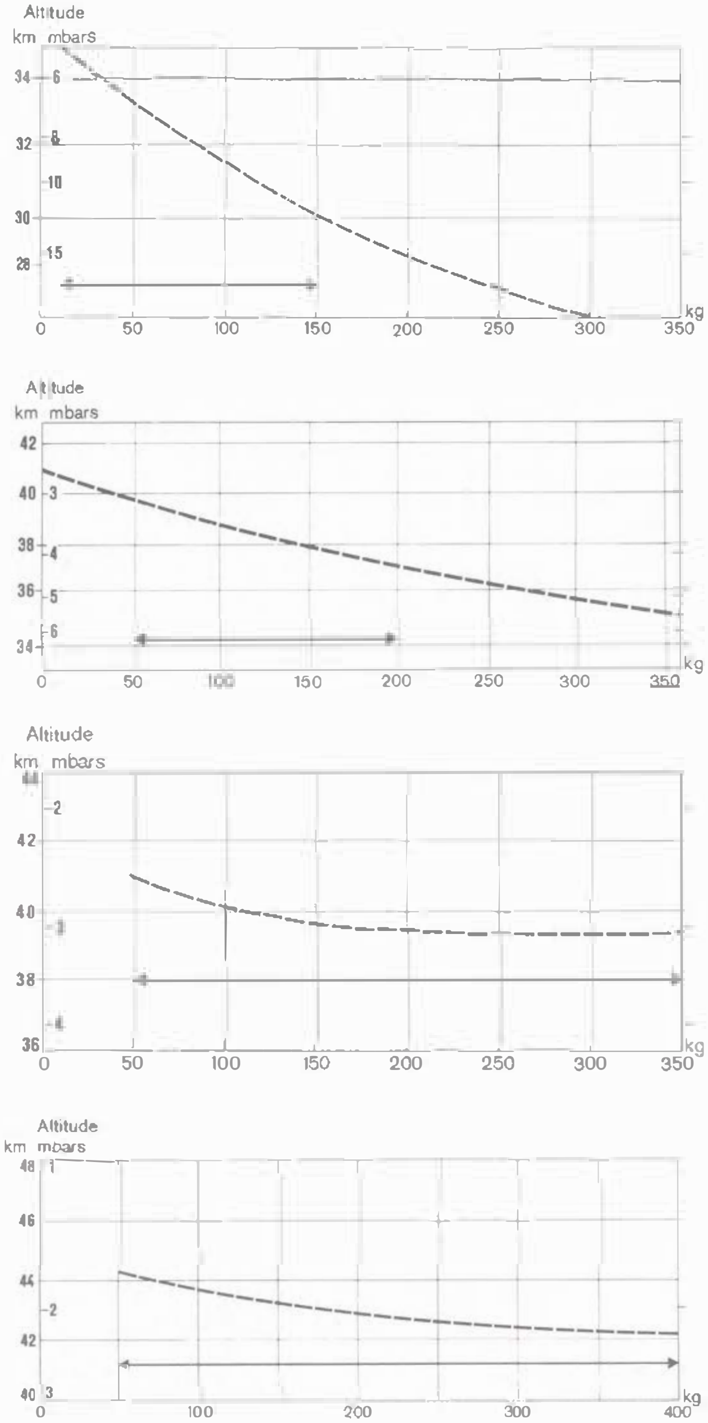
— Hermetic pressurised balloons with a volume of 20 to 45 m^3, made of mylar and capable of drifting at constant altitude for several weeks. 480 of these balloons with a volume of 20 cubic metres were released for the Eole meteorological experiment. Their average lifetime was about 82 days at an altitude corresponding to 200 millibars.

— Low-volume (20-65 m^3) tethered balloons which remain at low altitudes for a few days, as well as high-altitude tethered balloons.

— Tetrahedral stratospheric balloons made of polyethylene, with volumes ranging from 1 350 to 87 000 m^3. However, these balloons cannot lift more than 200 kg to an altitude of 25-30 km. Flight time is usually limited to 6-10 hours, and the balloons are recovered after 24 hours.

— Normally shaped stratospheric balloons. In order to overcome the limitations of tetrahedral balloons, spherical polyethylene balloons have been manufactured since 1971. They are made in volumes of 100 000 or 350 000 m³ and are capable of lifting 350 kg to an altitude of 40 km and 360 kg to 42 km respectively. Their first flights in France date back to the end of 1972. These balloons are more costly than tetrahedral balloons.

The manufacturing techniques employed ensure automatic balloon assembly, either by welding a film of polyethylene in the case of tetrahedral balloons or by using reinforcing strips to join the gores of spherically shaped balloons. Launching involves the use of an auxiliary balloon, and scientific campaigns have been conducted in regions where very different climatic conditions prevail (e.g. Brazil, Guiana, Iceland, the Kerguelen Islands, Sicily, South Africa and the Soviet Union). In the case of launches made from its two bases at Aire-sur-l'Adour and Cap Tallard, the French space agency (CNES) handles all launching and recovery operations on behalf of investigators. Teams of CNES specialists also operate in any other parts of the world where scientific laboratories are likely to want balloon launches to be made.



Performances of stratospheric balloons: from top to bottom, tetrahedral shape, 13 000 and 87 000 m³; "natural" shape, 100 000 and 350 000 m³.

Balloon launching from the Aire-sur-Adour Centre (CNES photo).

FLIGHTS BY STRATOSPHERIC TETRAHEDRAL BALLOONS MADE IN FRANCE

	1967	1968	1969	1970	1971
Total flights	197	183	146	134	142
Scientific flights	125	141	109	115	120
French Laboratories	94	108	78	83	78
Other Laboratories	31	33	31	32	42
Technical flights	72	42	37	19	22
Operational flights	196	171	143	134	142
Successes	152	148	129	124	124
Failures due to balloons	31	18	13	10	13
Failures due to equipment	3	1	1	0	2
Failures due to operations	10	4	0	0	3
Total payload launched [1]	12	17	20	20	22.4
Total volume of balloons launched (mm^3)	5	6	8.5	8.5	9
Average payload (kg)	60	95	135	152	157
Average volume of balloons (1 000 m^3)	25	35	60	63	63
Time in operation (hours)	—	990	830	750	750

Balloon manufacture, Aire-sur-l'Adour (Zodiac photo).

XII - GROUND STATION DEVELOPMENT

ESRO and some European countries have installed earth monitoring centres and a network of telemetry, telecommand and tracking stations for low-orbiting satellites. These stations operate on metric waves and are very numerous indeed.

At first, these networks were designed according to 1965 NASA practice, and they are therefore compatible. However, following the December 1972 resolution of the European Space Conference recommending rationalised space activities, ESRO undertook to conceive an integrated European system of earth stations. This unified network, which will retain only certain of the existing stations and monitoring centres, should lead to substantial savings in the operating costs of such networks.

New telemetry, telecommand and tracking stations are to be set up to meet the needs of the GEOS, Meteosat, OTS, IUE and Marots synchronous satellites. These stations will be equipped with high-gain antennae and will function on decimetric waves. Their locations have not yet been finalised, however.

In addition to these stations designed to receive signals from the satellites and to transmit commands to them and to determine their orbits, there are other stations to be used for transmission to and reception from satellites of telephony, television, telemetry and other signals which the satellites are required to relay . Notable among them are the Intelsat network stations, which are microwave relays belonging to the Posts and Telecommunications authorities. Together with the satellite, they form links in a chain, and there are approximately 100 of them around the globe today. Some of these stations, particularly in Europe and Africa, have been built by European industry.

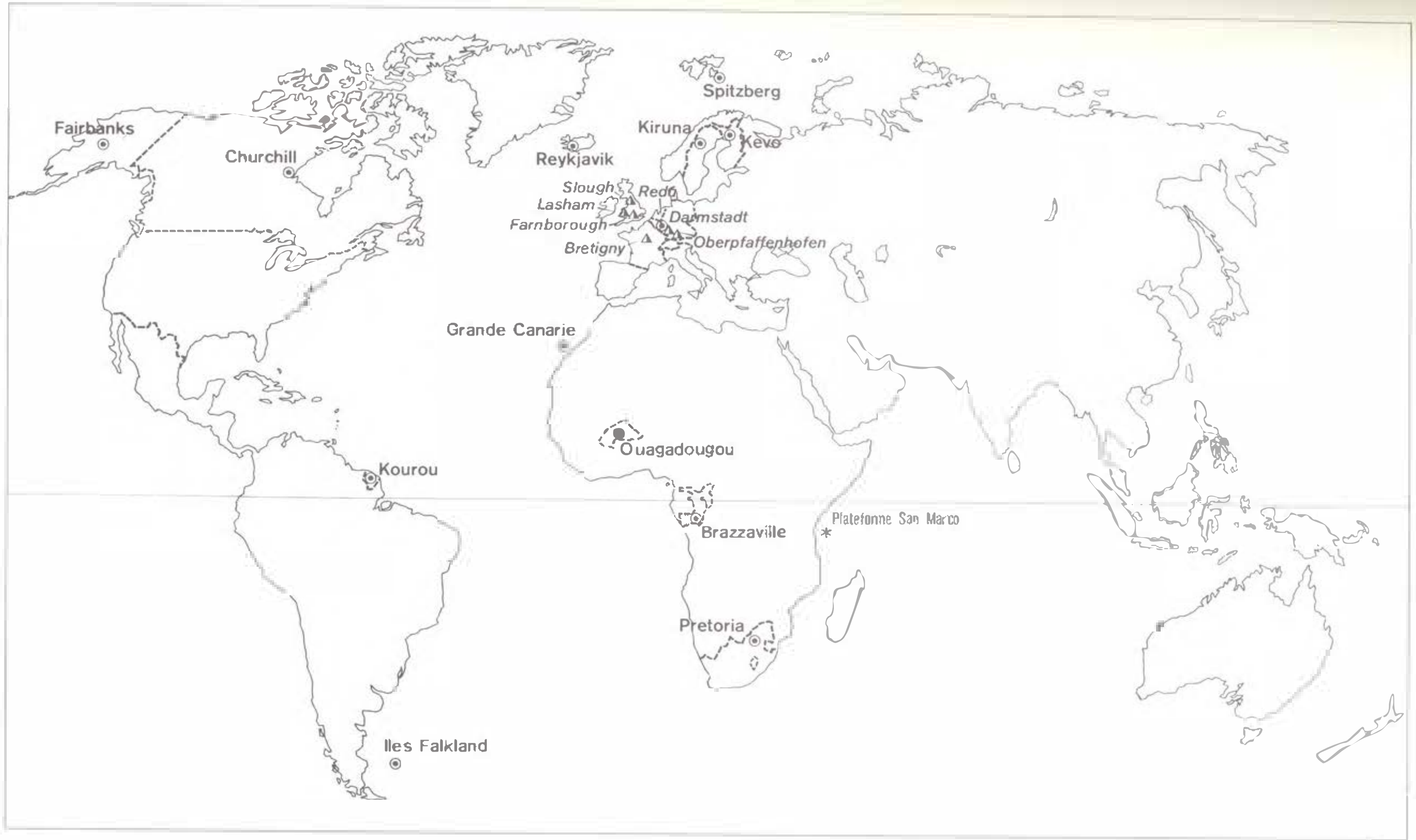
A) THE TELEMETRY, TELECOMMAND AND TRACKING STATIONS AND THE MONITORING CENTRES

1. Principal contractors

AEG-Telefunken	— Three transportable polar stations for telemetry and telecommand. — The Weilheim telemetry and telecommand station.
Siemens	— The Oberpfaffenhofen monitoring station.
Thomson-CSF	— The CNES telemetry and telecommand station. — The « Diane » tracking stations for CNES and ESRO. — The Symphonie satellite SHF monitoring station at Toulouse.

2. Telemetry systems

Intertechnique	— Simulators and synchronisers for the CNES and ESRO VHF telemetry stations. — Reception chains of the ESRO stations used for the GEOS, Meteosat and IUE synchronous satellites.
Montedel	— « Quick look » equipment for the ESRO telemetry stations.
SAT	— Reception and demodulation chains for the CNES and ESRO telemetry stations.
Siemens	— Telemetry receivers for the German polar stations. — The receiver for the Helios programme's station at Effelsberg.
Starec	— The telemetry receivers at Fortalezza (Brazil).



European control centres (▲) and networks (◉) of tracking stations for low-orbit satellites.

3. **Tracking systems**

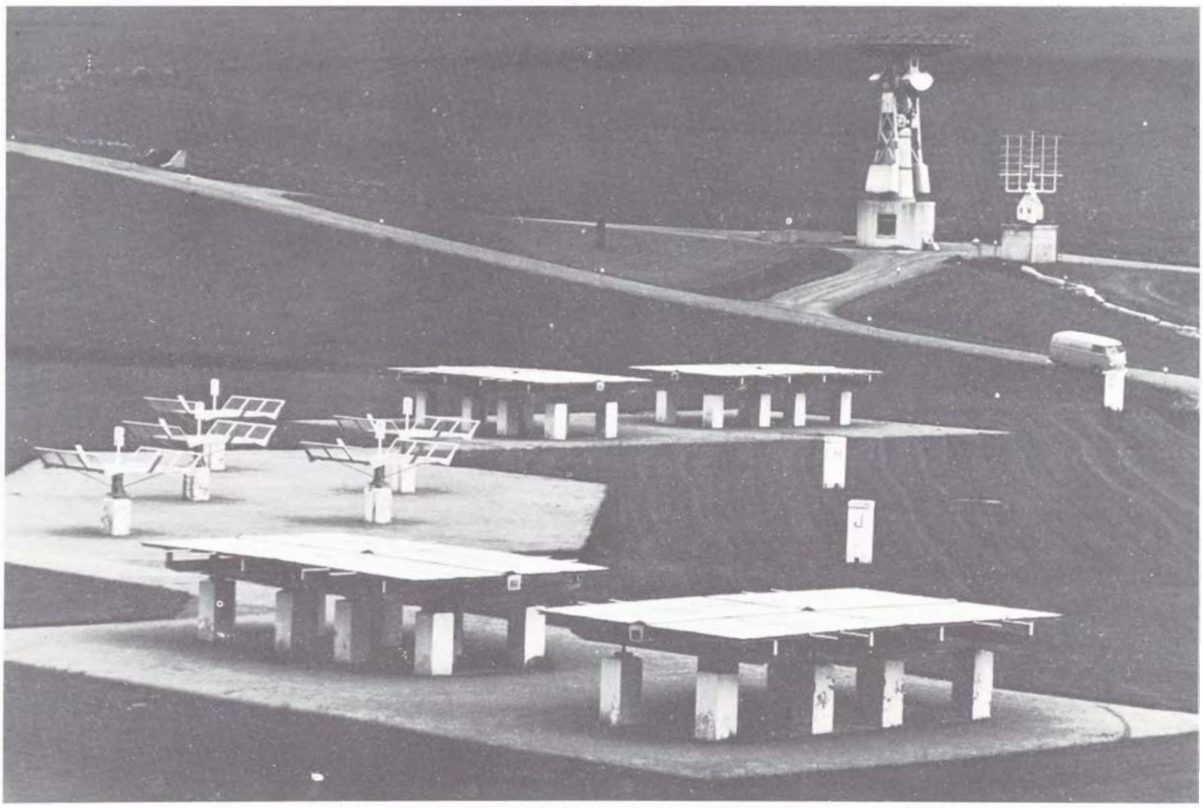
AEG-Telefunken	— The modulator for the Weilheim VHF interferometer.
Siemens	— Tracking receivers at the Weilheim station.

4. **Telecommand systems**

AEG-Telefunken	— The modulator for the Helios S-band telecommand station. — The modulator and encoder for the Weilheim VHF telemetry station.
Siemens	— Telecommand transmitters for the Weilheim station. — The telecommand transmitter and RF section of the telecommand antenna for the Helios project at Weilheim.
Thomson-CSF	— Telecommand transmitters and encoders for the CNES and ESRO networks.

5. **Antennae and antenna pointing mechanisms**

Elecma	— The CNES network's telemetry and telecommand antennae.
CGE	— The Kourou telemetry antennae.
Rhode-Schwarz	— The antennae and antenna mechanisms for the German polar stations.
Selenia	— The antennae and antenna pointing mechanisms for ESRO's metric-wave telemetry and telecommand stations.
Siemens	— The decimetric-wave antennae for ESRO's geostationary satellite stations.
Starec	— The interferometer antennae for the CNES and ESRO networks. — The Kourou telecommand antenna.



Interferometer of the ESRO station at Redu (Belgium).

B) THE INTELSAT STATIONS AND THE EXPERIMENTAL TELECOMMUNICATIONS STATIONS

1. Principal contractors

AEG-Telefunken	— The Raisting telecommunications and monitoring station for the Symphonie programme. — The Leeheim experimental station for the Sirio programme.
BTM	— The Lessive station.
Marconi	— The Goonhilly I extension. — The Goonhilly II and III stations, and the following Intelsat stations: Ascension Island, Bahrein, Hong Kong I and II, Trinidad, Barbados and Jamaica.
Siemens	— The three Raisting antennae.
STS (a consortium formed by SIT, Siemens, GTE and SIRTI)	— The third antenna at Fucino. — Two antennae at Balcarce (Argentina). — The Tanum antenna.
Telspace (a consortium formed by CGE and Thomson-CSF)	— The French SHF telecommunications station at Pleumeur Bodou for the Symphonie programme. — The French 11-14 GHz experimental station. — Pleumeur Bodou stations I, II and III. — The Intelsat stations in Martinique, Senegal, the Ivory Coast, Madagascar, Gabon, Cameroun, French Guiana and Réunion Island.

2. Reception systems

AEG-Telefunken	— The receivers, converters, demodulators and parametric amplifiers for the three Raisting antennae.
CGE	— The amplifiers for the Telspace stations.
GTE (as part of the STS consortium)	— The parametric amplifiers, receivers and demodulators for the Fucino, Balcarce (Argentina) and Tanum stations.
LCT	— The parametric amplifiers for the German SHF telecommunications and monitoring station at Raisting, for the Symphonie programme's SHF monitoring station at Toulouse, and for the Leeheim station in the Sirio programme.
SAT	— The reception chains for the Pleumeur Bodou and Martinique stations.
BTM	— The tracking receiver for the Lessive station. — The tracking receivers for the three Raisting antennae, for the Burum antenna and for the Intelsat station in the Republic of Zaire.

3. Transmission systems

Elecma	— The preamplifiers and local oscillators for the stations built by Telspace.
GTE	— The modulators and amplifiers for the Fucino, Balcarce and Tanum stations.

4. Antennae and antenna mechanisms

AEG-Telefunken	— The antenna mechanisms for the Symphonie tracking station at Weilheim.
Krupp	— The Raisting antenna. — The Leeheim antenna.
Starec	— The interferometer antennae for the CNES and ESRO network. — The telecommand antenna at Kourou.

ANNEX I

MILESTONES IN THE HISTORY OF ESRO AND ELDO

1959-1964: CREATION OF ESRO AND ELDO

April 1959	European cooperation in the realm of satellites is envisaged for the first time by Professor Eduardo Amaldi (Italy) and Professor Pierre Auger (France), both of whom had helped to create the first European scientific organisation, the European Nuclear Research Organisation (CERN).
Early 1960	The United Kingdom proposes the joint development of a European satellite launcher, the first stage of which would be the British « Blue Streak » military missile, whose development had just been agreed. This marked the beginning of discussions which led to the creation of ELDO.
June 1960	A European Space Research Study Group (ESRSG) is formed on the European level to consider an initial space research programme. This was the prelude to the birth of ESRO.
November 1960	An intergovernmental conference brings together representatives of Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom and creates a preliminary committee (COPERS) to investigate the possibilities of cooperating in the realm of space. COPERS undertakes to prepare a satellite space research programme, a related budget and a draft convention for an European organisation.
Early 1961	A conference between representatives of Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom, as well as representatives from four observer countries, is held at Strasbourg to discuss the European launcher project. The conference proposes to build a three-stage rocket whose first stage would be Britain's Blue Streak and the second stage French designed. This rocket would be launched from Woomera (Australia).
October 1961	Meeting in London at Lancaster House, representatives of Australia, Belgium. Denmark, France, Germany, Italy, the Netherlands, Spain and the United Kingdom, as well as from several observer countries, continue the Strasbourg discussions and decide that construction of the European rocket's third stage will be entrusted to Germany, the development of test satellites to Italy, the ground guidance station to Belgium and the telemetry station to the Netherlands. A sum of £ 70 million is earmarked for this initial programme, and it is further decided that the future organisation will investigate the possibility of developing other launchers as well.
30 April 1962	Seven countries—Australia, Belgium, France, Germany, Italy, the Netherlands and the United Kingdom—sign the Convention of the European Launcher Development Organisation (ELDO).
14 June 1962	Nine European countries—Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom (joined by Denmark a few months later)—sign the Convention for establishing a European Space Research organisation (ESRO). Norway, Austria and (later) Ireland are granted observer status.

29 February 1964 — The ELDO Convention becomes effective. The Organisation is required to develop a three-stage launcher—Europa-1. Belgium's participation in the programme represents 2.85 %, France's 23.93 %, Germany's 22.01 %, Italy's 9.78 %, the Netherland's 2.64 % and the United Kingdom's 38.79 %. Although Australia makes no contribution to the Organisation, it undertakes to place the Woomera range and all its facilities at the disposal of ELDO member countries. In June 1964 ELDO successfully launches the Europa-I rocket's Blue Streak first stage.

20 March 1964 — The ESRO Convention comes into force. The Organisation becomes responsible for a programme of scientific research and technology activities to the extent of 306 million accounting units (at the time, an accounting unit was equal to one US dollar), spread over an eight-year period from 1964 to 1971. This programme is to make use of both scientific satellites and sounding rockets. Each country's financial contribution is proportional to its GNP. From 1962 to 1970 the average annual percentage contributions were as follows: Belgium 4.01 %, Denmark 2.24 %, France 20.46 %, Germany 24.38 %, Italy 11.03 %, the Netherlands 4.29 %, Spain 1.77 %, Sweden 4.52 %, Switzerland 3.37 %, United Kingdom 23.93 %. ESRO launched its first sounding rocket in 1964.

June and October 1964 — At Woomera, ELDO successfully conducts the first two flight tests of the Europa-1 rocket's Blue Streak first stage surmounted by two dummy stages.

First steps: 1965-1967

January and April 1965 — A conference of the ELDO member states at ministerial level reassesses the cost of the initial programme and raises it to 400 MAU. Initial design studies for a more powerful launcher equipped with one or two cryogenic stages (ELDO-B) are submitted to the ministers. In April that year a fresh ministerial conference results in a request for a more detailed study of the cost and development schedule for a future launcher.

March 1965 — For the third time ELDO successfully flight-tests the Blue Streak first stage of the Europa-1 rocket.

April, June July 1966 — Following a British memorandum expressing concern about the increase in the cost of the Europa-1 rocket, a ministerial conference of the ELDO member countries holds three sessions in April, June and July 1966. In June 1966 the Conference decides to revise the member countries' financial contributions as follows: Belgium and the Netherlands to share 9 % (to be divided by mutual consent), France 25 %, Italy 12 %, Germany and the United Kingdom 27 % each. In July that year several decisions are taken. Beginning in January 1967 ELDO is to undertake a further programme. The Europa-1 rocket is to be equipped with fourth and fifth stages (a perigee-apogee system) and with a new guidance system. This more powerful rocket, Europa-2, would be capable of placing communications satellites weighing about 190 kg in earth-synchronous orbit and would be launched from Guiana. The budget allocation set by the conference for the Europa-1 and Europa-2 programmes was 626 MAU. The ELDO Secretariat was granted wider powers, notably in connection with the awarding of contracts to industry.

For the first time, furthermore, a resolution provided for the possibility of setting up a single European space agency to coordinate space activities in the realm of satellites and launchers. The Conference also created a Committee of Alternates (Comité des Suppléants) charged with preparing future ministerial conferences and submitting a coordinated space programme. In addition, the Conference invited the ESRO, ELDO and CETS (Conférence Européenne des Télécommunications par Satellite) Councils to set up a coordinating committee composed of representatives of the Secretariats of the three organisations.

July 1966 — The ESRO Council sets up a panel of experts chaired by Mr. J. H. Bannier (Netherlands) to analyse the Organisation's structure, procedures and working methods and recommend improvements.

May and November 1966 — Two successful launches of the Europa-1 rocket, with a first active stage and second and third dummy stages, are made from Woomera.

September 1966	Inauguration of ESRO's sounding rocket launch facility at Kiruna.
December 1966	The first European Space Conference (ESC) is held in Paris pursuant to the ESRO, ELDO and CETS coordinating committee's labours. The post of Secretary General to the Conference is created, with ESRO and ELDO taking over the Secretariat of the Conference. That same month, the ELDO Secretariat gives details of the planned internal reforms to a further Ministerial Conference.
April 1967	The ESRO Council examines the recommendations contained in the Bannier Report and decides to separate planning and policy functions from executive functions. ESRO's internal structure, particularly at directorate level, is modified. The European Space Operations Centre (ESOC) is set up at Darmstadt and groups together the Control Centre previously located at Noordwijk and the European Space Data Centre (ESDAC) already at Darmstadt.
July 1967	The European Space Conference (ESC) becomes an institution having its « headquarters » in Rome. Initial steps are taken to establish a coordinated European space policy, and a Programmes Consulting Committee is formed.
August and December 1967	Two launches of the Europa-I rocket, with active first and second stages and a dummy third stage, are only partly successful due to a second-stage malfunction.

1968-1970: The difficult years

March 1968	The Advisory Committee on Programmes set up by the ESC in Rome submits a proposed future space programme to the European governments. The Committee's report—known as the Causse Report after its chairman—suggests developing applications satellites which would culminate in a direct-viewing television satellite in 1980, preceded by several smaller experimental satellites. This satellite programme would be completed by a programme for developing cryogenic launchers.
April 1968	The ESRO member countries hesitate to continue to fund the programme for the TD-1 and TD-2 astronomical satellites, the costs of which have escalated considerably since the first estimates were made.
April 1968	The United Kingdom gives notification of its wish to withdraw from ELDO at the end of 1971 and is reticent about the scope of programmes proposed by the Causse Report.
May 1968	ESRO has its first scientific satellite, ESRO II, successfully launched by an American rocket from Vandenberg Base in California.
July, October, November 1968	A further ELDO Ministerial Conference holds three sessions to consider the problem posed by a further cost overrun on the ELDO programme, which can no longer be implemented within the budget limits set in 1966. In November the ELDO Secretariat suggests that certain test launches and the development of experimental satellites be scrubbed from the programme so that it can be kept within prescribed budget limits. Two member countries—the United Kingdom and Italy—express reserves on this.
October 1968	The member countries of ESRO (Italy excepted) decide to pursue development of the first of the two TD satellites as a special project. They also contemplate placing those of the TD-2 experiments which do not need to be pointed at the sun on a satellite similar to ESRO-II. This plan enables ESRO not to exceed the budget limit set in 1964.
November 1968	The first flight of the Europa-1 rocket with three active stages is only partly successful. The first two stages function properly but the third stage fails. The third European Space Conference meets in Bonn to consider the difficulties being experienced by Europe in its space activities. It is acquainted with a further report (the Spaey Report) containing proposals for a future programme, drafted by a committee formed at ELDO in October that year. The United Kingdom indicates for the first time that it would be interested in a communications satellite programme, and a final resolution is adopted entrusting its ultimate implementation to ESRO. ESRO is given a formal budget guarantee spread over three years (1969-71), with a firm ceiling of 172 MAU. The European countries reaffirm their desire to arrive at the creation of a single European Space Agency and entrust a committee of senior civil servants with the task of preparing a first draft Convention. Voiced for the first time is the concept of distinguishing in future between a minimum compulsory programme and a basic programme which would include both satellites and launchers.

March 1969	The ESRO Council decides to launch the second flight model of the ESRO-1 satellite and to develop an ESRO-IV satellite to carry those of the TD-2 satellite's experiments which are not pointed at the sun.
April 1969	The ELDO Ministerial Conference meeting in Paris decides to continue the development of Europa-2. The United Kingdom and Italy succeed in getting their contributions reduced, and Belgium, France, Germany and the Netherlands agree to fund larger shares of the programme, still within the ceiling figure of 626 MAU. Within the ELDO Secretariat, the Conference creates a new future programmes directorate to conduct design studies on a new Europa-3 launcher.
July 1969	A further launching of the Europa-3 rocket proves only partly successful.
October 1969	NASA Administrator Dr. Thomas O. Paine comes to Europe to inform the European countries of America's future post-Apollo programme and to invite them to participate in it.
May 1970	The ELDO Council selects the future Europa-3 rocket's configuration: a two-stage launcher, with a liquid oxygen/hydrogen second stage, capable of placing a 750 kg payload on a geostationary orbit. ELDO decides to conduct a conceptual study of a space tug, following the NASA invitation to participate in the post-Apollo programme.
June 1970	Another only partly successful launch of the Europa-2 rocket is made, with the first two stages functioning correctly and the third again experiencing a failure. This is the last launch to be made from the Australian facility at Woomera.
July 1970	The first session of the fourth European Space Conference is held in Brussels. Several resolutions are adopted by the European countries. They decide to initiate design studies on an experimental communications satellite, an air navigation satellite and a weather satellite for a total sum of 12.5 MAU. ELDO is to continue to develop Europa-2 and will pursue its studies relating to Europa-3 and the spage tug. A working group is instructed to continue with the task of drafting a convention for the future single space agency.
September 1970	Pursuant to the wish expressed by the Conference at Brussels, a delegation of ESC member countries led by Mr. Theo Lefevre, Belgium's minister of Scientific Planning, goes to the United States to investigate the possibilities of participating in the post-Apollo programme and procuring US launchers for the planned applications satellites.
October 1970	The United States undertakes to launch European applications satellites, even commercial ones, provided the Intelsat international accords are strictly observed.
November 1970	The second session of the fourth European Space Conference is held in a tense atmosphere. Belgium, France and Germany decide to go ahead with a space programme involving scientific satellites, applications satellites and launchers and invite their partners to state their positions.
December 1970	Belgium, Federal Germany and France vote a 1971 ELDO budget of 88 MAU.

1971-1973: Expansion of ESRO

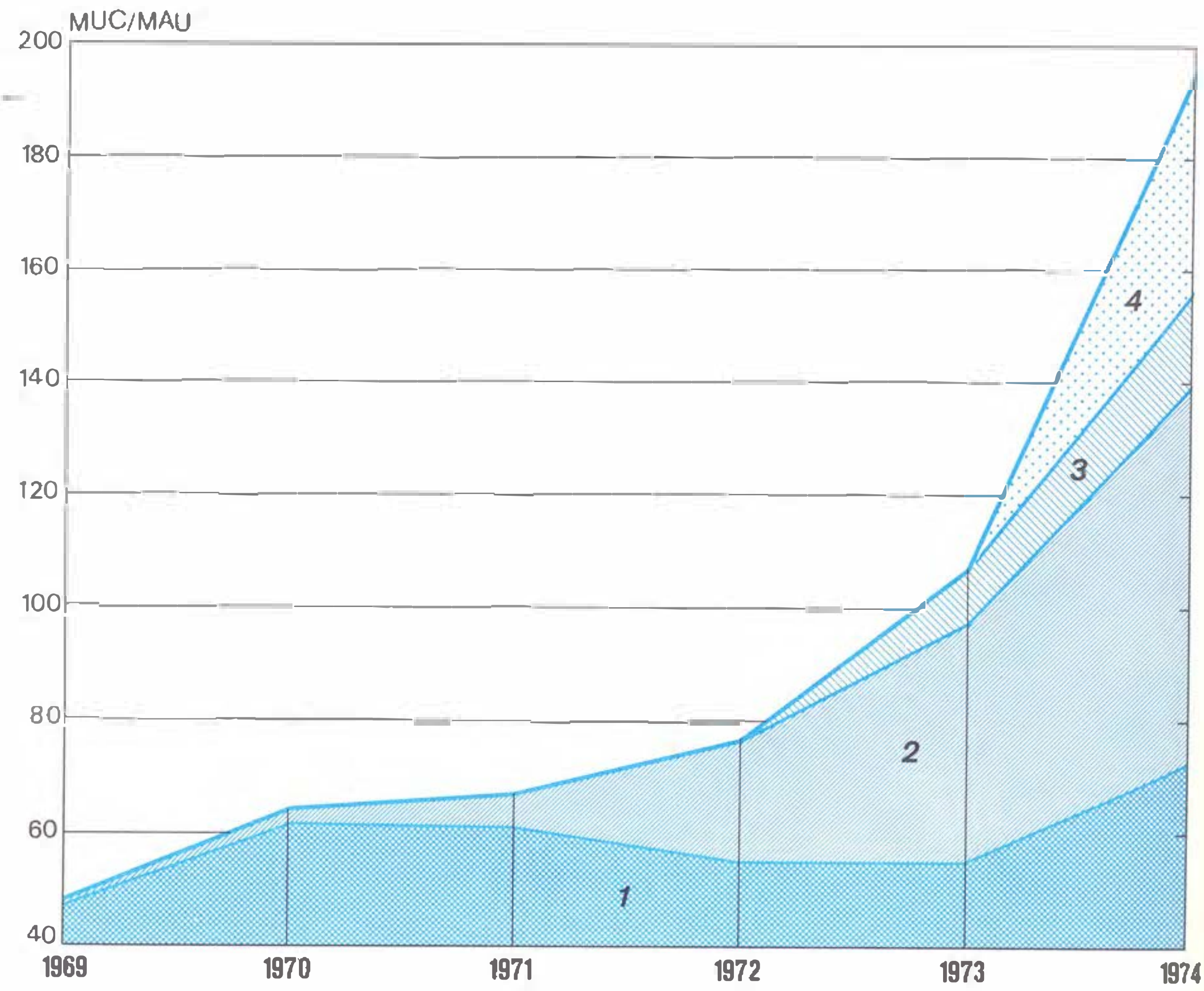
cancellation of ELDO programme, creation of ESA

February 1971	Another European mission goes to the United States to study participation in the post-Apollo programme.
July 1971	Meeting at Noordwijk, the ESRO Council outlines a scientific and applications satellite programme up to 1980, with corresponding budget estimates.
November 1971	Launched for the first time from the Kourou range in Guiana, the Europa-2 rocket explodes a few minutes after lift-off. An enquiry is opened to determine the causes of the failure.

December 1971	The ESRO Council makes a series of decisions relating to a long-term satellite programme. For the first time, the European countries make a distinction between compulsory activities within ESRO on basic and scientific programmes, and special programmes in which countries may participate on a voluntary basis. Provision is made for amending the Convention in order to institutionalise this new concept. The funds to be allocated to the scientific satellites programme are set at 27 MAU per annum, and a new applications satellites programme is expected to involve 70 MAU per year by 1974. This applications programme includes experimental communications satellites, culminating in an operational satellite by 1980, a geostationary meteorology satellite, and an air navigation satellite to be developed jointly with the United States. The European countries decide to give priority to future European launchers for launching their applications satellites providing their cost does not exceed that of the corresponding American launcher by more than 25 %. It is further decided that, under a special ESRO project, Sweden will take over management of the Kiruna sounding-rocket range from ESRO. The activities of the ESRIN research institute at Frascati (Italy) are abandoned. The location is to house ESRO's Space Documentation Centre. A 283 MAU budget is granted to ESRO from 1972 to 1974.
February, June 1972	ELDO undertakes an internal reorganisation. The board of enquiry's report on the failure of the Europa-2 is made public and states that this rocket is unsuitable for flight in its existing configuration. The report recommends a number of steps for remedying the situation.
June 1972	NASA proposes that the European countries develop a manned orbital laboratory instead of a space tug as part of the post-Apollo programme. The United States promises to launch the operational communications satellites which ESRO plans to build around 1980.
December 1972	France proposes that she and her European partners build a rocket a little less costly than the Europa-3—the L III S launcher—which would also be capable of placing 750 kg satellites in synchronous orbit. The L III S rocket would be built by an industrial consortium but the programme would be managed by France.
December 1972	The fifth European Space Conference meeting in Brussels decides to create a new organisation called the European Space Agency (ESA), based on ESRO and ELDO, and to rationalise national and European programmes. The Europa-3 launcher project is abandoned. A *de principio* decision is taken to develop the L III S rocket and the Spacelab orbital laboratory.
April 1973	It is decided to abandon development of the Europa-2 rocket and to liquidate the programme. With no further programmes in hand, ELDO is now condemned to disappear.
July 1973	Two further sessions of the fifth European Space Conference on 12 and 31 July result in a decision to initiate three new programmes for a total of more than 800 MAU under ESRO supervision and, from April 1974 onwards, under the supervision of the future European Space Agency which is to succeed ESRO. Ariane (the L III S rocket) will be built under French project management but with the participation of the other European countries under ESRO supervision. In addition, ESRO will develop the Spacelab manned laboratory for a sum of 308 MAU, and also a new application satellite—the Marots maritime satellite.
September 1973	The agreement under which Europe is to build the Spacelab orbital laboratory for launching by the American Space Shuttle is signed in Washington. The arrangements relating to the Marots and Ariane programmes are signed between the European countries shortly afterwards.

ANNEXE II

EUROPEAN SPACE BUDGETS



ESRO *budget: 1. basic activities and scientific programme (including* TD-1A *special project); 2. applications programmes; 3. Spacelab; 4. Ariane.*

GEOGRAPHICAL DISTRIBUTION OF ESRO CONTRACTS
(in thousands of accounting units)

Distribution from January 1972 to 31 March 1974

	Belgium	Denmark	France	Germany	Nether-lands	Italy	Spain	Sweden	Swit-zerland	United Kingdom	Total Member States	Total non-Member States	General Total
Non-weighted total	7 682	5 025	58456	61 768	11 468	36 783	2 891	6 931	5 499	47 806	244 309	23 465	267 774
Weighted total	7 482	3 781	56 118	58 539	5 546	36 448	2 104	6 871	4 808	45 117	226 814	22476	249 290
Ideal total	8 868	5 035	50006	59 316	5 962	32 688	2 735	10 349	7 244	44456			
Ratio weighted total / ideal total	0.84	0.75	1.12	0.99	0.93	1.12	0.77	0.66	0.66	1.01			

Cumulative breakdown from 1963 to 31 March 1974

	Belgium	Denmark	France	Germany	Nether-lands	Italy	Spain	Sweden	Swit-zerland	United Kingdom	Total Member States	Total non-Member States	General Total
Non-weighted total	18 638	9 616	119 348	106 141	26 991	55 806	6 131	18 419	10 558	86 586	458 234	78162	536 396
Weighted total	17 404	7 033	112 663	98 379	12 628	53 002	5 202	15 259	9 467	81 070	412 107	68 903	481 010
Ideal total	16 227	9 108	88 283	104 407	14 109	53 664	6 267	18 734	13 473	87 678			
Ratio weighted total / ideal total	1.07	0.77	1.28	0.94	0.90	0.99	0.83	0.81	0.70	0.92			

ELDO *budget: dotted line, payment appropriations (concept not clearly defined during the Organisation's early years); solid line, contract authority.*

ANNEX III

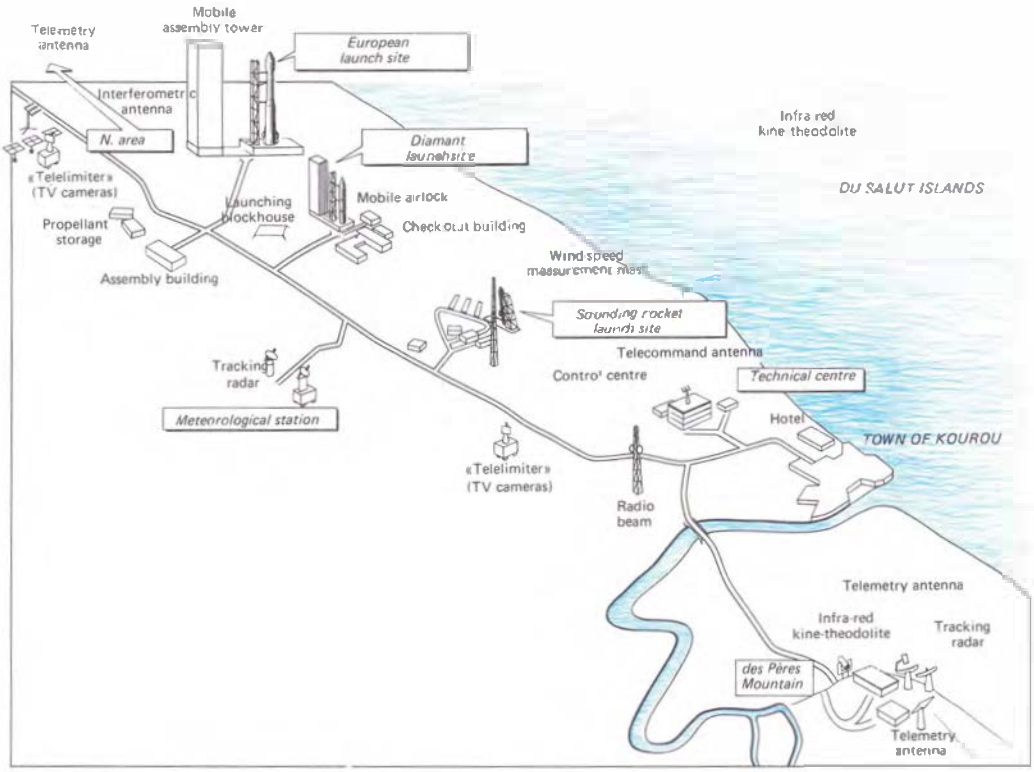
LAUNCH SITES

GUIANA LAUNCH FACILITY

Located 5° 15' N latitude and 52° 44' W longitude, at Kourou, the Guiana Space Centre became operational on 9 April 1968 when the first Véronique sounding rocket was launched. Launches can be made within a 130° sector, both in northerly and easterly directions, which means that satellites can be placed in equatorial or polar orbits. Rockets launched at an angle of 120° do not fly over inhabited land for 3 000 kilometres. Meteorological conditions are highly favourable from July to November, though launches can be made all the year round. Winds blow gently and steadily and Kourou is situated outside the region of tropical cyclones.

There are three launch sites on the firing range: for sounding rockets, for Diamant launches and for European rockets.

The facility includes an operations and command centre, plus the necessary measurement and control equipment (for tracking and trajectory plotting, telemetry data links, and communications and flight safety).



The Kourou launching base, Guiana.

Launch Sites

The *sounding rocket launch site* includes three launching ramps for solid rockets, a launch pad for the Véronique and Vesta liquid-fuelled rockets, a 100-metre high mast for measuring wind velocity, two rocket preparation halls and a blockhouse. The coordination of prelaunch operations, firing commands and the preparation of small or medium size nosecones, all take place in this blockhouse.

The *Diamant launch site* is located about 4 km north of the sounding rocket launch site. This is where Diamant-B rocket launches were made and where the Diamant BP-4 rockets will be fired. It includes a rocket stage checkout hall, an assembly tower by means of which the rocket stages are assembled vertically over the launch pad, and a launching blockhouse. Shortly before launch, the mobile assembly tower moves 50 metres away on rails to clear the rocket for launching.

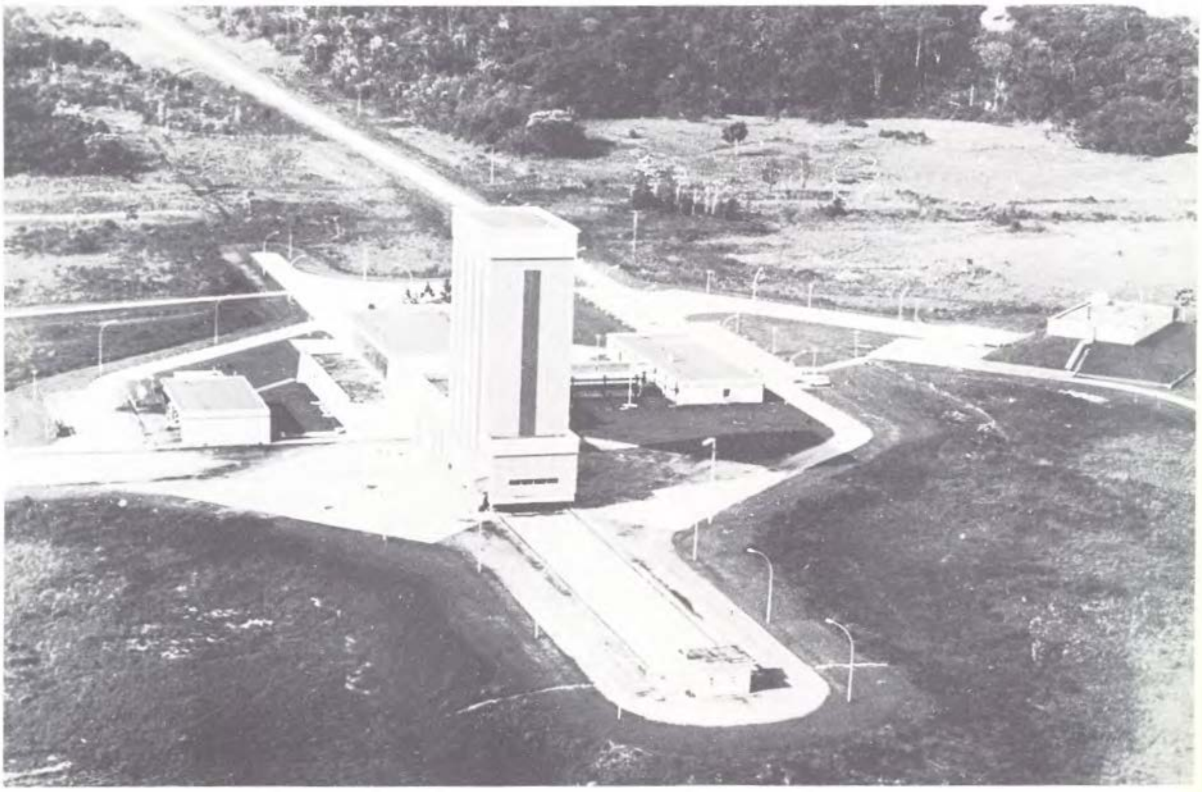
The *European launch site*, located 2 km away, was used to launch the Europa-2 rocket in 1971 and will probably be modified to enable it to be used to launch the Ariane rocket. It includes an assembly area where the stages are checked out and, 1 200 metres away, the launching blockhouse and a 45-metre high mobile assembly tower. Weighing 800 tons, this tower encloses the launch pad and the umbilical ramp. One kilometre away from the launch pad is the UDMH and nitrogen peroxide storage facility. An oxygen plant has been set up near the port of Kourou.

Operations Centre

The operations centre comprises a control centre, a photographic laboratory, a payload preparation hall, a telecommunications centre, computers and office space.

The operations centre coordinates the preparation and execution of launch operations and the observation data exploitation phase until the data is turned over to the range users. For each launch, the firing range designates a Director of Operations and the users of the Operations Centre a Mission Chief. All prelaunch and meteorological data, and subsequent flight data, are centralized in a control room.

Close to the Operations Centre is the payload preparation hall, together with laboratories and a clean room for preparing the satellites.



Diamant launch site at Guiana Space Centre.

Measuring equipment

The Guiana Space Centre has extensive ground facilities for receiving and processing data on the rocket's flight path and behaviour during and after launch:

Trajectory plotting means: A high precision radar about 20 km away on Montagne des Pères mountain, along with two radars on the firing range near the weather station, provide real-time elevation, azimuth and range data. A radar similar to the one on Montagne des Pères has been installed at Cayenne, about 60 km away. Two infrared tracking cine-theodolites about 20 km from the launch pads supply elevation and azimuth data. Motion picture cameras record the rocket's trajectory over the first few hundred metres, and an interferometric station is used to localize satellites on their orbits.

Computer and display equipment: The radars and cine-theodolites transmit the real-time data to several computers. This data is processed by the computers, which then display the rocket's trajectory on the plotting tables in the operations room.

Compressed-time processing equipment: Automatic machines very quickly develop the black-and-white and colour films exposed during the launch, and another machine automatically analyses each frame for elevation and azimuth readings and to establish the instant of exposure. The computers are also used in compressed-time to determine the trajectory more accurately.

Telemetry equipment: Two telemetry stations are located on Montagne des Pères (employing two receiving units operating in the 215-260 MHz and 136-138 MHz bands with two 26 dB and 22 dB gain antennae). Another station is located at Cayenne (with an antenna operating in the 215-260 MHz band with a gain of 18 dB), and a fourth station is provided in an area north of the launch pads (using a 21 dB gain antenna operating on 136-138 MHz). Two downrange stations are also available at Fortaleza (Brazil), 2 000 km from Kourou, and Brazzaville (Zaire), respectively.

Communications

Communication between the different sites is by cable or microwave link. Radio communications are used between mobile locations. Operations personnel within the centre communicate by telephone, intercom, television or teletransmission. This essential control equipment is hooked up to operational consoles located beside the different facilities and inside the control rooms.

Safety measures

The Guiana Space Centre is responsible for safeguarding life and property against risks incurred as a result of operations taking place on the launch facility. Strict regulations have been drawn up and must be observed by all users and personnel on the launch facility. During the initial part of a rocket's flight, television cameras (or « telelimiters ») provide a check on the TV screens that the rocket has kept within the preset boundary limits. During the subsequent flight phases, the tracking system first shows the rocket's position (the horizontal projection of the trajectory and the horizontal distance of the rocket from the confines of the areas to be protected), then its point of impact. Should the rocket become dangerous, it can be destroyed by a remote-control signal (405-450 MHz).

Logistic facilities and Kourou town

The Guiana Space Centre can be reached by air (Rochambeau airport at Cayenne can handle all currently existing jets, including the Boeing 747) or by sea (the three ports of Cayenne, Saint Laurent and Kourou can handle 3 000-ton vessels).

The town of Kourou is an urban centre with a population of several thousand residing in villas and blocks of flats. It has a shopping centre, a teaching centre and two modern hotels with 140 beds each.

THE SAN MARCO BASE

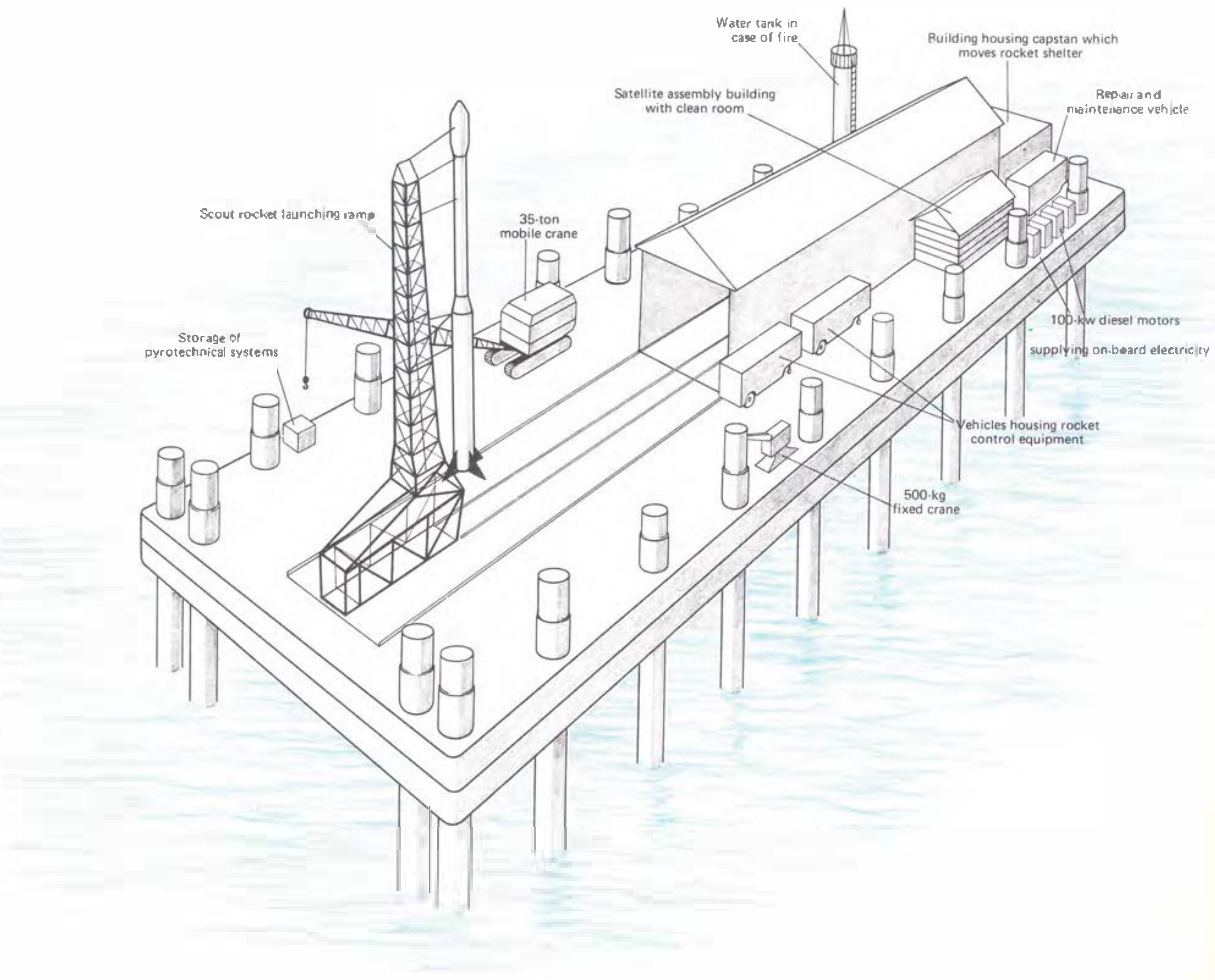
Lying 2 degrees S latitude by 40 degrees E longitude, San Marco base consists of two floating platforms in Ngwana Bay along the Kenyan coast. These two platforms are located about 500 metres from each other. One of them, the San Marco platform, is used to launch American Scout rockets; the other, the Santa Rita platform, carries the control centre and the telemetry and trajectory plotting equipment.

The idea of a floating launch facility was born in 1961 at the Aerospace Research Centre (ARC) in Rome. Both platforms are converted former offshore oil-rigs. Weighing 3 000 tons, the San Marco platform is 90 × 27 metres and is supported above water by 20 columns resting on the seabed. The Santa Rica platform weighs approximately 1 000 tons and is shaped roughly like an isosceles triangle measuring 34 metres along its base and 38 metres along each side. This platform is supported above water by three columns.

The launch azimuth angle can vary between 80 and 130 degrees, though allowance must be made for the Seychelles and Maldive Islands and the Chagos archipelago in the Indian Ocean. Launches can be made at any time of the year except July. Responsibility for maintaining and running the base is assumed by the ARC.

Launch Sites

The San Marco platform is equiped with a launching ramp for Scout rockets and another ramp for American Nike-Apache and Nike-Tomahawk sounding rockets. Sounding rockets are assembled inside a special shelter.



San Marco platform of the Italian mobile launch base.

ANNEX IV

THE MAIN INDUSTRIAL COMPANIES

Having presented a broad picture of the capabilities of European industrial firms, it was felt desirable to append additional information on most of those companies mentioned in previous chapters which produce onboard equipment for satellites, sounding rockets and sometimes balloons.

We have therefore prepared a synopsis on each company, indicating its importance and certain space skills which could not be covered by a separate chapter. These include, for example, participation in developing certain scientific instruments, and study contracts under way. Also listed are the company's test facilities and principal installations.

The list of companies is by no means exhaustive. It takes into account each country's industrial importance and does not include companies which manufacture ground equipment almost exclusively, companies which have been awarded only study contracts, or companies which manufacture only certain subsystems or equipments of lesser importance.

The information contained in this Annex was supplied by the companies themselves and we have been unable to verify it all. Some of the synopses will be found to be incomplete. We have merely corrected some errors in the replies and added a few details in certain cases on the basis of documents attached to the replies. Equally, we have deleted certain details, such as claims to membership of industrial consortia in cases where the company concerned was only a subcontractor of a member company of these consortia.

Further details can readily be obtained, however, by consulting a much more exhaustive study which was carried out by ESRO in 1970-71 and brought up to date in 1971-72, « European Activities in Space Technology », an inventory prepared by the Technical and Industrial Policy Division of ESRO (Volume I - 1970-71; Volume II - 1971-72, ESRO SP-91).

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AERITALIA SPA

Italy

• **Associations:** Aeritalia has concentrated Fiat's Aviation Division, Aerfer (Finmeccanica) at Pomigliano d'Arco, and Salmoiraghi at Nerviano. Aviation activities were merged on 31 December 1971, space activities on 1st January 1973.

• **Personnel:** 8 810 employees including 2 540 engineers and technicians

civil space sector: 190 employees including 120 engineers and technicians

• **Turnover**

1971: lire 75 300 million

1972: lire 90 300 million including 800 million for the civil space sector

• **A member of the MESH consortium,** succeeding Fiat, a member of the international consortium formed by the US Lockheed Aircraft for the Intelsat-V satellites, a member of the consortium set up by TRW Systems, the US company, in response to a NATO request for proposals on third-generation communications satellites

• **Test facilities:**

— laboratories and workshops	3 used for the manufacture and assembly of electronic subsystems; 3 for satellite and missile integration and testing
— clean rooms	Turin: one for satellite thermal control (1969) one for onboard electronic systems (1968) Nerviano: 2 for electronic systems and inertial systems (1970) Pomigliano d'Arco: one, used for integration operations (1968)
— vacuum chambers	one of 12 m^3 capacity (10^{-11} mm Hg)
— simulation chambers	one 17.2 m^3 (10^{-7} mm Hg) chamber at Turin, equipped with infrared devices
— vibrators	one 3.4 kN vibrator at Turin
— balancing tables	one EU.3 microbalancing table at Turin
— other facilities	simulators for studying satellite shroud and heat shields separation shock machines, environmental chambers, antenna testing equipment

• **Total sum invested** in civil space test facilities: lire 1 500 million

• **For further information please contact**

Dr. Ing. Giovanni Cesarani
Aeritalia SPA
Corso Marche 41
10136 Turin

Tel.: 33 21 33;
Telex: AERITOR 21076

AEG-TELEFUNKEN

Germany

AEG-Telefunken
AEG-Hochhaus
6000 Frankfurt 70

Tel.: 0611 6011
Telex: 411076

• **Personnel:** 166 700 employees

civil space sector: 550 employees including 440 engineers and technicians

• **Turnover**

1971: DM 10 042 million including 42 million for the civil space sector

1972: DM 55 million for the civil space sector

• **A member of the CIFAS consortium** for the Franco-German Symphonie satellite; several sub-contracts from the Hugues Company for the Intelsat-IV satellites

• **Scientific instruments:** in connection with ESRO satellites, has helped to develop the solar wind measuring instrument on HEOS-A2 on behalf of the Max Planck Institute (MPI) at Garching, and the gamma-ray detector on the TD-1A on behalf of the Centre d'études nucléaires at Saclay, the Physics Institute of Milan and the MPI at Garching. It is also developing the telescope of the scientific payload on ESRO's COS-B satellite

• **Test facilities**

— laboratories and workshops	several for satellite electronics, solar generators and other power sources, telemetry and command systems, satellite antennae
— clean rooms	one in the 100 000 class at Backnang (1969) for satellite electronics 2 (1971 and 1972) in Hamburg for solar generators and power sources 2 (1965 and 1972) at Ulm for satellite electronics
— vacuum chambers	4 with capacities of 1 m^3, 0.8 m^3, 0.4 m^3 and 0.4 m^3 respectively; one of the 0.4 m^3 chambers can be equipped with a solar simulator one 23-litre vacuum bell
— simulation chambers	2 non evacuated (140 and 18 m^3); one of 17 m^3 (vacuum, 3 torr)
— vibrators	3 C 10; one C 50; one C 21; 2 C 60; one C 30; one Bruel & Kjaer 4802-4818
— balancing tables	2, for determining centres of gravity and moments of inertia
— other facilities	solar simulator, jolting tables, magnetic field measuring equipment, centrifuges, climatic chambers

• **For further information please contact**

Mr. Börner
AEG
Fachbereich Weitverkehr und Kabeltechnik
Fachgebiet Raumfahrt
Gerberstrasse 34
715 Backnang *Tel.: (7191) 891 506*

Mr. J. Emser
AEG
Fachbereich Hochfrequenztechnik
Fachgebiet Bewegliche Stationen
Elisabethenstrasse 3
79 Ulm *Tel.: (731) 192635*

Dr. E. Schmidt
AEG
Fachbereich Schiffbau Flugwesen Sondertechnik
Abt. V224, Ramfahrttechnik und Neue Technologien
Industriestreasse 29
2 Wedel *Tel.: (4103) 700 1*

BELL TELEPHONE MANUFACTURING COMPANY SA (BTM) — **Belgium**

Line and Radio Transmission Division
Military and Aerospace Group
162 A, Jan van Rijswjcklaan *Tel.: (03) 38 98 90*
2020 Antwerpen *Telex: Belltel Antwerpen 31 369*

• **Associations:** part of the ITT (International Telephone and Telegraph) group

• **Personnel:** 14 700 employees including 1 500 engineers and technicians
civil space sector: 56 employees including 34 engineers and technicians

• **Turnover**

1971: $ 180 million including 0.8 for the civil space sector
1972: $ 220 million including 1.2 for the civil space sector

• **Test facilities**

— workshops, laboratories	one, for conceptual design work
— clean rooms	one of class 100 (1965)
— vacuum chambers	one of 125-litre capacity (10^{-8} torr)
— vibrators	one Ling rated at 6.6 kN
— other facilities	environmental chambers, shock machines, etc.

• **Total sum invested** for civil space test facilities: $ 325,000

• **For further information please contact**

M. X. Chaintrain
Manager, Military and Aerospace
Bell Telephone Manufacturing Company
7, Electronikalaan
B 2610 Wilrijk *Tel.: (03) 28 1111*

BRISTOL AEROJET (BAJ) **United Kingdom**

• **Personnel:** 620 employees including 165 engineers and technicians

civil space sector: 15 engineers and technicians

• **Turnover**

1971: £ 2.4 million including 0.325 for the civil space sector
1972: £ 2.4 million including 0.330 for the civil space sector

• **For further information please contact**

Mr. A.C. Johnson (Chief Engineer)
Bristol Aerojet Ltd.
Banwell, Weston-super-Mare *Tel.: Banwell 2251, ext. 7*
Somerset *Telex: 44 259*

BRITISH AIRCRAFT CORPORATION LTD. (BAC) **United Kingdom**

• **Associations:** since December 1972, BAC Ltd. has been owned equally by General Electric Company Ltd. and Vickers Ltd.

• **Personnel:** 36 000 employees

civil space sector: 480 employees including 303 engineers and technicians

• **Turnover for the civil space sector**

1971: £ 3.83 million
1972: £ 2.5 million

• **A member of the STAR consortium** and the CESAR consortium for ESRO satellites; helped in the conceptual design of the Intelsat-II satellite and was the Hughes Company's main foreign contractor on the Intelsat-IV satellites; was prime contractor for the British Ariel-3 and Ariel-4 satellites

• **Scientific instrumentation:** developed the micrometeorite detector for Britain's X-3 satellite on behalf of University of Birmingham, the X-ray spectrometer and the EHT generator for Britain's Ariel-1 satellite on behalf of University College (London), the ozone density measuring instrument on Ariel-2 for the Meteorological Office, and instruments for measuring electron density and temperature for the Petrel sounding rockets on behalf of University of Birmingham

• **Test facilities**

— workshops, laboratories	a satellite assembly hall with 2 sections measuring 604.8 and 331.2 m²; several laboratories
— clean rooms	2, measuring 52.56 and 19.44 m² (class 100,000), since 1967 and 1969; one class 2 area (1969)
— vacuum chambers	2 of 1 m³ and 1.06 m³ (each of 8 torr) since 1960 one of 0.95 m³ (10^{-6} torr) since 1969 2 vacuum bells (10^{-6} torr) since 1969

— vibrators	2 Ling Altec 330 (17.8 and 13.3 kN; 1966) one Ling Altec 1005 (4.4 kN; 1966) one Ling Altec 335 (46.7 kN; 1967) one Ling Altec 340 (97.8 kN; 1970)
— balancing tables	2 Carl Schenk tables (1968 and 1969)
— other facilities	centrifuges, computer facilities, environmental chambers

• **Total sum invested** in civil space test facilities: over £ one million (including computers)

• **For further information please contact**

Mr. D. O. Fraser
Marketing Manager
British Aircraft Corporation Ltd.
Electronic & Space Systems Group
G.P.O. Box 77
Filton House
Bristol BS99 7 AR
Tel.: (272) 69 38 31, ext. 768

CHRISTIAN ROVSING A/S — Denmark

• **Personnel:** 100 employees including 50 engineers and technicians
civil space sector: 25 employees including 20 engineers and technicians

• **For further information please contact**

Mr. Alex Hvidfeldt
Christian Rovsing A/S
46 B Marielundvej
2730 Herlev
Tel.: 91 88 33
Telex: 27272 ROVSNG DK

COMPAGNIA GENERALE DI ELETTRICITA (CGE-FIAR) — Italy

• **Personnel:** 1 000 employees including 250 engineers and technicians
civil space sector: 80 employees including 60 engineers and technicians

• **Turnover**

1971: $ 28 million including 1.5 for the civil space sector
1972: $ 30 million including 2.5 for the civil space sector

• **A member of the STAR consortium** for ESRO satellites

• **Scientific instrumentation:** developed the electronic subsystems for the gamma-ray detector on ESRO's TD-1A satellite, on behalf of the Physics Institute of the University of Milan

• **Test facilities**

— workshops, laboratories	for developing electronic subsystems
— clean rooms	one (1969)
— vacuum chambers	one of 0.1 m^3 capacity (1969)
— simulation chambers	one of 0.6 m^3 capacity (1970)
— vibrators	one rated at 550 kgf (1966) one rated at 3 500 kgf (1969)
— other facilities	environmental chambers; an electrical and mechanical measurement laboratory

• **Total sum invested** for civil space test facilities: about $ 500,000

• **For further information please contact**

M. G. Pizzi
CGE-FIAR
Divizione Elettronica Professionale
Via G.B. Grassi 93
20157 Milano
Tel.: 35 70 541; 35 70 841
Telex: 31 295 FIARADIO

COMPAGNIA INDUSTRIALE AEROSPAZIALE (CIA) **Italy**

• **Associations:** formed in 1965, the CIA's shareholders are CGE Fiar, Fiat Finmeccanica, Montedel, Selenia and Snia Viscosa, who are developing Italy's Sirio satellite.

• **Personnel** active in the civil space sector: 70 employees including 45 engineers and technicians

• **Turnover**

1971: lire 3 800 million
1972: lire 4 200 million

• **Test facilities**

— workshops, laboratories	a satellite integration and test facility
— clean rooms	one of class 100 000 (1969)
— simulation chambers	one of 50 m³ capacity (1973), fitted with infrared equipment
— balancing tables	a Schenck table for measuring moments of inertia (1969) a Schenck table for determining centre of gravity locations (1969) a Schenck spin table (1969)
— other facilities	a 3-axis motion simulator used in the design and testing of satellite attitude control systems (1970) equipment for testing auxiliary propulsion subsystems (1973)

• **Total sum invested** for civil space test facilities: lire 1 650 million

• **For further information please contact**

M. G. Barresi
CIA
23, Viale di Villa Grazioli *Tel.: 581192; 851371; 841544*
Roma 00198 *Telex: 61 295 CIASPA*

CONSTRUCCIONES AERONAUTICAS SA (CASA) **Spain**

Rey Francisco, 4
Madrid 8
Apartado 193 *Tel.: 247 24 00*

• **Associations:** in 1972 Construcciones Aeronauticas absorbed Hispano Aviacion SA and Empresa Nacional de Motores Aviacion SA

• **Personnel:** 6 260 employees including 300 engineers and technicians
civil space sector: 60 employees including 46 engineers and technicians

• **Turnover**

1971: pesetas 2 500 million including 36 for civil space sector
1972: pesetas 2 500 million including 39.5 for civil space sector

• **Scientific instrumentation:** helped to develop instruments for various Spanish experiments on American Nike and French Centaure sounding rockets, particularly for the emission of artificial sodium and TMA (trimethyl aluminium) clouds

• **Test facilities**

— workshops, laboratories	for satellite structures and thermal control systems
— clean rooms	one for producing electronic equipment (1972) one for satellite integration (1972)

• **Total sum invested** for civil space test facilities: pesetas 12 million in 1972 and pesetas 25 million in 1973

• **For further information please contact**

M. Y. Caballero
Construcciones Aeronauticas
Division, Espacial y eletronica
Factoria de Getafe *Tel.: 2327358*
Getafe-Madrid *Telex: 27418*

CONTRAVES AG — **Switzerland**

- **Personnel:** 1 700 employees including 765 engineers and technicians
civil space sector: 50 employees including 40 engineers and technicians

- **A member of the STAR consortium** formed for ESRO satellites; a member of the Lockheed international consortium for the future Intelsat-V satellites

- **Scientific instrumentation:** Contraves is scheduled to develop the University of Bern's mass spectrometer for the GEOS satellite

- **Test facilities**

— workshops, laboratories	2
— clean rooms	2 (1968 - 1970)
— vacuum chambers	one 1 m^3 chamber
— vibrators	one Pye Ling type 340, one Pye Ling type V 1001

- **For further information please contact**

Mr. N. Schliep
Dept. ETW
Contraves A.G.
Schaffhauser Strasse 580
CH 8052 Zurich
Tel.: (01) 48 72 11, ext. 826

CROUZET — **France**

- **Personnel:** 4 110 employees (excluding subsidiaries) including 778 engineers and technicians
civil space sector: 80 employees including 50 engineers and technicians

- **Turnover** (excluding subsidiaries)

1971: F 228.3 million including 4.94 for the civil space sector
1972: F 265 million including 10 for the civil space sector

- **Scientific instrumentation:** helped to develop the Atlas camera and associated console for the Laboratoire d'Astronomie Spatiale (LAS) at Marseille (an experiment on board the US Skylab orbiting laboratory); particle counting modules for the Signe and Gémeaux experiments designed by the Centre d'étude spatiale des rayonnements (Toulouse) carried on board the Soviet Cosmos satellites; and opto-mechanical instruments for studying UV dispersion, designed by the LAS (Marseille) on board the French D-2B satellite

- **Test facilities**

— workshops, laboratories	several electronics design, mechanical engineering and electronic production laboratories
— clean rooms	one class 10 000 room (1971) one class 100 room (laminar-flow facilities) (1971)
— vacuum chambers	one 6-litre (10^{-7} torr) thermal chamber
— vibrators	one Pye Ling 300
— other facilities	a shock machine, a centrifuge, environmental chambers

- **For further information please contact**

M. F. Théveny
Chef du Département Spatial Engins
Crouzet, Division Aérospatiale
Route d'Alixan
BP 138
26010 Valence
Tel.: (75) 42 91 55; (75) 42 91 44

DBA - DIVISION AIR EQUIPMENT

France

• **Personnel:** 1 953 employees, including 461 engineers and technicians

• **Turnover**

1971: F 139.5 million including 116 200 for the civil space sector
1972: F 160.3 million including 420 000 for the civil space sector

• **Tests facilities**

— clean rooms	one class 10,000 room one laminar-flow hood of class 100 (1967)
— vibrators	one (1968)
— other facilities	one helium leakage detector (10^{-10} std cm³/sec.)

• **For further information please contact**

M. F. d'Arcangues
DBA — Division Air Equipement
18, rue Basly
92601 Asnières
Tel.: 793 45 80
Telex: Airquip 62124

DORNIER SYSTEM GmbH

Germany

• **Personnel:** 800 employees including 700 engineers and technicians
civil space sector: 390 employees including 300 engineers and technicians

• **Turnover**

1971 and 1972: DM 45 million for the civil space sector

• **A member of the STAR consortium**

• **Scientific instrumentation:** has helped to develop the UV spectrometer and the ion and electron energy measuring instrument for the Aeros satellite, on behalf of the Arbeitsgemeinschaft für Physikalische Weltraumforschung at Freiburg; is developing instruments for measuring zodiacal light and magnetic fields and the telescope for Germany's Helios solar probes; is participating in the development of the particle detector and the electron and proton spectrometer for ESRO's GEOS satellite, on behalf of the University of Bern and the Max Planck Institute (MPI) at Garching and the MPI at Lindau

• **Test facilities**

— Laboratories and workshops	several
— clean rooms	Two 105 m² rooms (class 100) since 1970, which can be joined to form a single room
— vacuum chambers	capacities: 0.14 m³ (10^{-6} torr) 0.2 m³ (10^{-8} torr) 0.21 m³ (10^{-5} torr) 0.17 m³ (10^{-6} torr)
— vibrators	one type MBC 60/T 452
— other facilities	a revolving table; optical, mechanical and other test equipment

• **For further information please contact**

Mr. W. Hesse
Head of Space and New Technologies Marketing Division
Dornier System GmbH
Marketing Space Division VA/VA 20
799 Friedrichshafen
Postfach 648
Tel.: (07545) 8 2515

DYNATEL

United Kingdom

• **Associations:** EMI Ltd. now owns Dynatel

• **Personnel:** 14 employees including 8 engineers and technicians
civil space sector: 4 employees including 3 engineers and technicians

• **Turnover**

1971: £ 80 000 including 30 000 for the civil space sector
1972: £ 100 000 including 20 000 for the civil space sector

• **For further information please contact**

Mr. P. Lambert-Williams
Product Sales Manager
Dynatel Ltd.
Spur Road
North Feltham Trading Estate
Feltham, Middlesex — *Tel.: (01) 8901116*

ELECTRONIQUE MARCEL DASSAULT (EMD) — **France**

• **Personnel:** 1 700 employees, including 1 300 engineers and technicians; 80 to 100 people are liable to be active at any time in the civil space sector, including 60 to 80 engineers and technicians

• **Turnover** (excluding taxes)

1971: F 175 million including 19.238 for the civil space sector
1972: F 270 million including 25.078 for the civil space sector

• **Test facilities**

— vacuum chambers and vibrators

• **For further information please contact**

M. A.-M. Jeanjean
Electronique Marcel Dassault
55, Quai Carnot — *Tel.: 602 50 00*
92214 Saint-Cloud — *Telex: 257 87F EMD SCLOU*

ELEKTRONIKCENTRALEN — **Denmark**

• **Personnel:** 70 employees including 55 engineers and technicians
civil space sector: 16 employees including 14 engineers and technicians

• **Turnover**

1971: Accounting Units (AU) 0.9 million including 0.2 for the civil space sector
1972: Accounting Units (AU) 1 million including 0.25 for the civil space sector

• **Test facilities**

— workshops, laboratories	one for satellite onboard electronic equipment
— clean rooms	one (1971)
— vacuum chambers	one 100-litre chamber (1966)
	one 2.5 m^3 chamber currently being installed (1973)
— vibrators	one rated at 13.5 kN (1970)

• **Total sum invested** for civil space test facilities: 2 MAU

• **For further information please contact**

Mr. E. Petersen
Elektronikcentralen
Venlighedsvej 4
DK 2970 Horsholm — *Tel.: (01) 86 77 22*

EMI ELECTRONICS LTD — **United Kingdom**

• **Personnel:** 7 000 employees, 40 % of whom are engineers and technicians
• **For further information please contact**

Mr. D. Lane
Divisional Marketing Manager
EMI Electronics Ltd.
Systems and Weapons Division
Victoria Road — *Tel.: (01) 890 3600*
Feltham, Middlesex — *Telex: LONDON 23325*

ENGINS MATRA

France

4, rue de Presbourg
75116 Paris

• **Personnel:** 3 400 employees including 1 700 engineers and technicians
civil space sector: approx. 350 employees including 300 engineers and technicians

• **Turnover** (excluding taxes)

1971: F 343 million including 75 for the civil space sector
1972: F 365 million including 90 for the civil space sector

• **A member of the MESH consortium** for developing ESRO satellites; has been awarded sub-contracts for the Intelsat-III satellites

• **Scientific instrumentation:** helped to develop the electron detector of ESRO's HEOS-1 satellite on behalf of the Centre d'études nucléaires (CEN) at Saclay and the University of Milan; the gamma-ray telescope for ESRO's TD-IA satellite on behalf of the CEN (Saclay), the Max Planck Institute (Garching) and the Physics Institute of Milan; the UV spectrometer for France's D-2B satellite on behalf of the Laboratoire d'astronomie spatiale (Marseille) and the Laboratoire de physique stellaire et planétaire (LPSP) at Verrières-le-Buisson; also helped to develop French instrumentation carried on the American OSO-I and HEAO-B satellites, on behalf of the LPSP and the CEN, respectively

• **Test facilities**

— workshops, laboratories	at the Vélizy plant
— clean rooms	approximately 1 000 m² available since 1967
— vacuum chambers	one 70 dm³ vacuum bell (10^{-2} torr) one 35 dm³ Beaudoin vacuum bell (2×10^{-6} torr) three 10^{-6} torr vacuum chambers of 80, 225 and 900 dm³ capacity
— vibrators	6, consisting of 4 MB Electronic C 10 E, EL 250, C 50 and C 210 models rated at 5.3, 13.6, 22.7 and 91 kN respectively two 60 kN Ratier-Forest vibrators
— other facilities	environmental chambers; spin tables; helium type leakage detectors; vibration generators; equipment for making magnetic measurements; a solar simulator; a special chamber for making UV measurements, etc.

• **For further information please contact**

M. Michel Schmit
Directeur commercial des Affaires spatiales
Engins Matra
39-47, av. Louis-Bréguet
BP n° 1
78140 Vélizy-Villacoublay
Tel.: 946 96 00, poste 33/83
Telex: ENMATRA 690 77 F

ERNEST TURNER ELECTRICAL INSTRUMENTS LTD.

United Kingdom

• **Personnel:** 350 employees including 12 engineers and technicians
civil space sector: 15 employees including 4 engineers and technicians

• **Turnover**
1971 and 1972: £ 5 million including £ 25 000 for the civil space sector

• **Test facilities**

— clean rooms	2 (1971)
— vacuum chambers	2 (0.56 and 0.25 m³)
— vibrators	2 (rated at 600 and 110 kgf)
— other facilities	equipment for testing solar panels

• **Total sum invested** for civil space test facilities: approximately £ 30 000

• **For further information please contact**

Mr. K. A. Murray
Ernest Turner Electrical Instruments Ltd.
High Wycombe
Buckinghamshire
Tel.: 309 31

ERNO RAUMFAHRTTECHNIK GmbH — Germany

Part of the Zentralgesellschaft VFW-Fokker holding group

• **Personnel:** 1,000 employees, including 630 engineers and technicians

• **Turnover**

1971: DM 65 million including 50.8 for the civil space sector
1972: DM 64.8 million including 57.5 for the civil space sector

• **A member of the MESH consortium** for ESRO satellites; was awarded a subcontract from TRW, the US firm, for the Intelsat-III satellites

• **Test facilities**

— laboratories, workshops	several laboratories in Bremen for hydraulic, pneumatic, optical and electronic systems and for mechanical engineering design work
— clean rooms	one of 400 m^2 area (class 100 000) one of 28 m^2 area (class 100) one of 31 m^2 area (class 10 000)
— vacuum chambers	one of 72 dm^3 (5×10^{-7} torr) capacity and one of 1.2 m^3 (6×10^{-6} torr) capacity, both at Bremen one of 6.28 m^3 (6×10^{-6} torr) capacity for testing hydrazine thrusters for attitude control
— other facilities	apparatus for determining moments of inertia and centres of gravity, a revolving table, etc.

• **Total sum invested** for civil space test facilities: DM 4 million at Bremen (buildings included) and DM 2.5 million at Trauen

• **For further information please contact**

Mr. Dieter R. Ottemeyer
ERNO Raumfahrttechnik GmbH
28 Bremen 1
Hünefeldstrasse 1-5 — *Tel.: (0421) 519/4196*
Postfach 1199 — *Telex: 0245548*

ETUDES TECHNIQUES ET CONSTRUCTIONS AEROSPATIALES (ETCA) — Belgium

• **Personnel:** in the civil space sector: 238 employees (including those employed by ACEC, the parent company) including 102 engineers and technicians

• **Turnover for the civil space sector**

1971: BF 138.49 million
1972: BF 111.98 million

• **A member of the COSMOS and CESAR consortia** formed for ESRO satellites; was awarded subcontracts for Germany's Helios probes by GfW, for the Intelsat-IV satellites by the Hughes Company, and for the Franco-German Symphonie satellite.

• **Scientific instrumentation:** helped to develop the solar particle measuring instrument for ESRO's HEOS-1 satellite on behalf of the Laboratoire de recherche spatiale of the University of Brussels, and the four-channel (UV and IR) spectrometer for ESRO's TD-1A satellite on behalf of the Institut d'astrophysique of Liège; has developed electronic subsystems for balloon nacelles and sounding rocket experiment packages

• **Test facilities**

— workshops, laboratories	an integration and test laboratory
— clean rooms	one 240 m^2 room of class 100 (1965) one 325 m^2 semi-clean room (1967)
— vacuum chambers	one 0.03 m^3 (10^{-6} torr) chamber since 1965
— simulation chambers	one 0.45 m^3 (10^{-7} torr) chamber since 1965
— vibrators	one Bruel & Kjaer rated at 790 kgf one Schenk rated at 50 kgf
— other facilities	several environmental chambers; a shock machine; a magnetic tests room; computer facilities, etc.

• **Total sum invested** for civil space test facilities: BF 20 million

• **For further information please contact:**

M. André Dumont
Chef des Projets Futurs
ETCA
101, rue Chapelle-Beaussart
B6 100 Mont-sur-Marchienne *Tel.: 07 36 65 25*

FERRANTI Ltd. **United Kingdom**

• **Personnel:** *Gem Hill (Lancs) plants:* 1 200 employees including 600 engineers and technicians; 30 people active in the civil space sector including 20 engineers and technicians (mainly in producing solar cells)

Edinburgh (Scotland): 600 employees in the Inertial Systems Department, including 100 engineers and technicians

• **Test facilities**

— Clean rooms	several, also used for non-space products
— other facilities	environmental chambers

• **For further information please contact:**

Mr. P. S. Woodcock
Ferranti Ltd.
Gem Hill
Chadderton, Oldham *Tel.: (061) 624 6661*

Mr. A. Elias
Ferranti Ltd.
Inertial Systems Department
Silverknowes
Ferry Road
Edinburgh EH 4 4 AD *Tel.: (031) 332 2424, ext. 203*

FOKKER VFW NV **Netherlands**

• **Associations:** in May 1969 the Dutch Fokker company merged with Germany's VFW (Vereinigte Flugtechnische Werke) to form a holding company, Zentralgesellschaft VFW-Fokker mbH, with headquarters in Düsseldorf; Fokker-VFW N.V. is the branch located at Amsterdam (Netherlands) and VFW-Fokker GmbH the branch located at Bremen (Germany); Zentralgesellschaft VFW-Fokker holds 100 % of the capital of ERNO Raumfahrttechnik GmbH in Bremen

• **Personnel:**

— for the whole group in 1971: 19 200 employees
— Fokker VFW N.V: 6 000 employees
— *civil space sector:* in 1972, 86 employees including 77 engineers and technicians

• **Turnover**

1971: DM 1 069 million for the whole group including florins 5.9 million for the civil space sector
1972: DM 1 200 million for the whole group including florins 5.4 million for the civil space sector

• **A member of the STAR consortium** for ESRO's GEOS satellite

• **Scientific instrumentation:** helped to develop an X-ray spectrometer for the Skylark sounding rockets and the gas system for the 2 X-ray counters on the Netherlands' ANS satellite

• **Test facilities**

— workshops, laboratories	one 320 m² integration hall
— clean rooms	one 130 m² room (class 100) (1971)
— vacuum chambers	one with a capacity of 200 litres (1967)
— vibrators	one of 3.4 kN (1967) and one of 28 kN (1970)
— other facilities	one fluid-bearing table (200 kg) with one degree of freedom for testing the ANS satellite's attitude control system and precision damper

• **Total sum invested for civil space test facilities:** about 1.2 million florins

• **For further information please contact**

Mr. J. J. Schouten
Space Division Commercial Manager
Fokker VFW N.V.
Schipholdijk 231
P.O. Box 7600 — *Tel.: (020) 73 10 44*
Schiphol Oost 1148 — *Telex: ASD 12227*

GEC MARCONI ELECTRONICS — United Kingdom

Marconi House
Chelmsford — *Tel.: (0245) 53 221*
Essex

• **Associations:** Marconi and General Electric merged in 1968; previous to this, General Electric had merged with English Electric, which in turn had merged with Elliott Automation; the electronic activities of GEC Marconi and GEC Marconi Electronics are shared between Marconi Space and Defense Systems Ltd., Marconi Communication System Ltd., Marconi Elliott Avionic Systems Ltd., Marconi International Marine Company Ltd., Marconi Radar Systems Ltd., Marconi Instruments Ltd., and Easams Ltd. (Elliott Automation Space and Military Systems)

• **Personnel:**

— GEC group: 180 000 employees
— GEC Marconi: 29 000 employees
— *civil space sector:* 600 engineers and technicians

• **Turnover**

1971: £ 170 million by GEC Marconi

• **Scientific instrumentation:** helped to develop the infrared radiometers on the American Nimbus-D, E and F satellites on behalf of Oxford University's Clarendon Laboratory and the Physical Laboratory (Reading); the X-ray telescope on the American OAO-C satellite on behalf of University College (London); and the galactic noise measuring instrument on Britain's UK-2 satellite on behalf of Cambridge University's Mullard Radio Astronomy Observatory; is participating in the development of the American Tiros-N satellite's radiometer

• **Test facilities**

— workshops, laboratories	12
— clean rooms	5 (1969-1970)
— vacuum chambers	2 with capacities of 220 dm³ (1968) and 390 dm³ (1972) one 57 m³ chamber for testing satellite attitude control thrusters
— vibrators	one Ling 962 rated at 800 kgf one Ling L 200 rated at 1 100 kgf
— balancing tables	one Schenk type E 5 R table
— other facilities	climatic chambers, hydrazine thruster test equipment, etc.

• **For further information please contact:**

Mr. R. I. Simmonds
Marketing Manager (Space)
Marconi Space and Defence Systems Ltd.
Applied Electronics Laboratories
The Airport
Portsmouth, Hants — *Tel.: 0705 62271, ext. 228*

GTE TELECOMUNICAZIONI SPA — Italy

• **Personnel:** 5 600 employees including 300 engineers and technicians

civil space sector: 40 employees including 25 engineers and technicians

• **Turnover**

1971: lire 42 100 million including 723.8 for the civil space sector
1972: lire 47 540 million including 1 000 for the civil space sector

• **A member of the Italian STS consortium** (Consorzio per Sistemi di Telecomunicazioni via Satelliti)

• **Test facilities**

— clean rooms	for manufacturing and proving communications subsystems
— vacuum chambers	Yes
— vibrators	Yes

• **For further information please contact:**

M. Alberto Grosso
GTE Telecomunicazioni SpA
20060 Cassina de Pecchi — *Tel.: 951 99204*
Milan — *Telex: 31187*

HAWKER SIDDELEY DYNAMICS LTD (HSD) — United Kingdom

Manor Road
Hatfield
Hertfordshire

• **Personnel:** 7 800 employees
civil space sector: 1 150 employees including 650 engineers and technicians

• **Turnover**

1971: £ 29.3 million including 8 for the civil space sector
1972: £ 30.1 million including 8 for the civil space sector

• A member of the **MESH consortium** formed for ESRO satellites; has been awarded subcontracts in connection with development of the Intelsat-III satellites and is participating in the development of Spain's Intasat satellite

• **Scientific instrumentation:** developed a UV telescope for ESRO's TD-1A satellite on behalf of the Institute d'astrophysique of Liège and the Royal Observatory of Edinburgh

• **Test facilities** (at Stevenage)

— workshops, laboratories	several
— clean rooms	one (1966), 2 (1969) and 2 (1971)
— vacuum chambers	one of 10.85 m^3 (10^{-5} torr) since 1967 one of 0.34 m^3 (10^{-4} torr) since 1968 one of 0.26 m^3 (10^{-5} torr) since 1968
— vibrators	one MB C 210 vibrator rated at 12.6 tons (1971), plus several smaller ones
— balancing tables	one Schenk E 5 table (1972)
— other facilities	environmental chambers; a magnetic tests room; antenna testing equipment

• **Total sum invested** for civil space test facilities: £ 3 million

• **For further information please contact**

Hawker Siddeley Dynamics Limited
Gunnels Wood Road — *Tel.: Stevenage 3456 ext. 213*
Stevenage, Herts — *Telex: 82130*

THE HYMATIC ENGINEERING CO. LTD. — United Kingdom

• **Personnel:** 350 employees including 40 engineers and technicians
civil space sector: 8 employees including 6 engineers and technicians

• **Turnover**

1970-1971: £ 1.07 million including £ 20 000 for the civil space sector
1971-1972: £ 1.38 million including £ 50 000 for the civil space sector

• **Test facilities**

— clean rooms	one type Av P 89 (category B) (1971), for developing the valves for the propane system on the British UK-5 and X-4 satellites
— vibrators	one rated at 280 kg (1972)

- **Total capital invested** for civil space test facilities is about £ 20 000
- **For further information please contact**

Mr. A. A. Traves
Senior Sales Project Engineer
Hymatic. Engineering Company Ltd.
Glover Street — *Tel.: 073 92 63621*
Redditch, Worcestershire — *Telex: 339622*

IMPRESSION ENREGISTREMENT DES RESULTATS (IER) — **France**

- **Personnel:** 85 employees including 20 engineers and technicians

civil space sector: 7 engineers and technicians

- **Turnover** (excluding taxes)

1971: F 14.7 million including 6 for the civil space sector
1972: F 13.6 million including 4 for the civil space sector

- **Test facilities**

— clean rooms	one 100 m² room complete with laminar-flow hood (1967)
— other facilities	an environmental chamber

- **For further information please contact**

M. Alain Ranoux
IER
21, rue de Sébastopol — *Tel.: 333.67.81*
92 - Courbevoie — *Télex : 62289*

INTEGRATED PHOTOMATRIX LTD — **United Kingdom**

- **Association:** in June 1973 Muirhead Ltd., a British public company, took over approximately 40 % of the capital of Integrated Photomatrix Ltd.
- **Personnel:** 45 employees including 14 engineers and technicians

civil space sector: 3 engineers and technicians

- **Turnover**

1971: £ 123 000 including 12 151 for the civil space sector
1972: £ 172 000 including 24 270 for the civil space sector

- **For further details please contact**

Mr. G. R. Parsons
Integrated Photomatrix Ltd.
The Grove Trading Estate
Dorchester, Dorset — *Tel.: (0305) 3673*

INTERTECHNIQUE — **France**

- **Personnel:** 1 100 employees including 350 engineers and technicians

civil space sector: 30 engineers and technicians

- **Turnover** (excluding taxes)

1971: F 129.5 million including 4.15 for the civil space sector
1972: F 135.5 million including 3.4 for the civil space sector

• **Scientific instrumentation:** on behalf of the Laboratoire d'aéronomie (Verrières), the Laboratoire de physique stellaire et planétaire, Meudon Observatory and the Centre d'étude spatiale des rayonnements (Toulouse), has developed the electronic subsystems (DC-DC converters) for French instruments on board France's D-2A satellite, the American OSO and OGO satellites and Soviet Cosmos satellites (the Stéréo V, Arcade, Calypso and Gémeaux experiments)

• **Test facilities**

— clean rooms	one (1968)
— other facilities	environmental chambers

• **For further information please contact**

M. Gérard Minier
Responsable Commercial
Intertechnique
BP n° 1 - Zone industrielle — *Tel.: 460 33 00, ext. 559*
78370 Plaisir — *Telex: INTERTEC 25942 F*

ITT LABORATORIES OF SPAIN (Standard Electric SA) — **Spain**

Avenida de America km 7 200 — *Tel.: 754 02 00*
Madrid 27 — *Telex: 27707*

• **Personnel:** 460 employees including 320 engineers and technicians
civil space sector: 20 engineers and technicians

• **Turnover for the civil space sector**
1971: $ 100 000
1972: $ 130 000

• **Test facilities**

— clean rooms	one of class 100 000 one of class 100 (at laminar-flow level)
— vacuum chambers	one of 1 000 litres capacity

• **For further information please contact**

M. Y. M. Coronado
I.T.T. Laboratories of Spain
Ramirez de Prado n° 5
Madrid — *Tel.: 467 30 00*

LABORATOIRE CENTRAL DE TELECOMMUNICATIONS (LCT) — **France**

• **Associations:** part of the International Telephone and Telegraph (ITT) group

• **Personnel:** 775 employees including 372 engineers and technicians
civil space sector: 60 employees including 40 engineers and technicians

• **Turnover** (excluding taxes)
1971: F 76 million including 15 for the civil space sector
1972: F 74 million including 10 for the civil space sector

• **Scientific intrumentation:** LCT was prime contractor for the Eole scientific experiment in respect of a system comprising the memories, the logic devices, a balloon interrogation unit, the associated receiver and the ranging and Doppler devices

• **Test facilities**

— workshops, laboratories	several rooms which can be converted for satellite or subsystem integration
— clean rooms	two 85 and 126 m² rooms (1969)
— vacuum chambers	one of 125 dm³ capacity (1966)

— vibrators — one for use on components and subassemblies (1964)

— other facilities — environmental chambers, centrifuges, a helium leakage detector for small components or subsystems; LCT also has access to the Sopemea test facilities at Vélizy

• **For further information please contact**

M. G. Phélizon
Directeur des Relations Extérieures
LCT
18-20, rue Grande-Dame-Rose
78140 Vélizy Villacoublay — *Tel.: 946 9615*
BP 40 — *Telex: 69892*

LEITZ GmbH

Germany

• **Personnel:** 6 000 employees

• **Turnover**

1972: DM 160 million including 1 for the civil space sector

• **For further information please contact**

Dr. Frenk
Leitz GmbH Optische Werke
633 Wetzlar — *Tel.: 06441 292695*
P.F. 210 — *Telex: 483849*

MAN - Neue Technologie

Germany

Is part of the MAN group which includes the MAN—Neue Technologie branch, the only one to be engaged in space activities, and MTU (Motoren und Turbinen Union), which was formed following the merger on 1st April 1969 between the main branch of MAN Turbo and Daimler-Benz; MAN and Daimler-Benz hold equal shares in MTU's capital

• **Personnel:** 626 employees including 332 engineers and technicians

civil space sector: 93 employeers including 65 engineers and technicians

• **Turnover**

1970-1971: DM 21.6 million including 5 for the civil space sector

1971-1972: DM 46 million including 8.6 for the civil space sector

• **Scientific instrumentation:** produced the containers for the barium cloud experiments of the Max Planck Institute at Garching

• **Test facilities**

— vibrators — one Link 805 rated at 1 300 kgf

• **Total capital investments** for civil space test facilities: DM 2.5 million

• **For further information please contact**

Mr. J. Feustel
MAN-Neue Technologie
Abt. ETP
D 8000 München 50
Postfach 50 06 20 — *Tel.: (0811) 14 801*

MESSERSCHMITT-BÖLKOW-BLOHM GmbH (MBB) **Germany**

• **Associations:** the Space Division of MBB was formed in 1969 after the space-oriented departments of Bölkow GmbH and Junkers Flugzeug und Motorenwerke GmbH were merged

• **Personnel** *in the civil space sector:* 1 600 employees including 800 engineers and technicians

• **Turnover**

1971: DM 1 155 million including 165 for the civil space sector
1972: approx. DM 1 125 million including 166 for the civil space sector

• **A member of the COSMOS consortium** for the development of ESRO satellites

• **Scientific instrumentation:** developed the barium capsule ejected from ESRO's HEOS-1 satellite (on behalf of the Max Planck Institute, MPI, Garching) and the micrometeorite detector for ESRO's HEOS-A2 satellite (on behalf of the MPI at Heidelberg); designed and produced the impedance probe for the German Aeros satellite on behalf of the Arbeitsgemeinschaft für Physikalische Weltraumforschung at Freiburg, and the electronic subsystems for 2 experiments on board the German Azur and Aeros satellites; is developing the spark chamber to be carried aboard ESRO's COS-B satellite and a plasma probe for the German Helios satellite

• **Test facilities**

— laboratories, workshops	for developing a wide range of satellite onboard equipment (power supplies, antennae, attitude control, electronic and radio equipment)
— clean rooms	a 550 m² class 3 integration facility (1972)
— vacuum chambers	two 0.8 m³ rooms, one capable of achieving a vacuum of 1.10^{-6} mm Hg
— simulation chambers	the vacuum chamber capable of achieving a vacuum of 10^{-6} mm Hg can be equipped with a 20 cm diameter artificial sun
— vibrators	one type C.90, rated at 4,500 kgf, one type C.10 (550 kgf), one Ling 330 (700 kgf) and one Ling 962 (8 000 kgf)
— balancing table	one Schenk E4 table
— other facilities	climatic chamber, centrifuge, magnetic measurement laboratory, a Schenk table for measuring moments of inertia, a Schenk table for determining centres of gravity, etc.

• **Total sum invested** for civil space test facilities: DM 50 million

• **For further information please contact**

Dr. Ernst Pomp
Marketing Manager, Space Division
Messerschmitt-Bölkow-Blohm GmbH
Unternehmensbereich Raumfahrt
8000 München 80 *Tel.: 0811/6000 3735*
Postfach 80 11 69 *Telex: (05) 22279*

MONTEDEL (Montecatini Edison Elettronica) **Italy**

Laben Division

• **Associations:** Laben (Milan), OTE (Florence), Elmer (Rome) and Gregorini (Rome) were absorbed by Montedel SpA on 30 May 1969

• **Personnel:** (Laben Division): 1 600 employees including 450 engineers and technicians
civil space sector: 120 employees including 70 engineers and technicians

• **Turnover**

1971: lire 13 850 million including 920 for the civil space sector
1972: lire 14 150 million including 1 100 for the civil space sector

• **A member of the STAR consortium** for ESRO satellites

• **Scientific instrumentation:** helped to develop electronic subsystems for the gamma-ray detector for ESRO's TD-1A satellite, on behalf of the Centre d'études nucléaires (Saclay), the Max Planck Institute at Garching and the Physics Institute in Milan, as well as the electron and proton detector for ESRO's HEOS-A2 satellite on behalf of the University of Rome; also participated in the development of electronic subsystems for the gamma-ray detector on ESRO's COS-B satellite, the instrument for measuring the interplanetary magnetic field on the German Helios solar probes, and onboard X-ray sensors for American Nike-Apache sounding rockets

- **Test facilities**

— workshops, laboratories	one group in Milan, another in Florence
— clean rooms	yes, since 1965
— vacuum chambers	one of 40-litre capacity (10^{-7} mm Hg) one of 200-litre capacity (10^{-7} mm Hg)
— vibrators	one Pye Ling type V 1000 rated at 350 kg one Bruel & Kjaer
— other facilities	environmental chambers, shock machines, etc.

- **Total sum invested** for civil space test facilities: lire 400 million

- **For further information please contact**

M. Giancarlo Massobrio
Coordinator for Space Programs
Laben Division of Montedel SpA
Via Bassini, 15 — *Tel.: 236 55 51*
20133 Milan — *Telex: 33451*

OFFICINE GALILEO — Italy

- **Personnel**: 2 000 employees including 400 engineers and technicians
civil space sector: 78 employees including 45 engineers and technicians

- **Turnover**

1971: lire 15 000 million including 250 for the civil space sector
1972: lire 18 000 million including 400 for the civil space sector

- **Scientific instrumentation:** helped to develop the solar wind proton counter for ESRO's HEOS-1 satellite on behalf of the Universities of Florence, Rome and Brussels, and the Cerenkov-effect electron counter for ESRO's HEOS-A2 satellite on behalf of the Centre d'études nucléaires (Saclay) and the University of Milan

- **Test facilities**

— vacuum chamber	yes
— vibrators	yes
— other facilities	environmental chambers; a centrifuge; test equipment for solar sensors and infrared attitude sensors; an inclinable spin table; sinusoidal motion generators for accelerometer testing

- **For further information please contact**

Dr. Gian Luigi De Divelec
Officine Galileo
Divizione Sistemi
Via Carlo Bini, 44 — *Tel.: 4796, int. 334*
50100 Firenze — *Telex: 57126*

OTO MELARA SpA — Italy

- **Personnel:** 1 500 employees, including 200 engineers and technicians

- **Test facilities**

— workshops, laboratories	yes, for the design and development of hydrazine thruster subsystems
— vacuum chambers	one of 5 m³ capacity (1973)
— vibrators	one rated at 850 kgf (1970)
— other facilities	a test-stand for hydrazine thrusters

- **Total sum invested** for civil space test facilities: lire 300 million

- **For further information please contact**

Oto Melara SpA
Via Valdilocchi, 15 — *Tel.: (52005) 54 041*
19100 La Spezia — *Telex: 27368 OTO*

NV PHILIPS' TELECOMMUNICATIE INDUSTRIE — Netherlands

• **Scientific instrumentation:** developed the electronic subsystems for the ESRO-IV satellite's solar particle spectrometer (on behalf of Laboratorium voor Ruimteonderzoek, Utrecht and for the Netherlands ANS satellite's UV telescope (on behalf of Kapteyn Observatory, Groningen)

• **Test facilities**

— workshops, laboratories	at Huizen, Hengelo (HSA), The Hague (v.d. Heem Electronics) and Geldrop (Nat. Lab.)
— clean rooms	several, since 1969
— vacuum chambers	several
— vibrators	several, including one rated at 10 000 kgf, one at 1 500 kgf, one at 1 400 kgf and one at 1 000 kgf
— other facilities	environmental chambers, a one-axis table for attitude control systems, a shock machine, etc.

• **For further information please contact**

Mr. H.J. Verbiest
Philips' Telecommunicatie Industrie
Hilversum 1301 — *Tel.: 02150 - 91 615*
PO Box 32 — *Telex: 11274*

LA RADIOTECHNIQUE - COMPELEC (RTC) — France

• **Associations:** a member of the Philips group, La Radiotechnique has close links with Société Anonyme d'Etudes et de Réalisations Nucléaires (SODERN) and Laboratoires d'Electronique et de Physique Appliquée (LEP), which also belong to the Philips group

• **Personnel:** 7 286 employees, including 1 400 engineers and managerial staff; there is no personnel working exclusively in the civil space sector

• **Turnover** (excluding taxes)

1971: F 708.6 million
1972: F 889 million

• **Scientific instrumentation:** development of multiplier phototubes

• **Test facilities**

not specific to space applications; numerous clean rooms

• **For further information please contact**

M. Jean de la Chapelle
130, av. Ledru-Rollin
75540 Paris Cedex 11 — *Tel.: 357 69 30*

RAUMFAHRTELEKTRONIK GmbH (RFE) — Germany

• **Personnel** *in the civil space sector:* 39 employees including 24 scientists and technicians

• **Turnover**

1971: DM 3.9 million
1972: 4 million

• **Scientific instrumentation:** developed the electronic subsystem for the 2 cosmic dust detectors on the German Helios solar probe, on behalf of the Max Planck Institute at Heidelberg

• **Test facilities**

— laboratories, workshops	for developing instrumentation packages
— vacuum chambers	one with a capacity of 0.25 m³
— other facilities	climatic chambers. RFE also uses the test facilities of the Industrieanlagen Betriebsgesellschaft (IABG) at Ottobrunn

• **For further information please contact**

Mr. Manfred Steinich or
Mr. Hansjörg Volland
RFE Raumfahrtelektronik GmbH & Co
Projektierung Entwicklung Fertigung — *Tel.: (08095) 511*
8011 Göggenhofen über München — *Telex: 529693*

SAAB-SCANIA AB — **Sweden**

• **Personnel:** 30 000 employees, including approximately 10 000 engineers and technicians

• **Turnover**

1971: SKr. 4 110 million
1972: approx. SKr. 4 500 million

• A member of the **MESH** consortium

• **Scientific instrumentation:** SAAB-Scania is to develop a UV solar spectrometer for an Intercosm satellite

• **Test facilities**

— workshops, laboratories	one for subsystems
— clean rooms	2
— vacuum chambers	several, including one of 57 m^3 and one of 500 litre capacity
— vibrators	several, including one rated at 50 kN
— other facilities	climatic chambers; centrifuges; a shock machine; a gyroscope and accelerometer test system; metallurgical, chemical and other laboratories

• **For further information please contact**

Mr. Arne Svenson, Dept. code RME
Saab-Scania AB, Missile and Electronics Section — *Tel.: (013) 13 00 20/456*
S 581 88 Linköping — *Telex: 64940 Saablg S*

SOCIETE ANONYME BELGE DE CONSTRUCTIONS AERONAUTIQUES (SABCA) — **Belgium**

• **Personnel:** 1 934 employees including 414 engineers and technicians
civil space sector: 22 employees including 18 engineers and technicians

• **Turnover**

1971: BF 1 220 million including 24.36 for the civil space sector
1972: BF 1 380 million including 25.94 for the civil space sector

• **A member of the STAR consortium**

• **Test facilities**

— clean rooms	2 of class 10 000 (200 and 170 m^2) (1970) one of class 100 (66 m^2) (1970)
— vacuum chambers	one of 1 m^3 capacity (10^{-5} torr) since 1969
— simulation chambers	one of 0.25 m^3 capacity (10^{-5} torr) since 1970
— vibrators	one Derritron rated at 1 000 kgf (1960) one Ling rated at 3.5 t
— other facilities	a shock machine, vibration analysers, leakage analysers, hydraulic valve testing stands, etc.

• **For further information please contact**

M. J.-P. Mathieu, Engineer
SABCA
1470 Chaussée de Haecht — *Tel.: 845 8347*
1130 Brussels — *Telex: SABCA-BRU 21237*

SOCIETE DES ACCUMULATEURS FIXES ET DE TRACTION (SAFT) — France

- **Associations:** belongs to the Compagnie Générale d'Electricité group
- **Personnel** *in the civil space sector:* 26 employees including 22 engineers and technicians
- **Turnover for the civil space sector**

1971: F 2.7 millions
1972: F 2.9 millions

- **For further information please contact**

M. P. Boulais
SAFT
156, av. de Metz — *Tel.: 845 83 47*
93230 Romainville — *Telex: 22100*

SOCIETE ANONYME DE TELECOMMUNICATIONS (SAT) — France

- **Associations:** on 1st November 1970, SAT took over an electronics section from SNIAS at Suresnes, in the Paris area
- **Personnel:** 5 110 employees including 1 870 engineers and technicians
civil space sector: 150 employees including 75 engineers and technicians
- **Turnover**

1971: F 470 million (including taxes) of which 12 (excluding taxes) for the civil space sector
1972: F 535 million (including taxes) of which 20 (excluding taxes) for the civil space sector

- **A member of the COSMOS consortium.** A member of the CIFAS consortium formed to develop the Franco-German Symphonie satellite
- **Test facilities**

— clean rooms	251 m² available since 1968 58 m² more since 1972
— vacuum chambers	one of 1 m³ capacity (10^{-5} torr)
— vibrators	yes
— other facilities	shock machines, environmental chambers

- **For further information please contact**

M. Claude Guyot
Direction Commerciale Aéronautique et Espace
SAT
41, rue Cantagrel — *Tel.: 589 79 29*
75624 Paris Cedex 13 — *Telex : 25043 Telec Paris*

SELENIA INDUSTRIE ELETTRONICHE ASSOCIATE SpA — Italy

- **Personnel:** 3 500 employees including 1 350 engineers and technicians
civil space sector: 80 employees including 60 engineers and technicians
- **Turnover**

1971: lire 29 845 million including 1 100 for the civil space sector
1972: lire 37 423 million including 1 700 for the civil space sector

- **A member of the COSMOS and CESAR consortium** for ESRO satellites
- **Test facilities**

— workshops, laboratories	for antenna design, radio and digital systems, solar cells
— clean rooms	2, replaced in 1973 by a larger chamber
— vacuum chambers	one with a capacity of 1.36 m³ (10^{-8} torr)
— vibrators	2, up to 8 500 kgf
— other facilities	environmental chambers, centrifuges, shock machines

- **For further information please contact**

M. A. Marri
Selenia Industrie Elettroniche Associate SpA
Via Tiburtina km 12,400 — *Tel.: 436 06 45/4158 21*
00131 Rome — *Telex: 61106 Seleniat*

SENER SA

Spain

Avda del Triunfo, N° 56
Las Arenas (Viscaya)
Apartado 8

Tel.: 27 69 40
Telex: 33745

- **Personnel:** 450 employees including 150 engineers and technicians

civil space sector: 14 employees including 6 engineers and technicians

- **Turnover**

1971: pesetas 310 million including 3.5 million for the civil space sector
1972: pesetas 330 million including 2.5 million for civil space sector

- **For further information please contact**

M. Alvaro Azcarraga
Sener SA
Guzman el Bueno, N° 131
Madrid 3

SOCIETE EUROPEENNE DE PROPULSION (SEP)

France

- **Associations:** in October 1971, following an agreement concluded with the French government, SEP took over part of the activities and facilities of the Laboratoire de recherches balistiques et aérodynamiques (LRBA) at Vernon, a government establishment responsible to the Délégation ministérielle pour l'armement; this takeover related to activities of an industrial nature, chiefly propulsion units and satellites

- **Personnel:** 2 164 employees including 1 150 engineers and technicians

civil space sector: 120 employees including 80 engineers and technicians

- **Turnover**

1971: F 230 million including 5.1 million (excluding taxes) for the civil space sector
1972: F 271.7 million including 9.85 million (excluding taxes) for the civil space sector

- **A member of the international consortium** formed by the US Lockheed Missiles & Space Co. for development of the future Intelsat-V satellites

- **Scientific instrumentation:** produced a model of a sequenced photography system for military observation satellites, comprising a telescope and an automatic development device

- **Test facilities**

— workshops, laboratories	yes, for subsystem design and development
— clean rooms	5, placed in service between 1966 and 1971, including one 400 m³ and one 500 m³ room
— vacuum chambers	10, ranging from a few dm³ to 10 dm³
— vibrators	yes
— other facilities	environmental chambers; centrifuges; test-stands for electric and ion thrusters; test-beds for solid-fuel motors; chemical, metallurgy, plastics, metrology and other laboratories; SEP has access to LRBA's test facilities (optics and space environment)

- **Total sum invested** for civil space test facilities: FF 16 million, not including the solid-fuel test-beds and the buildings

- **For further information please contact**

M. René Morin
Directeur Commercial
SEP
Tour Nobel, Cedex N° 3
92080 Paris (La Défense)

Tel.: 772 12 12, ext. 7390
Telex: 56678 SEP Blagt

SIEMENS AG — Germany

- **Personnel**

— Siemens group around the world: 301 000 employees
— Siemens AEG: 198 400 employees
— *civil space sector:* 230 employees including 205 engineers and technicians (office and production personnel not included)

- **Turnover**

1970-1971: DM 13 635 million including 25 for the civil space sector
1971-1972: DM 15 147 million including 50 for the civil space sector

- **A member of the COSMOS consortium** for design work on ESRO satellites; a member of the CIFAS consortium for development of the Franco-German Symphonic satellite

- **Test facilities**

— laboratories, workshops	a group of laboratories for space research and technology
— clean rooms	several
— other facilities	extensive test and checkout equipment; Siemens also has access to the facilities operated by Industrieanlagen-Betriebsgesellschaft (IABG) at Ottobrunn

- **For further information please contact**

Dr. K. Garbrecht
Siemens AG/N Wv Fu Sat.
B 8000 München 70
Hofmannstrasse 51
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Telex: 524721

SOCIETA NAZIONALE INDUSTRIA APPLICAZIONI VISCOSA (SNIA VISCOSA) — Italy

Via Montebello 18
20121 Milan
Tel.: 6332
Telex: 34503 Snia

- **Personnel:** 1 700 employees including 200 engineers and technicians
civil space sector: 50 employees including 20 engineers and technicians

- **Turnover**

1971: lire 15 700 million including 800 for the civil space sector
1972: lire 18 800 million including 600 for the civil space sector

- **Test facilities**

— vacuum chambers	one 250-litre chamber for nozzle testing
— simulation chambers	one 35 m^3 chamber for rocket motor testing
— vibrators	yes
— balancing tables	yes

- **Total sum invested** for civil space test facilities: about lire 1 000 million

- **For further information please contact**

Dr. Claudio Stolfi
Snia Viscosa
Defence and Space Department
Via Lombardia 31
00187 Rome
Tel.: 46 80, ext. 345
Telex: 61114

SOCIETE NATIONALE INDUSTRIELLE AEROSPATIALE (SNIAS) — France

- **Associations:** SNIAS (Aérospatiale) was formed on 1st January 1970 as a result of the merger between Nord-Aviation, Sud-Aviation and SEREB

- **Personnel:** 43 000 employees including 6 500 engineers and technicians
civil space sector: 800 employees including 200 engineers and technicians

• **Turnover** (excluding taxes)

1971: F 3 870 million including 58 for the civil space sector
1972: F 66 million for the civil space sector

• **A member of the CIFAS consortium** for the Franco-German Symphonie satellite and a mem the CESAR and COSMOS consortia for ESRO satellites

• **Scientific instrumentation:** developed the electric field measuring dipoles and magnetic field measuring coils and helped to develop the electron density measurement probe for the French FR-1 satellite; participated in the development of the TL-2 laser reflector used on the Soviet Lunakhod-1 and 2 moon rovers and the laser reflectors for France's D-1C, D-1D, D-2A and Péole satellites

• **Test facilities**

— workshops, laboratories	Cannes: 4 (thermal, optical, electromechanical, electric) Les Mureaux: one for electromechanical equipment (stabilization and wiring) and one for integration of the Symphonie satellite
— clean rooms	Cannes: one 120 m^2 room (1968) and 5 more placed in service in 1973 Les Mureaux : 6, of which 5 have capacities of 90, 95, 190, 170 and 60 m^2
— vacuum chambers	Cannes: 4 with a capacity of about 1 m^3 (10^{-5} to 10^{-9} torr) in use for 3 years; one 80 m^3 chamber (10^{-6} torr) in use for 8 years Les Mureaux: one 120 m^3 (5 × 10[illegible] torr), two 15 dm^3 (5×10^{-10} torr) and one 100 dm^3 (5×10^{-11} torr) capacity chambers
— simulation chambers	Cannes: the 90 m^3 chamber can be equipped with a 60 cm diameter sun simulator and a liquid nitrogen cooled skin a 12 m^3 chamber featuring cryogenic pumping and equipped with a 60 cm diameter sun simulator and a cooled skin became available in mid-1973
— vibrators	Cannes: two C 210 rated at 120 kN; 4 rated at 2 kN Les Mureaux: one C 210 rated at 50 kN
— balancing tables	Cannes: one Schenk table Les Mureaux: one Schenk table
— other facilities	several environmental chambers, angular acceleration tables at Cannes and Les Mureaux

• Total sum invested for civil space test facilities exceeded FF 7 million from 1962 to 1970; about FF 1.7 million was invested over 1971 and 1972, and FF 0.5 million in 1973

• **For further information please contact**

M. A. Dauguet
Aérospatiale
Space & Ballistic Systems Division
Systems Subdivision
6, route de Verneil
78130 Les Mureaux *Tel.: 4747213*
M. Rouquet
Aérospatiale
78130 Les Mureaux *Tel.: 474 72 13, ext. 623*
M. L. Abadie
Aérospatiale
06322 Cannes la Bocca *Tel.: (15 93) 47 06 52, ext. 502*

SOCIETE ANONYME D'ETUDES ET DE REALISATIONS NUCLEAIRES (SODERN) — **France**

• **Associations:** part of the Philips group, SODERN has close connections with the Laboratoire d'Electronique et de Physique appliquée (LEP) which also belongs to the Philips group; SODERN took over the activities of Air Equipment (analog solar sensor) and, in May 1972, those of Compteurs Schlumberger in connection with a digital solar sensor and a stellar sensor

• **Personnel:** 300 employees including 170 engineers and technicians
civil space sector: 61 employees including 35 engineers and technicians

• **Turnover**

1971: F 38.6 million including 4.3 for the civil space sector
1972: F 39.6 million including 3 for the civil space sector

• **Test facilities**

— clean rooms	2, totalling 90 m^2 (1965) one 40 m^2 room (1970) 3 totalling 100 m^2 (1972)

— simulation chambers	one for testing horizon traversing sensors one 0.5 m³ chamber for vacuum and temperature tests on station infrared horizon sensors
— vibrators	one rated at 3 750 kgf, one at 700 kgf
— other facilities	2 collimated solar simulators; one star simulator; one three-axis table associated to an infrared collimator; one calibration bench for infrared detectors; environmental chambers

• **Total sum invested** for civil space test facilities: approximately FF 7 million (excluding buildings and environmental test facilities)

• **For further information please contact**

M. Claude Frédéric
SODERN
Département commercial
1, av. Descartes
94450 Limeil-Brévannes

Tel.: 925 39 00
Telex: 20716 Leparis Limel

STANDARD ELEKTRIK LORENZ AG (SEL) — Germany

• **Associations:** is part of the ITT (International Telephone and Telegraph) group

• **Personnel:** 38 864 employees
civil space sector: 140 employees including 70 engineers and technicians

• **Turnover**

1971: DM 1 931 million including DM 12 million for the civil space sector
1972: about DM 13 million for the civil space sector

• **Scientific instrumentation:** developed the electronic subsystem for the German Helios probe's electron spectrometer on behalf of the Max Planck Institute at Lindau

• **Test facilities**

— laboratories, workshops	several for development work on electronic systems
— clean rooms	one of class 10 000 (1967)
— vacuum chambers	yes
— vibrators	yes

• **For further information please contact**

Mr. H. Graf
Department: CNS/VSA
Standard Elektrik Lorenz AG
7000 Stuttgart-Zuffenhausen
Hellmuth-Hirth-Strasse 42

Tel.: (0711) 821 2176
Telex: 722861

SOCIETE TECHNIQUE D'APPLICATION ET DE RECHERCHE ELECTRONIQUE (STAREC) — France

• **Personnel:** 100 employees including 40 engineers and technicians
civil space sector: 15 employees working part-time, including 7 engineers and technicians

• **Turnover**

1971: F 8 million including 0.3 for the civil space sector
1972: F 8.7 million including 2 for the civil space sector

• **Test facilities**

— vacuum chambers	an 0.3 m³ chamber transparent to electromagnetic waves
— other facilities	a temperature chamber

• **For further information please contact**

M. Tocquée, Engineer
STAREC
12-14, av. Carnot
91300 Massy

Tel.: 920 13 30, ext. 24

CONSORZIO PER SISTEMI DI TELECOMUNICAZIONI VIA SATELLITI (STS) **Italy**

Via Pirelli 20
20124 Milan

• **A permanent industrial consortium** formed in 1967, whose partners are SIT Siemens (Milan), GTE Telecomunicazioni (Milan) and SIRTI (Milan)

• **Personnel:** approximately 100 employees, including 80 engineers and technicians (not counting the personnel of the consortium's three member companies), all active in the civil space sector

• **Turnover**

1971: $ 4 million
1972: $ 5 million

• **Participation in the Eurocan consortium** for the second phase of NATO's communications satellites programme

• **Test facilities**

one space communications laboratory, representing a capital investment of about $ one million

• **For further information please contact**

Dr. Roberto Del Papa
STS SpA
Via Abruzzi, 25 — *Tel.: 478 351 - 479 087*
00187 Rome — *Telex: 61126*

SVENSKA RADIO AB (SRA) **Sweden**

• **Personnel:** 1 850 employees, including 700 engineers and technicians

• **Turnover**
1971: SKr. 149 million including 1 for the civil space sector

• **Test facilities**
a clean room for electronic equipment

• **For further information please contact**
Dr. Sven Olof Ohrvik
Svenska Radio AB — *Tel.: (08) 22 31 40*
S 102 20 Stockholm 12 — *Telex: 100 94 SRA S*

TELDIX GmbH **Germany**

• **Personnel:** 820 employees including about 400 engineers and technicians
civil space sector: 30 employees including about 20 engineers and technicians

• **Turnover**

1971: DM 36 million including 0.7 for the civil space sector
1972: DM 36 million including 1.5 for the civil space sector

• **Test facilities**

— laboratories, workshops	for work on flywheels
— clean rooms	4 (1968)
— vacuum chambers	several, with capacities up to 2.10^{-3} torr
— vibrators	one type MB C-10, one type MB C-30
— balancing tables	several, for work on flywheels and gyroscopes
— other facilities	revolving tables, climatic chambers, etc.

• **For further information please contact**

Dipl. Ing. Wolfram Asprion
Teldix GmbH
D 6900 Heidelberg 1
Grenzhöfer Weg 36 — *Tel.: (06221) 5121*
Postfach 1730 — *Telex: TELDX D 461735*

TELEFONAKTIEBOLAGET L.M. ERICSSON

Sweden

M1 Division
Fack
S 431 20 Mölndal 1

Tel.: 031/275 000

• **Personnel:** 1 400 employees including 600 engineers and technicians
civil space sector: 20 engineers and technicians

• **Turnover** for the civil space sector

1971: SKr. 0.7 million
1972: SKr. 1.7 million

• **A member of the STAR consortium** for ESRO satellites

• **Test facilities**

— vacuum chamber	one 50-litre (10^{-6} Torr) chamber, for use at the Chalmers Institute of Technology (Göteborg)
— vibrators	2 Ling Altec A 246 and B 290, rated at 3 200 and 700 kgf one Brüel & Kjaer (1972)
— other facilities	climatic chambers, shock machines, a centrifuge, an acoustic chamber, an antenna tester, etc.

• **For further information please contact**

Mr. Henry Schefte
Telefonaktiebolaget LM Ericsson
DtF
S 126 25 Stockholm

Tel.: (08) 719 0000
Telex: 17440 LMES

TERMA ELKTRONISK INDUSTRI A/S

Denmark

Finlandsgade 12
8200 Aarhus N

Tel.: (06) 16 99 00
Telex: 4599

• **Personnel:** 350 employees including 100 engineers and technicians
civil space sector: 20 employees including 15 engineers and technicians

• **Turnover**

1971: DKr. 30 million including 1 for the civil space sector
1972: DKr. 32 million including 3 for the civil space sector

• **Test facilities**

— clean rooms	2 (1968 and 1972)
— vibrator	one (190 kgf)
— other facilities	electrical testing equipment

• **Total sum invested** for civil space test facilities: DKr. 500 000

• **For further information please contact**

Mr. P.M. Borggaard
Head of Research & Development Department
Terma Elktronisk Industri A/S
Haslegaardsvej 12
8210 Aarhus V

Tel.: (06) 15 91 99

THOMSON-CSF

France

• **Associations:** in December 1969, Compagnie électronique Thomson-Houston merged with Compagnie générale de télégraphie sans fil to form Thomson-CSF

• **Personnel:** 52 000 employees including 26 000 engineers and technicians
civil space sector: 1 800 employees including 1 200 engineers and technicians

• **Turnover** (excluding taxes)

1971: **F** 3 400 million including 140 for the civil space sector
1971: F 3 340 million including 178 for the civil space sector

• **A member of the STAR consortium** for ESRO satellites; was awarded sub-contracts by Hughes Aircraft on Intelsat-IV satellites and sub-contracts on the German Helios probes and Canada's CTS experimental communications satellite

• **Test facilities**

— workshops, laboratories	2
— clean rooms	one 400 m² room (1968) for satellite electronic equipment one 100 m², class 1000 room with class 100 hoods for satellite vacuum tubes (1969)
— vacuum chambers	one of 0.5 m³ capacity (10^{-5} Torr)
— simulation chambers	one of 1 m³ capacity (10^{-8} Torr)
— vibrators	4 Ling, rated from 850 to 3 750 kgf
— other facilities	an environmental chamber, an antenna test base

• **Total sum invested** for civil space test facilities: FF 15.65 million

• **For further information please contact**

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Aéronautiques et Spatiales
23, rue de Courcelles
B.P. 96-08
75362 Paris Cedex 08

Tel.: 256 52 52
Telex: TESAFI 25731 F

ZODIAC ESPACE

France

• **Personnel:** 96 employees including 18 engineers and technicians
civil space sector: 40 employees

• **Turnover**

1971: F 3.47 million including 3.1 for the civil space sector
1972: **F** 3.41 million including 3.12 for the civil space sector

• **For further information please contact**

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