esa bulletin

number 52

november 1987

european space agency

The European Space Agency was formed out of, and took over the rights and obligations of, the two earlier European Space Organisations: the European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). The Member States are Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Finland is an Associate Member of the Agency. Canada is a Cooperating State.

In the words of the Convention: The purpose of the Agency shall be to provide for and to promote, for exclusively peaceful purposes, co-operation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems.

(a) by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
(b) by elaborating and implementing activities and programmes in the space field;
(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

The Agency is directed by a Council composed of representatives of Member States. The Director General is the chief executive of the Agency and its legal representative.

The Directorate of the Agency consists of the Director General; the Inspector General; the Director of Scientific Programmes; the Director of the Earth Observation and Microgravity Programme; the Director of the Telecommunications Programme; the Director of Space Transportation Systems; the Director of the Space Station and Platforms Programme; the Director of ESTEC; the Director of Operations and the Director of Administration.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

THE EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTRE (ESTEC), Noordwijk, Netherlands.

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr H. Grage.

Director General: Prof. R. Lüst.

agence spatiale européenne

L'Agence Spatiale Européenne est issue des deux Organisations spatiales européennes qui l'ont précédée — l'Organisation européenne de recherches spatiales (CERS) et l'Organisation européenne pour la mise au point et la construction de lanceurs d'engins spatiaux (CECLES) — dont elle a repris les droits et obligations. Les Etats membres en sont: l'Allemagne, l'Autriche, la Belgique, le Danemark, l'Espagne, la France, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse. Finlande est membre associé de l'Agence. Le Canada beneficie d'un statut d'Etat coopérant.

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

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

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

Le Directoire de l'Agence est composé du Directeur général; de l'Inspecteur général; du Directeur des Programmes scientifiques; du Directeur des Programmes d'Observation de la Terre et de Microgravité; du Directeur du Programme de Télécommunications; du Directeur des Systèmes de Transport spatial; du Directeur du Programme Station spatiale et Platesformes; du Directeur de l'ESTEC, du Directeur des Opérations et du Directeur de l'Administration.

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie

Président du Conseil: M H. Grage.

Directeur général: Prof. R. Lüst.

esa bulletin

no. 52 november 1987

contents/sommaire

Front cover: Ariane V19 ready for launch in Kourou, French Guiana (see p. 8).

Back cover: Main Control Room at ESOC during Ariane V19 launch rehearsal.

Editorial/Circulation Office
ESA Publications Division
c/o ESTEC, Noordwijk, The Netherlands

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Assistant Editor
Erica Rolfe

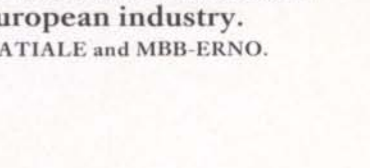
Layout
Carel Haakman

Montage
Keith Briddon

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

Printed in The Netherlands
ISSN 0376-4265

european space agency
agence spatiale européenne



Creativity on earth - reality in space!

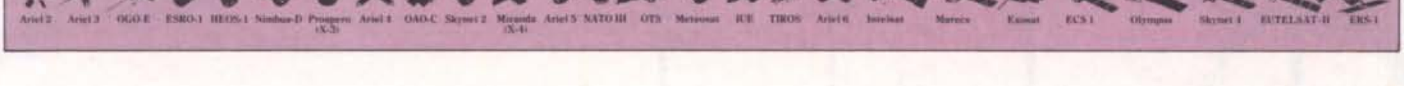
Producing any image requires creativity; the landscape picture on the left was the genius of J. M. W. Turner. The picture on the right, the achievement of many.

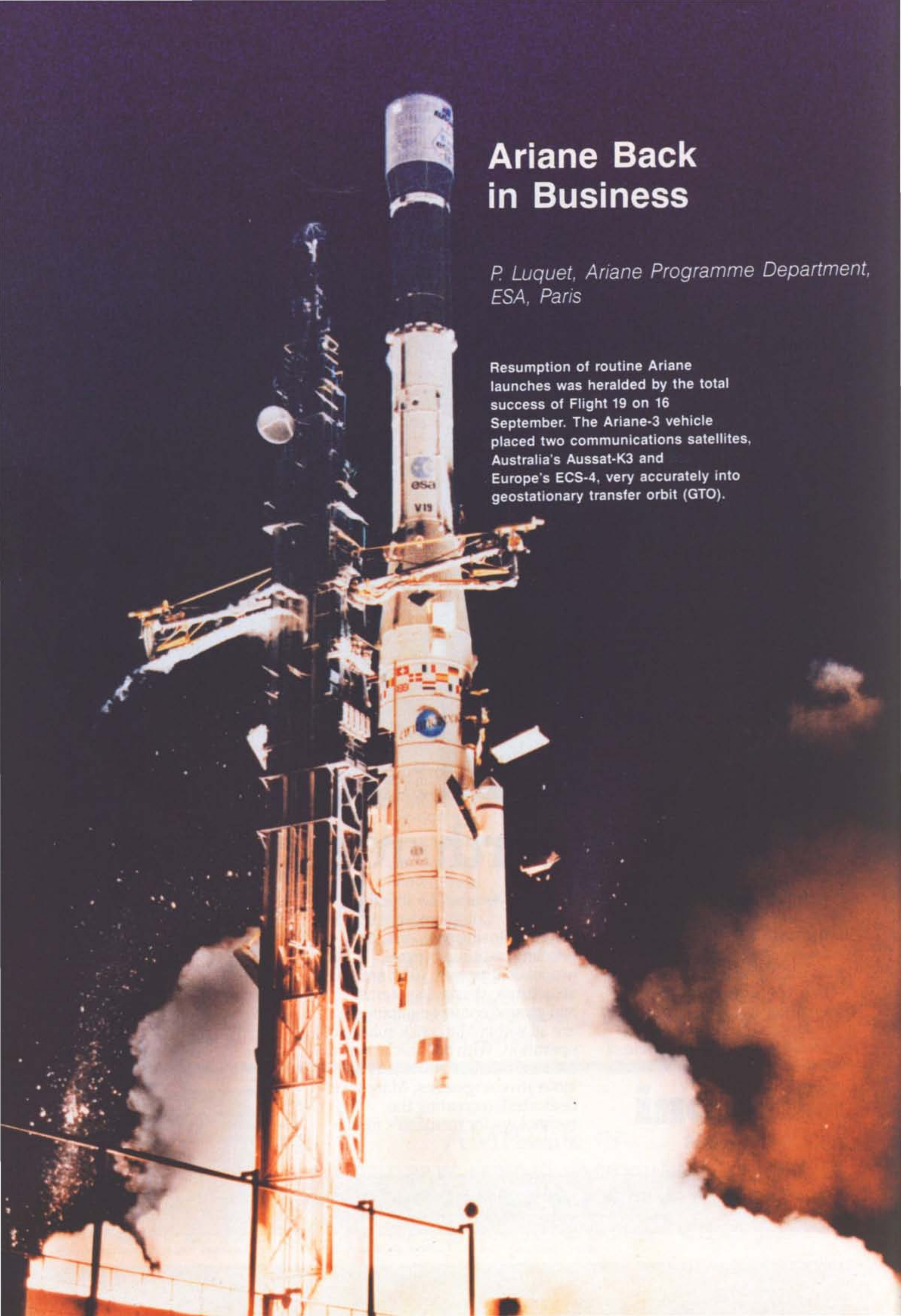
A key contributor was Marconi Space Systems, one of the few companies in the world offering a total space satellite capability. Communications and remote sensing payloads, data handling, attitude control, propulsion, power, solar arrays, structures, thermal systems, and ground control equipment are all within Marconi's sphere of operation. With our track record, modern facilities and teams of innovative engineers, Marconi is dedicated to creating the technology for mankind's future in space.

Marconi
Space Systems
A GEC-Marconi Ltd company

Marconi Space Systems Limited, Anchorage Road, Portsmouth, Hants, England PO3 5PU.
Tel: (0705) 664966.
Fax: (0705) 690455.
Telex: 86666 MARSAT G.

Above left: Morning amongst the Coniston Fells, Cumberland (exh 1798) Tate Gallery
Above right: Part of the earth from 36,000 km taken by ESA's Meteosat weather satellite. Photograph courtesy of the National Remote Sensing Centre, Farnborough, England.





Ariane Back in Business

P. Luquet, Ariane Programme Department, ESA, Paris

Resumption of routine Ariane launches was heralded by the total success of Flight 19 on 16 September. The Ariane-3 vehicle placed two communications satellites, Australia's Aussat-K3 and Europe's ECS-4, very accurately into geostationary transfer orbit (GTO).

1.

2. ECS-4 mated with its launch adapter

Launch from the ELA 1 launch complex at the Agency's Guiana Space Centre took place at 00:45:28 UT. Analyses carried out immediately after launch showed the performances of all systems and stages to have been entirely nominal. In particular, third-stage ignition was very smooth with the new ignition system, confirming the success of the rectification programme conducted during the previous fifteen months.

The Ariane-3 vehicle lifted a total of 2562.5 kg into GTO, made up as follows:
- Aussat-K3: 1195.6 kg (upper position in the Sylda)
- ECS-4 : 1173.4 kg (lower position in the Sylda)
- Sylda* : 193.5 kg

Extremely accurate transfer orbits were achieved for both satellites, the main orbit parameters, measured after spacecraft separation, being as follows:

	Aussat-K3		ECS-4	
	Measured	Diff. from prediction	Measured	Diff. from prediction
Inclination of orbit (deg)	7.0	0	7.0	0
Perigee altitude (km)	199.9	−0.1	200.5	0
Apogee altitude (km)	36 016	−13	35 952	−7

Aussat's apogee boost motor was fired at the spacecraft's third apogee, during the night of 16/17 September at 03:45h UT. The Mage-2 apogee boost motor aboard ECS-4 was fired during its fourth apogee, on 17 September at 13:47h UT.

By mid-day on 18 September, the ECS-4 satellite had been despun, Sun-acquisition had been achieved, the spacecraft's solar arrays had been deployed, and three-axis stabilisation had been achieved.

* Système Lancement Double Ariane / Ariane Dual Launch System

Photography S. Vermeer

ECS-4 then began a 21-day drift manoeuvre to take it to its initial operating location of 10°E. The satellite will subsequently be turned over to EUTELSAT as soon as practicable, which will use it (re-designated as 'Eutelsat-IF4') to extend the operating capacity that it currently has with the ECS-1 and ECS-2 satellites, launched by Ariane in 1983, and 1984, respectively.

The next Ariane launch (Flight 20/ Ariane-2) is scheduled for mid-November 1987, and will lift the 2000 kg-class TV-SAT satellite into orbit.

3.

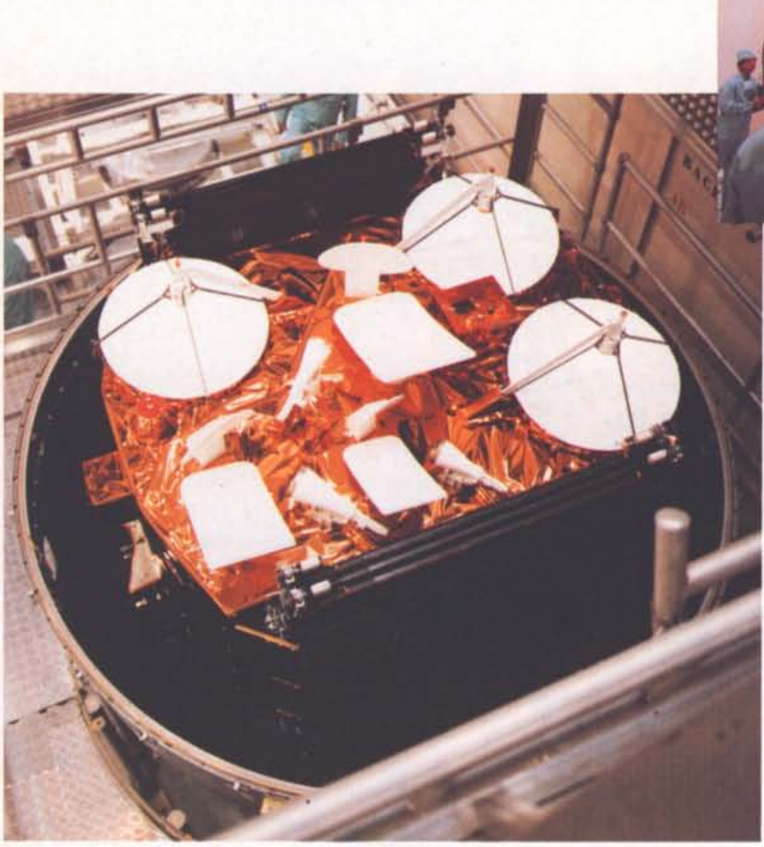
4.

3,4. Final preparation of the ECS-4 spacecraft

5,6. Installation of ECS-4 into the Ariane dual-launch system (Sylda)

7. Aussat-K3 mounted on the Sylda

5.



6.

7.

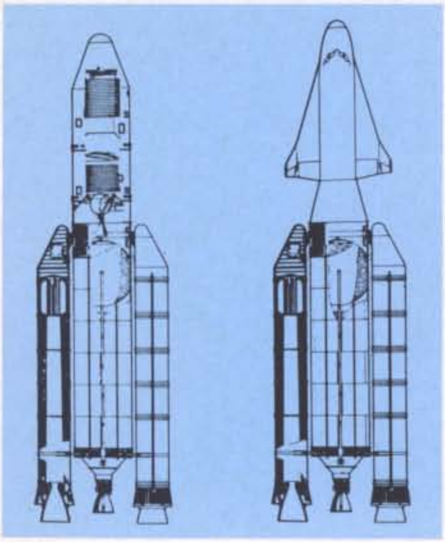
8.

10.

9.

8,9. Launch at 00:45:28 UT on 16 September

10. ESA's Director General, Prof. Reimar Lüst (holding microphone), giving an impromptu, post-launch interview for French television



Challenge '95 — The Ariane-5 Development Programme

M. Vedrenne, Ariane Programme Department, ESA, Paris

A new launcher that is both more powerful and less expensive to use than today's generation of launchers will be required by Europe from 1995 onwards in order to: (i) remain competitive in the satellite-launching market, and (ii) take up Space-Station and low-orbit-intervention activities, with the ability to launch Columbus elements and the Hermes spaceplane.

This article describes the current situation and foreseen medium-term plans for the Ariane family of vehicles, the expected trend for payloads and launch systems from 1995 onwards, and the missions and objectives for Ariane-5.

The demand for Ariane-5

Europe took the decision to develop its own launcher, able to put a 1600 kg satellite into Geostationary Transfer Orbit (GTO), back in 1973. As soon as development was complete, however, it became clear that if Ariane was to remain competitive, it would have to be able to launch two STS/PAM-D class satellites simultaneously. Follow-on development of Ariane-3, able to lift 2560 kg into GTO, was therefore decided upon in 1981, and this vehicle successfully carried out its first dual launch in August 1984.

The Ariane-4 Programme will continue the policy of providing dual launches, offering a lift performance of up to 4200 kg into GTO, with greater volume under the fairing.

Enquiries among manufacturers show that, from 1995 onwards, most satellites to be put into geostationary orbit will weigh between 2000 and 2800 kg, so that the policy of dual launches on Ariane-4 can no longer be routinely followed. In addition, an improved version of the Titan launcher is being developed, following the failure of Challenger mission 51L, which will offer the same payload diameter as the Shuttle, confirming a shift in satellite diameter to 4.55 m (compared with the 3.65 m for Ariane-4).

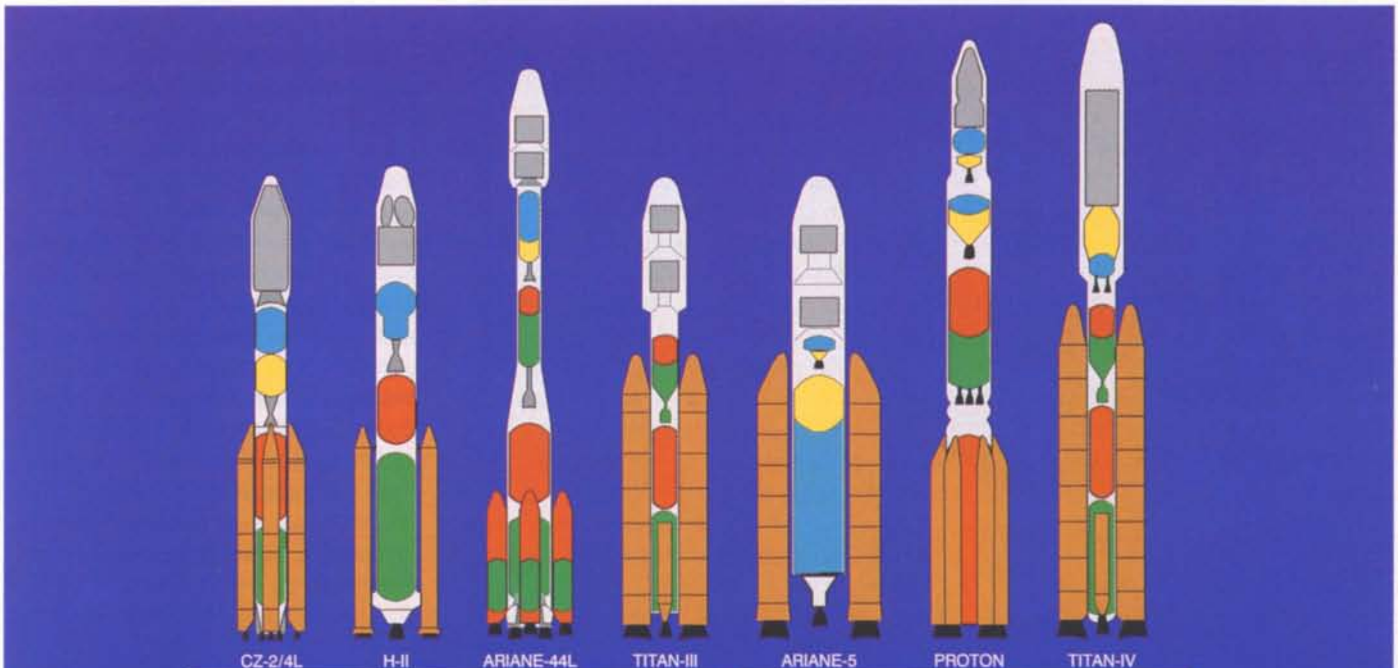
The United States and the Soviet Union already have sizeable launch capabilities and are now busy making improvements to their existing launchers and developing new systems. Japan and China are working hard to gain launcher knowhow (Fig. 1). Though, for the moment, Europe is favourably placed, thanks to its Ariane-3 and -4 vehicles, this privileged position could be undermined in the medium term by the changes now taking place in payloads and launch systems.

There are two prime requirements that are being cited more and more by the users, and which will have to be fully satisfied by the future launch system. Firstly, there is the stringent demand for launch reliability, as the payloads themselves are becoming more and more costly, and the losses in operating income after a launch mishap more and more substantial. Secondly, there are the launch costs themselves, which form a major part of the total cost of a satellite system. Future users are going to choose whichever launch system is the most economical.

Alongside the battle being waged on the commercial satellite launch market, the USA and the USSR have embarked on major Space-Station and low-orbit intervention programmes. Europe, which is seeking to participate in this promising sector of space activity, must:

- contribute to the permanently manned Space Station and Platforms (the elements of the European Columbus Programme)
- acquire the ability to service and intervene in the Columbus system (via the Hermes spaceplane)
- acquire the ability to launch Hermes and elements of the Columbus system.

Figure 1 — Future expendable-launch-vehicle competition scenario



	CZ-2/4L	H-II	ARIANE-44L	TITAN-III	ARIANE-5	PROTON	TITAN-IV
PERFORMANCE GTO ? (KG)equiv.	2300 to 2700	3800	4200 (dual: 3700	4600 – 4200 to 4400	6800 5900)	3800	8200 (5300 with transtage)
LIFT-OFF MASS (t)	420	258	471	692	717	770	860
LENGTH (m)	47	48	58.4	47	47	60	63

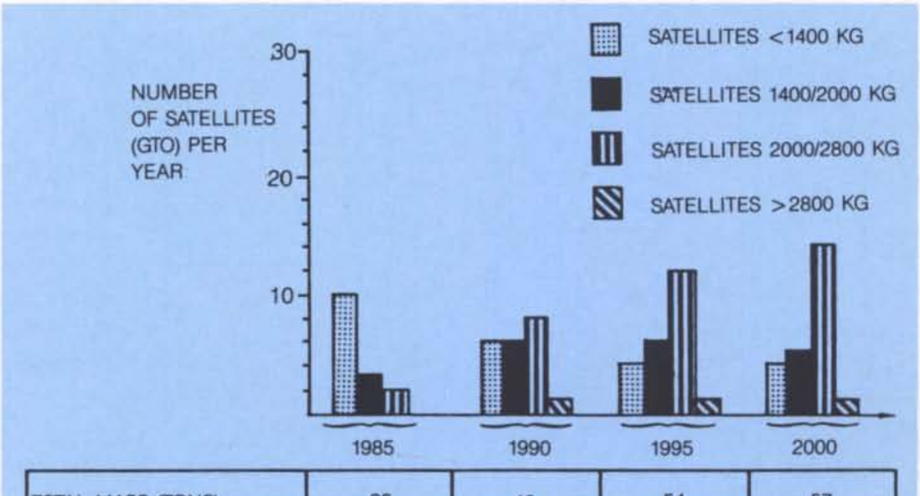
It is evident from the foregoing that an entirely new launch system needs to be developed, and this realisation lay behind the adoption, by the European Ministers meeting in Rome in January 1985, of the concept of developing the Ariane-5 launcher.

Ariane-5 missions

The Ariane-5 launch system is destined for three kinds of mission:

- Launching geostationary and Sun-synchronous commercial satellites, and scientific and trial applications satellites. A survey of the number of satellites to be launched between 1985 and the early 2000s, together with identification of the projects currently under way among the manufacturers, shows that there will be a very sizeable increase in the mass to be put into GTO per year, rising by almost 25% between 1990 and 2000, despite a virtually constant annual launch rate (Fig. 2). In the case of low-Earth-orbit launches also, there should be a significant increase in activity, with a stepping-up of the Soviet presence, the development of a manned Space Station by the USA, and ultimately, the setting-up of Europe's own in-orbit infrastructure.
- Launching the Hermes spaceplane. The novel approach taken with the Ariane-5/Hermes configuration makes the launching of automatic satellites

Figure 2 — Market forecast for satellites to be launched into Geostationary Transfer Orbit (GTO)



	1985	1990	1995	2000
TOTAL MASS (TONS)	25	46	54	57
SATELLITES PER YEAR (GTO)	15	21	23	24

Figure 3 — Useful payload volume of Ariane-5

distinct from flights by astronauts. It nevertheless takes full advantage of the similarity in performance demanded of a launcher for automatic satellites and for a crew-carrying vehicle. The fact that the same type of launcher can be used for both missions avoids a substantial spreading of resources.

— Launching elements of the Columbus system. Ariane-5 is designed to launch the elements of the European in-orbit infrastructure, developed under the Columbus Programme. These include the Man-Tended Free Flyer (MTFF) and the Polar Platform (PPF).

The Ariane-5 mission models for launches into GTO could take the following form:

— more than 80% of missions in dual-launch configuration, coupling a 2800 or even 3200 kg satellite with a 2200—2800 kg satellite, and

— less than 20% of missions in triple-launch configuration, with one 2000 kg satellite coupled with two satellites of the PAM-D2 or even PAM-D class (1200—1600 kg).

In the case of low Earth orbit, they will be mostly single launches, both because combining payloads is difficult in such a case, and because the single payload being put into orbit could well take up the full capacity of the launcher (e.g. when Columbus elements are being launched).

Ariane-5 programme objectives

The objectives of the Ariane-5 Development Programme are as follows:

— Ariane-5 must be able to put into GTO one or more satellites with a total mass of 6800 kg (including the adapter or multiple-launch devices), using an upper stage. This equates, in the dual-launch configuration, to a lift performance of 5900 kg.

— Ariane-5 must be able to put into a circular low Earth orbit (550 km × 550 km × 28.5°) Station modules or Platforms with a guaranteed mass of 18 000 kg (Columbus MTFF element). It will be capable of lifting 12 000 kg into a circular orbit of 800 km altitude and 98.6° inclination (Columbus PPF element).

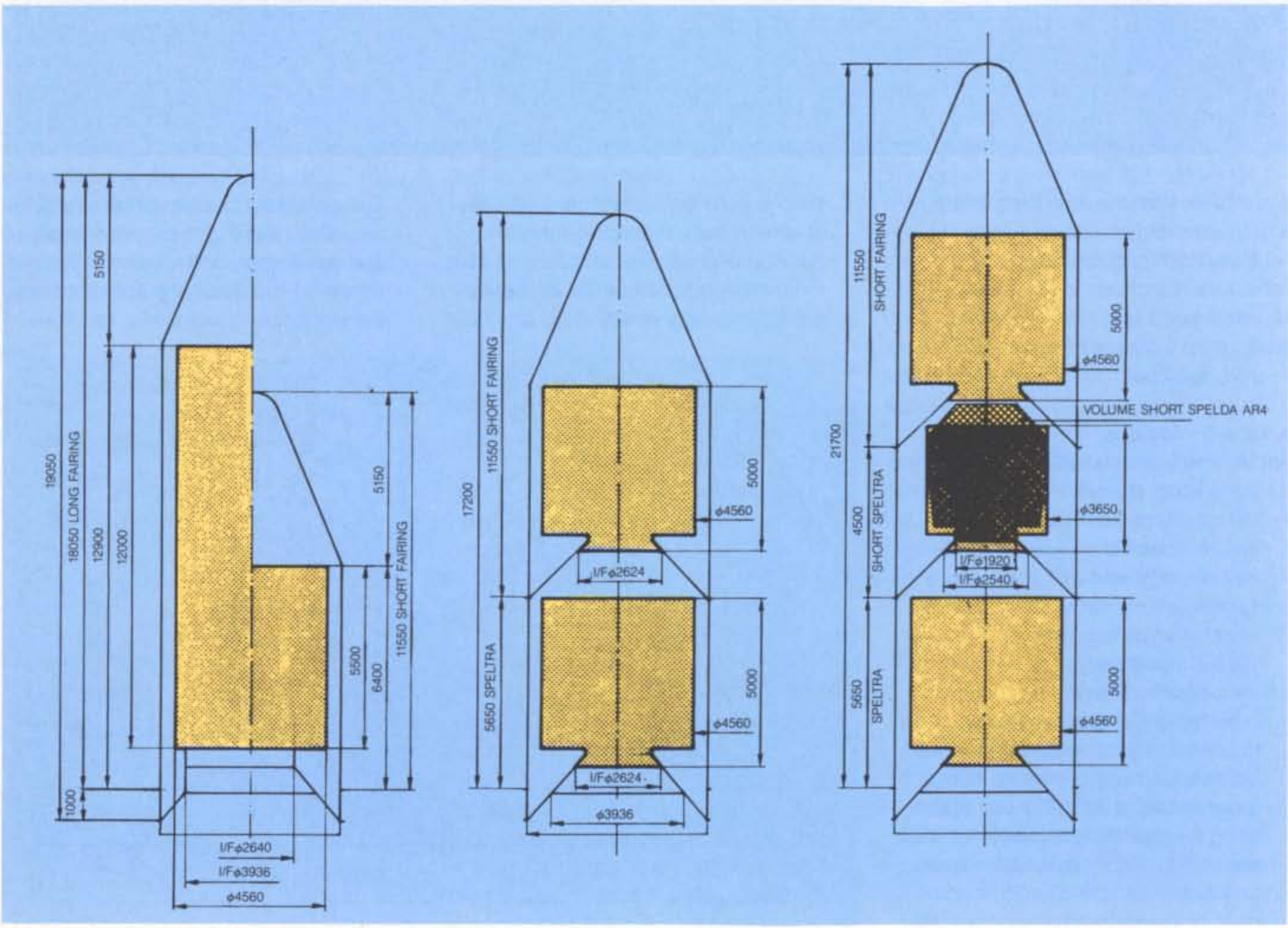
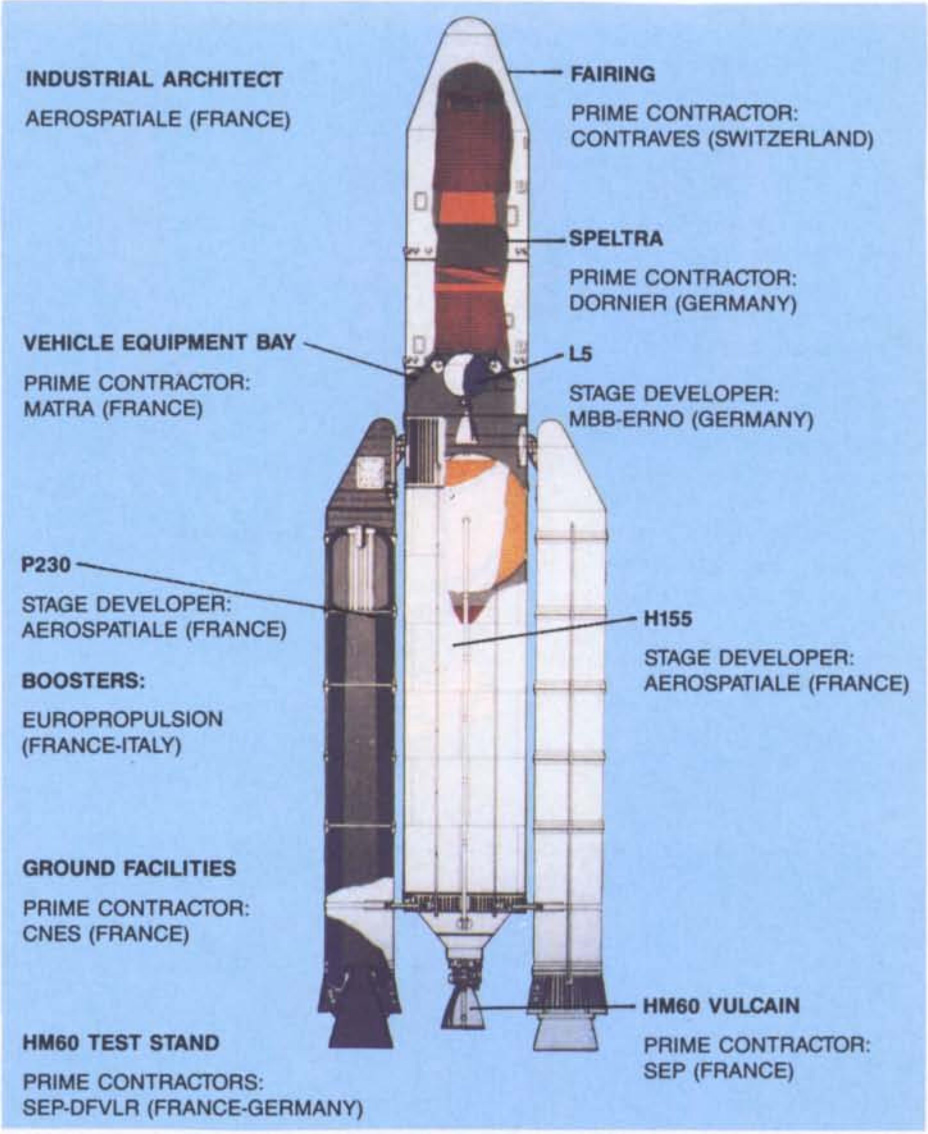


Figure 4 — Major Ariane-5 elements and their respective industrial contractors



- Ariane-5 must be able to put the Hermes spaceplane into transfer orbit in such a way that the spaceplane mass in the final circular orbit (500 km × 500 km × 28.5°) is 21 000 kg.
- The volume provided for payloads should be cylindrical and of 4.57 m diameter, as defined in Figure 3.
- The reliability target is 0.98 for the launcher's total mission; this results in a predicted reliability of 0.99 for the lower composite (for flights carrying a crew). This is an order of magnitude higher than the predicted reliability of 0.90 for Ariane-3 and -4.
- The Ariane-5 design has, in addition to respecting the safety of persons and property, to allow for safe fallback of the stages, and the safety of the crew must not be compromised in the event of a mishap on the ground or in flight. The intrinsic safety target for the Ariane-5/Hermes configuration is set at 10^{-3}.

The aim is to make the cost of using Ariane-5 for a dual launch into GTO at least 10% lower than that of using an Ariane 44L vehicle, assuming eight launches a year including four into GTO. On the basis of this target, Ariane-5 should provide a reduction of some 45% in the cost-per-orbital kilogram compared with Ariane 44L. The production facilities, the design and development of which are an integral part of Ariane-5 development, will support the production of 10 launchers a year. The new ELA-3 launch complex will also support this launch rate.

The Ariane-5 design will also have to provide growth potential, with a view to cutting launch costs still further, or improving performance, or providing a larger volume for payloads, or increasing reliability and/or safety. Conservative measures are taken, whenever this is possible at low cost, to meet this requirement for growth potential, both in the launcher design itself and in the ground infrastructure and test facilities.

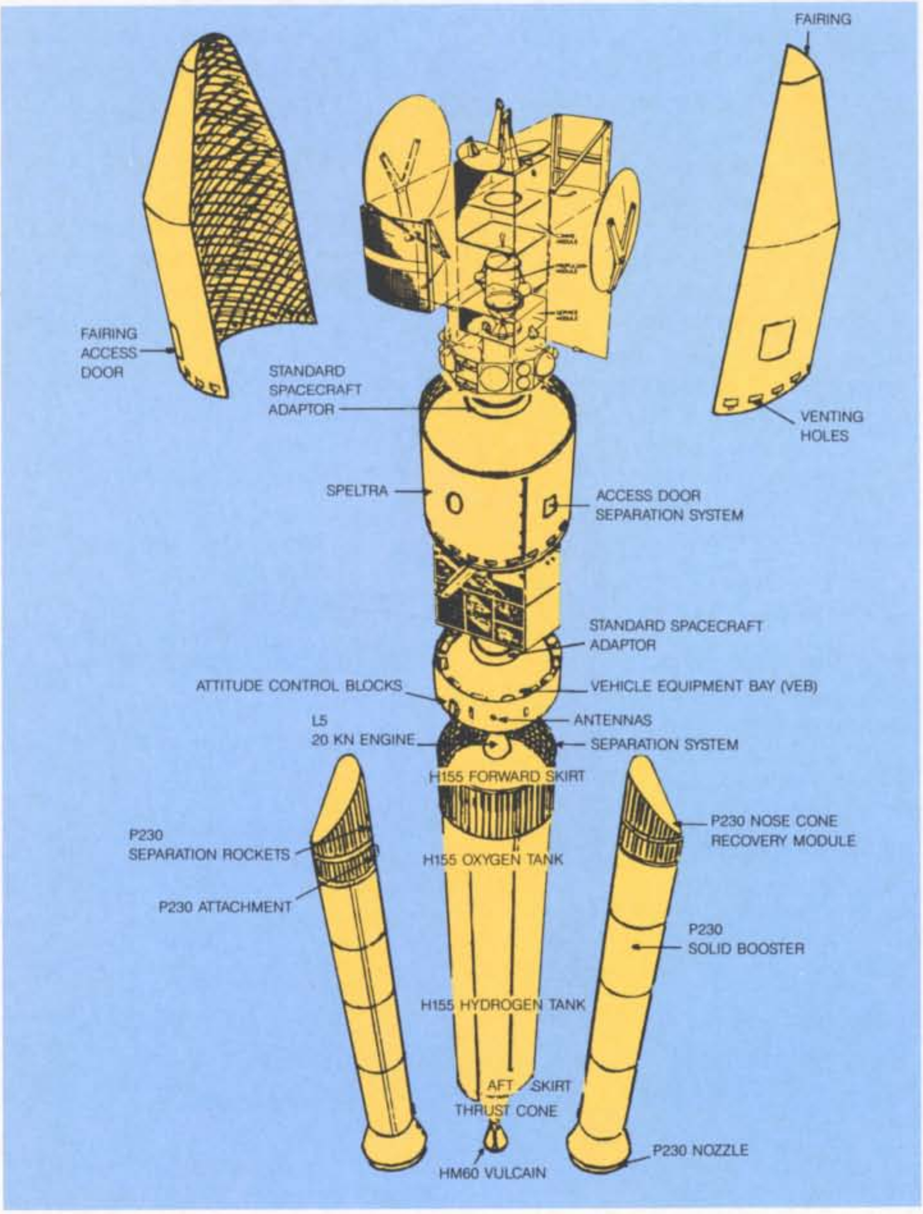
The Ariane-5 launcher

The Ariane-5 launcher is made up of a lower composite which is mission-independent, and an upper composite comprising, for automatic missions, a final stage, a vehicle equipment bay, a fairing and — if required — a Speltra* payload-support structure. For manned missions, this upper composite is replaced with the Hermes spaceplane and its adapter (Figs. 4—6).

The lower composite consists of:
- a main cryogenic stage (H155) ignited on the ground, powered by an HM60 engine and holding 155 t of liquid hydrogen and oxygen; its burn-time is about 615 s
- two large solid-propellant boosters (P230s), each containing 230 t of grain and delivering a thrust of about 750 t at liftoff for a burn-time of about 120 s.

* Speltra: Structure Porteuse Externe de Lancements Triples Ariane (= external support structure for Ariane triple launches). One Speltra makes it possible to lift two satellites; two Speltras fitted one on top of the other will allow a triple launch.

Figure 5 — Exploded view of the Ariane-5 launch vehicle



For automatic missions (Table 1), the upper composite consists of:
- a storable-propellants stage (L5) used for low-Earth-orbit or Sun-synchronous-orbit missions and for putting a payload into geostationary transfer orbit
- a vehicle equipment bay, and
- an upper section that depends on the particular mission in hand, i.e.
  - in the case of a single launch, a short or a long fairing (the Columbus-specific configuration) plus an adapter,
  - for dual or triple launches, one or two Speltra* support structures, the short fairing and the adapter for the payload occupying the lower position.

For manned missions, the upper composite will be the Hermes spaceplane mounted on its adapter (fitted with an additional propulsion unit).

The launcher's powered flight will have two main phases. The lower-composite flight will be virtually identical for all missions. It begins with ignition of the HM60 Vulcain engine on the ground; once the proper functioning of this has been checked, the command is given to ignite the P230 solid boosters, leading to liftoff. At P230 burnout, the boosters are jettisoned and the H155 core stage continues powered flight on its own.

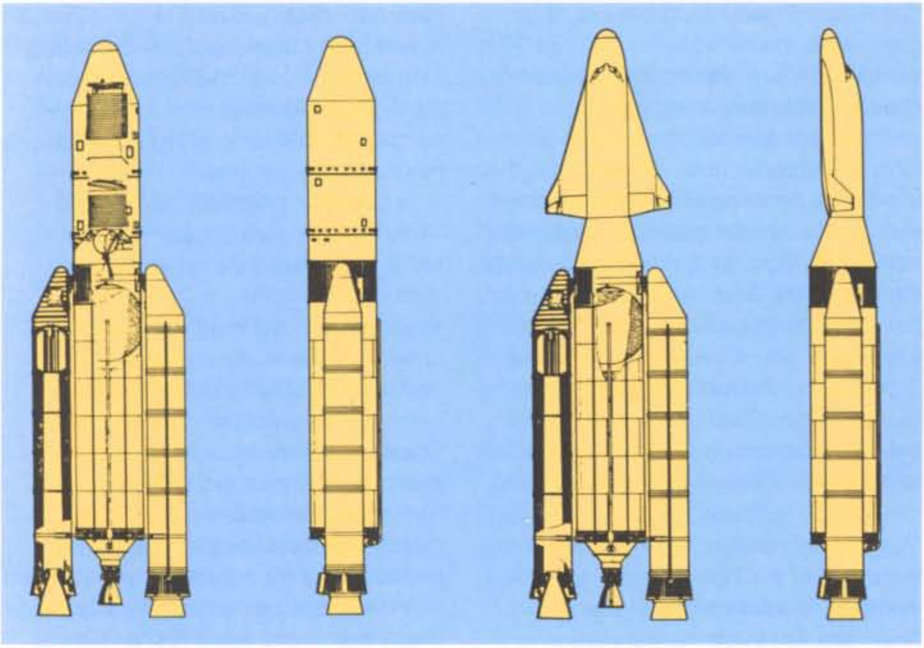
For a geostationary mission, the L5 engine will be ignited immediately after

Table 1 — Functional characteristics of the Ariane-5 launcher (automatic version, GTO mission)

	P230	H155	L5	VEB	Fairing	Complete launcher
Diameter (m)	3	5.4	5.4	5.4	5.4	—
Height (m)	30	30	4.5	2.2	20/11	50
Total mass (t)	269/unit	170	6.0	1.1	2.4/1.4	725
Propellant mass at lift-off (t)	230/unit	LOX: 130 LH2: 25	MMH: 1.7 N_2O_4: 3.5	Hydrazine: 60 kg	—	620
Burn-time (s)	125	615	800	-	-	1415
Thrust (t)	750/unit at lift-off	104 in vacuum	2	-	-	1590 at lift-off

Figure 6 — General configuration options for Ariane-5

Figure 7 — Flight sequence for an Ariane-5/Hermes spaceplane launch



H155 separation. For low-Earth-orbit missions, at the end of the first phase the L5 engine will be placed into final orbit together with the vehicle equipment bay and payloads.

In the case of a Hermes launch, the spaceplane will be separated from the H155 at the end of the first phase. Hermes will then be put into a transfer orbit, using the propulsion unit housed in its adapter. After separation from the adapter, the spaceplane will circularise its orbit at the first apogee and commence the manoeuvres demanded by its mission (Fig. 7).

The fallback of the stages is an important problem since they can neither be left drifting in orbit, nor be allowed to fall back unsupervised. The launcher's

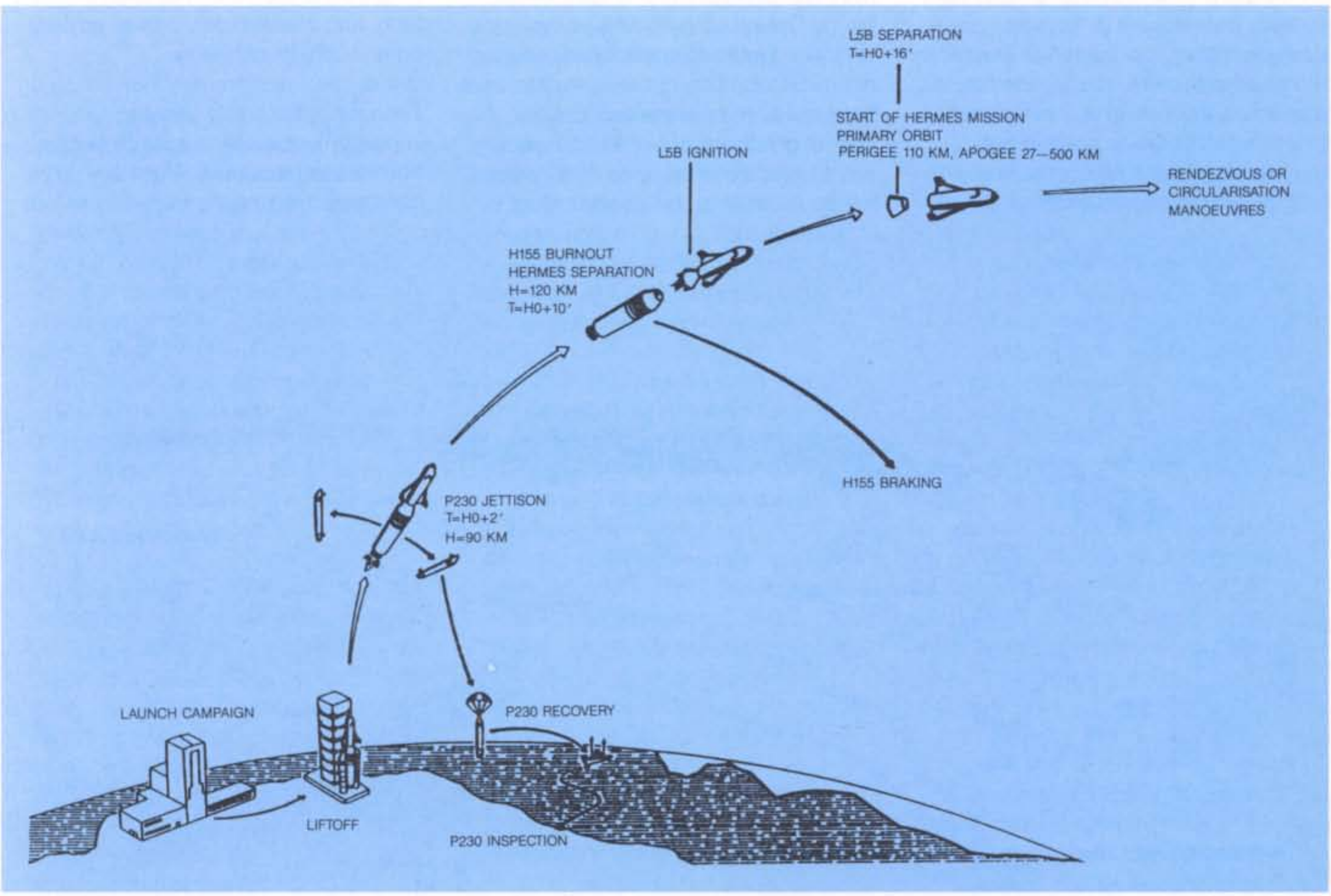


Figure 8 — General overview of the Ariane launch pads

trajectory will be chosen so that the H155 stage will splash down well out in the ocean. However, in some instances (mostly Hermes missions), this stage will have to be de-orbited without using its full performance. In these cases, the pressurisation gases remaining in the tanks are to be used for the de-orbiting process. De-orbiting of the L5 and vehicle equipment bay, which will be in an orbit close to that of the payload, will be commanded by the onboard computer. The P230 boosters will fall back into the sea and be recovered for inspection, so that dimensioning margins can be checked during the qualification flights. Their recovery in the operational phase will make it possible to detect any creep in manufacturing tolerances.

Ariane-5 system interfaces

The Ariane-5 system will, of course, be perfectly interfaced with the other prime elements making up the future European in-orbit infrastructure, namely Hermes and Columbus. However, it has also to be easily adaptable to commercial payloads, and must be compatible with existing ground infrastructures.

The Ariane-5 lower composite must be compatible mechanically, aerodynamically, electrically and more generally at system level, with the Hermes spaceplane, with which it will form a composite quite different from that used for automatic missions. In particular, Hermes houses the electrical equipment needed for flight control and guidance of the composite, since it wholly replaces the functions carried out by the vehicle equipment bay in the automatic version. A propulsion module, derived from the L5 engine and fitted in the adapter, will put the composite into transfer orbit prior to orbit circularisation by the spaceplane.

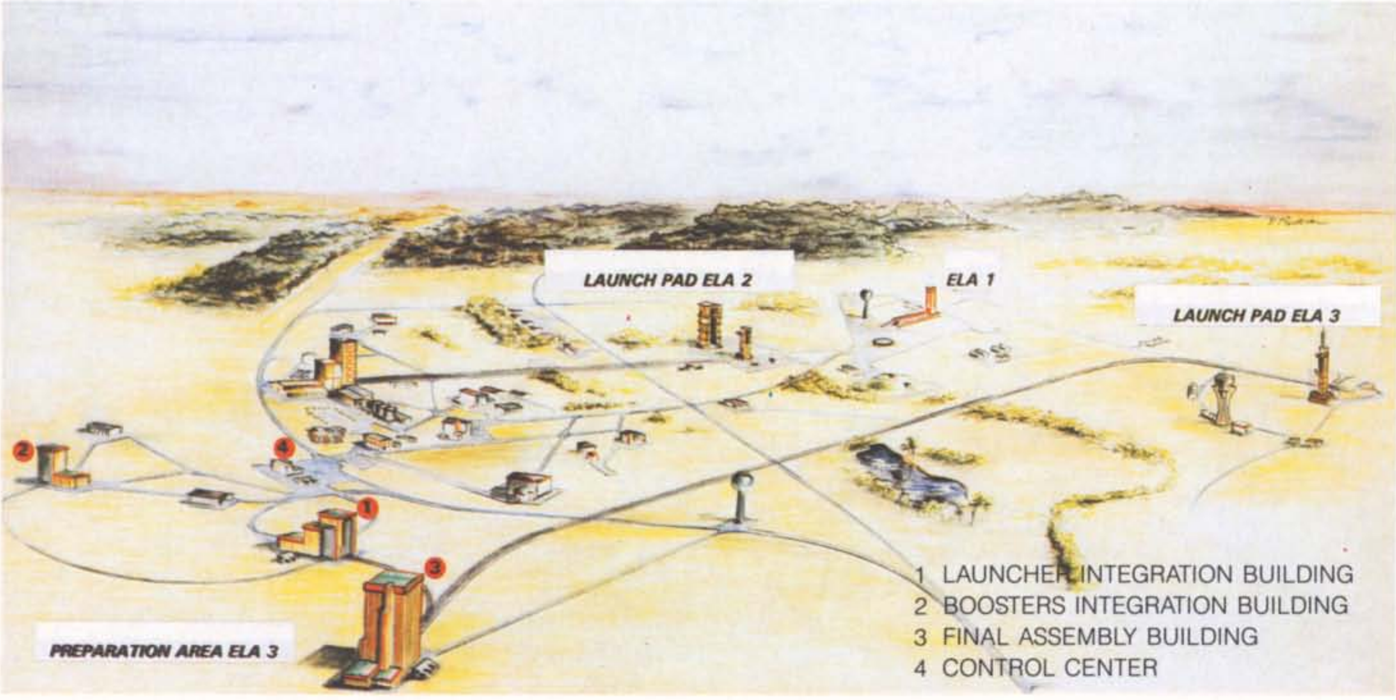
The Ariane-5 design has to allow the launching of the Columbus Programme elements, which in terms of size and mass, constitute very special payloads. A long fairing has been planned, to provide the volume needed for the Columbus elements, as well as a special adapter. At system level, coupled Ariane-5/Columbus dynamic studies have been made to take into account the special characteristics of this payload, and to ensure, for instance, that Ariane-5 will be pilotable in this configuration.

Ground infrastructure

A new launch complex, ELA-3, is being built for the Ariane-5 launcher close to the Agency's existing ELA-1 and ELA-2 complexes in Kourou in French Guiana. It has two distinct zones
— a launcher preparation zone, and
— the launch zone proper,
which are linked by a railway track.

To allow up to ten launches a year, and to make it less vulnerable to any launch-pad accidents, the ELA-3 infrastructure has been simplified as far as possible. Operations in the launch zone, for example, will be limited to those of the final countdown phases. This, in turn, means that launcher preparation and payload integration have to be conducted in a dedicated preparation zone at a safe distance from the launch zone. The launcher will then be transferred from one zone to the other in a fully-integrated form, and checked-out, with its payload, on a mobile launch table.

Because of the safety constraints imposed by the use of solid-propellant boosters, separate buildings have to be constructed, far enough apart to ensure



the safety of personnel. There will therefore be four main buildings in the preparation zone (Fig. 8):
- the Booster Integration Building, where the P230s will be assembled and checked out
- the Launcher Integration Building, where all the assembly and checkout operations will be carried out on the main body of the launcher (H155 and L5) and where the P230 boosters will be mated with it
- the Final Assembly Building, where the payload composite will be assembled and erected, the fairing assembled, the L5 tanks filled and the final electrical checkout conducted
- the Launch Centre (CDL3) where the checkout and command equipment will allow the activation of two launchers at the same time, and from where operations will be controlled and monitored up until the moment of launch.

The ELA-3 development also involves the construction of:
- a liquid-hydrogen production plant, and another for producing liquid oxygen and liquid nitrogen, with the associated storage facilities
- the various logistic facilities needed by the new launch complex (generally an extension of those already existing at ELA-1 and ELA-2)
- the maritime transport needed for shipping the launchers from Europe to French Guiana, and
- the port and road facilities needed for unloading and moving the launchers once in French Guiana.

ELA-3 will, in particular, be used as a site for testing the H155 stage; this involves some adaptation of the launch table and checkout facilities. Similarly, some ELA-3 facilities intended for booster preparation are to be used for tests on the P230s in Guiana, on a special stand located 3 km from ELA-3 and linked to it by a railway. The launcher tracking, safety and telemetry reception facilities will be adapted for Ariane-5 launches.

In particular, additional down-range facilities to be used or setup for the various Ariane-5 trajectories (GTO, LEO or SSO) are envisaged to complement the existing down-range stations.

The Preparatory Programme
Following on from the Resolution adopted at Ministerial Level on 31 January 1985, the Ariane-5 Preparatory Programme covers work on the HM60 engine (Part 1), and on the launcher itself without the engine (Part 2).

Preparatory Programme work on the HM60 engine, scheduled for the period December 1984 to December 1987, is of three kinds:
- technological work on the engine's critical elements (bearings, dynamic seals, turbines, pumps, materials and manufacturing methods)
- the definition of hardware and fabrication (drawings for and fabrication of the turbopump prototypes), and
- full development and acceptance of the liquid-hydrogen turbopump test stand at Vernon, development of the chamber test stand at Hardthausen, studies and choice of firms to build the engine test stands at Vernon and Hardthausen, and carrying out the civil-engineering work involved.

The work on the launcher itself, planned for the period January 1986 to December 1987, is in five distinct parts:

- studies and tests at system level (trajectories, performance, aerodynamics, flight guidance, general loads) and the associated tests (aerodynamics and acoustics)
- studies connected with dependability
- study of subassemblies (solid boosters, cryogenic-stage propulsion system, linking structures and nozzle gimballing systems)
- upper composite
- technology studies:
  - development of solid-booster barrel sections
  - choice of solid propellant and fabrication process
  - development of large-dimension nozzle and its flexible mounting
  - choice of insulating material for the cryogenic stage
  - search for optimum solution for the injector of a 20 kN engine for the upper stage
  - launch system (detailed pre-project study, and preparatory work)

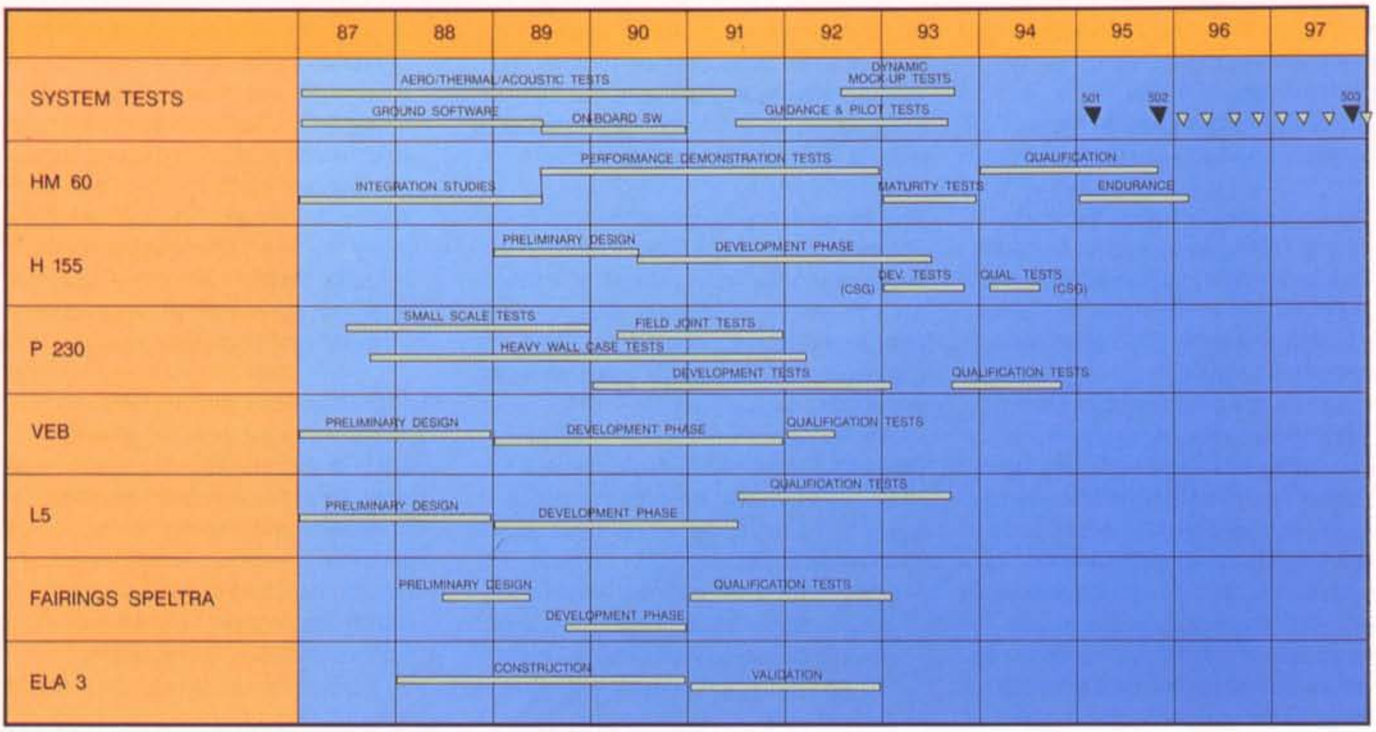
The Development Programme
Development of the Ariane-5 launch system (Fig. 9) involves:
- development and ground qualification of the elements making up the launcher
- development and qualification of the launch and logisitic facilities
- flight qualification of the system.

System activities include:
- overall studies allowing definition of the general system characteristics and performance and of the general specifications vis-à-vis the launcher's subassemblies
- studies connected with dependability (reliability, availability and safety)
- system tests:
  - reduced scale — aerodynamic, acoustic and thermal
  - 1:1 scale — static/dynamic structural tests, flight control and guidance simulation, validation of electrical systems.

The development work on the P230 solid boosters will permit the running, at the end of the Development Programme, of two qualification tests on the complete stage under conditions as close as possible to those prevailing in flight. The overall plan can be set out as follows:
- individual tests on each of the subassemblies or items of equipment
- tests on subassemblies by integrating equipment (two bomb tests, circuit tests, vibration tests on subassemblies and recovery tests)
- booster tests with step-by-step integration of adjacent elements (four

Figure 9 — Ariane-5 overall development schedule

Figure 10 — ESA Long-Term Plan for Space Transportation Systems



development hot tests and two qualification hot tests)
- two-stage qualification hot tests in flight configuration.

This approach makes it possible to arrive at full-stage qualification by progressively integrating elements qualified at a lower level.

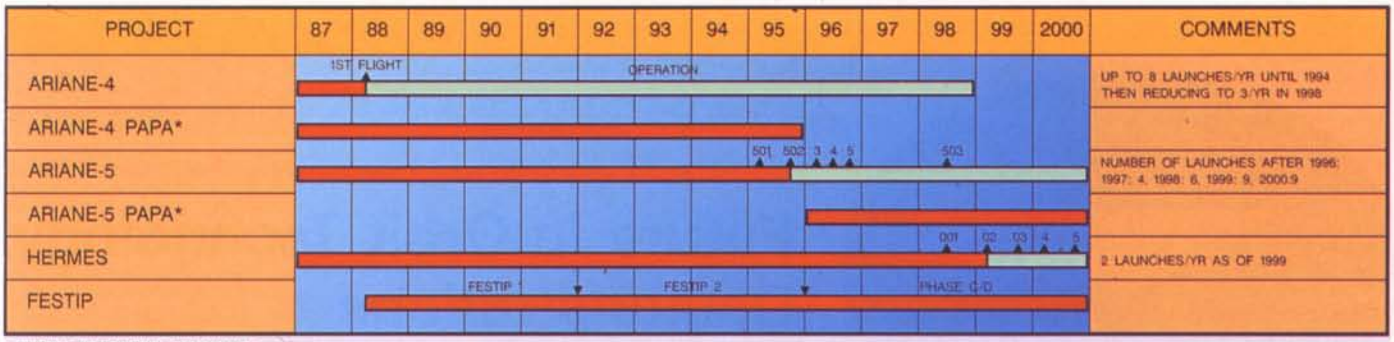
The HM60 Vulcain engine-development programme is divided into two phases:
- the present preparatory phase, leading to validation of the technologies and critical components, to prototype fabrication of the main subassemblies, and a start on building the necessary test stands
- a development phase that covers finalisation of the definition and production master files, completion of all the test facilities, and the carrying out of the development and qualification tests.

The diverted-flux engine configuration allows separate development efforts on the two turbopumps, the combustion chamber and the gas generator.

As for the P230 boosters, the test logic involves progressively integrating subassemblies that have already been qualified, until a complete engine is arrived at. Endurance testing will be conducted at engine level.

Thus, a total of 350 tests at engine level will be run during the development programme, up to qualification flights in the automatic version, to which will be added 200 extra tests to demonstrate readiness for flight with a crew. This can be compared with 180 tests run on the HM7 during its development and the accompanying programme following on from this, and the 700 tests on the cryogenic engine of the US Space Shuttle (though in that case the engine was recoverable).

The main development and ground-qualification activities in respect of the H155 stage take in:
- development of the stage structures, including static tests for overall or local stiffness followed by a fracture test
- development of the insulated tank, including engineering studies and development and qualification tests (successive pressurisation tests on a sample filled with hydrogen and nitrogen until it bursts)
- development tasks on the propulsion elements (progressive integration of elements making up the propulsion unit, during battleship-tank tests)
- stage activities proper including, apart from engineering work, stage tests in Kourou over two campaigns:
  - the development ('M') campaign will serve, prior to the test-stand firing, to validate the facilities and procedures for fluid and mechanical operations on ELA-3. In particular, it will allow final development, via hot tests, of the stage's propulsion unit in close to flight configuration
  - the qualification ('Q') campaign will lead to the stage being qualified. The qualification H155 will be in flight configuration, fitted with



* PRODUCT IMPROVEMENT PROGRAMME

qualified subassemblies. Firings on the test stand result in ground qualification of the stage.

The same approach is used for the L5 stage as for the H155, namely design of the stage's components and subassemblies, verification and demonstration of their performance, integration of the subassemblies as soon as possible, and checks at stage level.

Steps at propulsion-unit level will include:
- characterisation of the injector in an engine chamber, at reduced scale
- investigation of the injector's stability range on a water-cooled engine chamber, followed by acoustic characterisation of the chamber
- startup tests in vacuum, engine qualification, and stage final development and qualification tests.

Development of the Vehicle Equipment Bay (VEB) is being based on past experience with the Ariane launchers, and is tied to the specific aspects of Ariane-5 (in particular the dimensions of the VEB and the use of a bus system). The equipment qualification tests will be as representative as possible of the VEB's flight environment. The attitude-control system will undergo hot tests at subsystem level. At assembly level, the VEB will undergo acoustic, thermal and separation tests, as well as validation tests and electrical functional tests.

Development of the Speltra and fairing will include:
- studies and characterisation and development tests to prove the technical solutions adopted, and
- qualification tests (static loading, continued to fracture) and separation tests (in a vacuum chamber, in the case of the fairing).

Three test flights, intended to validate the in-flight functioning of the entire Ariane-5 vehicle and the functioning of the launch base and associated tracking facilities, are planned:
- Flight A 501: A single launch into Sun-synchronous orbit, with the upper section consisting of a long fairing. This corresponds to the dimensioning of a commercial mission in terms of mission duration.
- Flight A 502: Launch into GTO of three payloads, with the upper section consisting of two Speltras and a short fairing. This is the dimensioning mission for the VEB's attitude-control system and the structural loading on the launcher.
- Flight A 503: Launch of the Hermes spaceplane into a circular 500 km low Earth orbit, inclined at 28.5°.

Main development milestones

The Ariane-5 Development Programme is planned to start in January 1988 at the latest, the main development milestones being:

System concept review: Late 1987
Start of development: 1 January 1988
Preliminary design review of launcher stages and elements: 1987 to 1990
Ground qualification of launcher stages and elements: 1993 to 1994
End of system tests in Europe: 1993
ELA-3 available: 1992
First test flight: Early 1995
End of development for launches of automatic payloads: 1995
First operational flight: Early 1996
First in-flight test (Hermes mission): Late 1997
End of development: 1997.

Figure 10 shows the timetable for the first flights by Ariane-5, set against other milestones in the Agency's Long-Term Plan.

Operational phase

After two qualification flights of the automatic version in 1995 (501 and 502), Ariane-5 will be declared operational, with the first commercial flight to put an automatic payload into orbit planned for early 1996 (conventional satellites or the Columbus Polar Platform).

After additional development work for manned flights and in-flight qualification for the first version of Hermes (H001) in late 1997, Ariane-5 will go into service for manned missions from 1998 onwards.

Until Ariane-5 is available operationally for automatic missions, operational launches of Ariane-4 are planned at a rate of eight per year to meet user demand. The decision timetable will have to be a compromise between the need to protect users from any delays or difficulties involved in Ariane-5's qualification and ensuring a rapid transition to solely Ariane-5 flights. This decision could be taken between flights 501 and 502; therafter, Ariane-4 production will be wound down, and Ariane-5 production will increase. The overall launch rate will accelerate from three launches in 1996 to reach full capacity of seven to nine launches in 1999, by which time the last Ariane-4s will have been launched.

Future In-Orbit Technology Demonstrations

H. Stoewer & G.G. Reibaldi, Systems Engineering and Programmatic Department, ESA Technical Directorate, ESTEC, Noordwijk, The Netherlands

The In-Orbit Technology Demonstration Programme plays an important role in the framework of the European Long-Term Space Plan. Together with the Basic Technology Research Programme and the Preparatory Support Technology Programme, it is one of the three 'pillars' of ESA's overall Technology Programme.

The First Phase of the In-Orbit Technology Demonstration Programme was initiated in 1987 and will be completed in 1990. Future phases will expand the number of technologies to be tested in orbit in order to reduce the development risks facing Europe's future, very challenging space programmes.

Introduction

An increasing number of advanced space technologies require in-orbit demonstration as the final stage in their development before they can be integrated, without excessive risk, into new projects or embraced by industry in commercial ventures. To cope with those needs, ESA has already initiated the first phase (1987—1990) of its In-Orbit Technology Demonstration Programme (TDP). This Programme will extend well into the 1990s, as envisaged in the European Long-Term Space Plan, with a steadily increasing number of in-orbit tests being conducted each year.

Such in-orbit testing reduces the risk element in more complex missions and provides European industry with the rapid flight testing of components and subsystems that it needs to compete in World markets.

The initial TDP phase will provide a series of individual flight opportunities for technology experiments, mostly involving technology items developed within the ESA or national technology programmes. Three specific themes are addressed:
- Space Environment Effects, e.g. atomic-oxygen effects on materials
- Space Engineering Data, e.g. microgravity disturbance measurements and sensor calibration
- Technology Performance Data, e.g. for inflatable space-rigidised antennas, gallium-arsenide solar arrays.

Figure 1 — ESA future infrastructure

Figure 2 — Experiment to assess the effects of atomic-oxygen interaction by means of ground testing and low-Earth-orbit exposure on Space-Shuttle flights and on Columbus

In subsequent programme phases, in addition to individual experiments, larger complements of equipment for, for example, robotics, in-orbit fuel-transfer tests, and fluid dynamics, will be flight-tested as partial payloads on Eureca, on Ariane (as piggy-back payloads), on various spacecraft, and later on the Columbus elements. The in-orbit TDP will also continue to provide a service, on a cost-reimbursement basis, to European companies that need to characterise their new technologies in orbit.

The TDP follow-up phases will concentrate on three avenues:
- Continuation of experiments of *common interest,* particularly in the field of space environmental interaction.
- Support to the *development and utilisation phases of new programmes,* especially Columbus, Ariane and Hermes, for which component testing for fuel cells, robotics, rendezvous sensors, re-entry materials, life-support and EVA constitutes one element, the other being the *preparation for the utilisation of the orbital infrastructure* (Fig. 1), i.e. experiments for the Columbus technology workbench and attached exposure facility.
- *In-orbit performance testing for new technologies,* such as large antennas, calibration of new sensors, electric propulsion and plasma interactions.

Selection criteria and experiment categories

The selection of the 13 experiments for the initial TDP phase resulted from the sifting of more than 150 experiment proposals received from industry, research centres and universities. The selection criteria applied were:
- cost effectiveness of the proposed experiment
- increased confidence in performance predictions
- reduction of technical and financial risks in the implementation of future programmes.

Similar criteria will be applied in the screening of the experiments proposed for the subsequent TDP phases, which are still in an early planning stage.

The areas of technology that are currently considered promising candidates for future TDP phases fall into a number of distinct categories.

Experiments of common interest to existing and future programmes

Materials

The space environment very often modifies the properties of materials in an unpredictable manner, making in-orbit testing a mandatory step.

In particular, the effects of radiation combined with high vacuum and thermal cycling are difficult to simulate on the ground. Also, the presence of atomic oxygen in low Earth orbit seems to induce degrading effects, which are particularly critical for solar-array components (Fig. 2).

Investigation of changes in the performances of advanced electronic components due to radiation is also foreseen as a follow-up to the present TDP phase, with a so-called 'Single-Event Upset in Electronics Experiment'.

In-orbit measurements of radiation environment are needed for the manned programmes to verify existing theoretical models. Astronaut dosimeters also require in-orbit testing.

Dynamics of flexible structures

Future space structures will be much larger and therefore more flexible than their forerunners, leading to potential coupling problems with attitude- and orbit-control systems, etc. Columbus and the Man-Tended Free Flyer (MTFF) are good examples in this respect (Fig. 3).

Complex, sophisticated software has been developed by the Agency in recent years to evaluate the coupling between such structures and their control systems, but no in-orbit verification studies have yet been made with real structures. An in-orbit test using a deployable structure will lead to improved confidence in the validity of these analytical models to be verified.

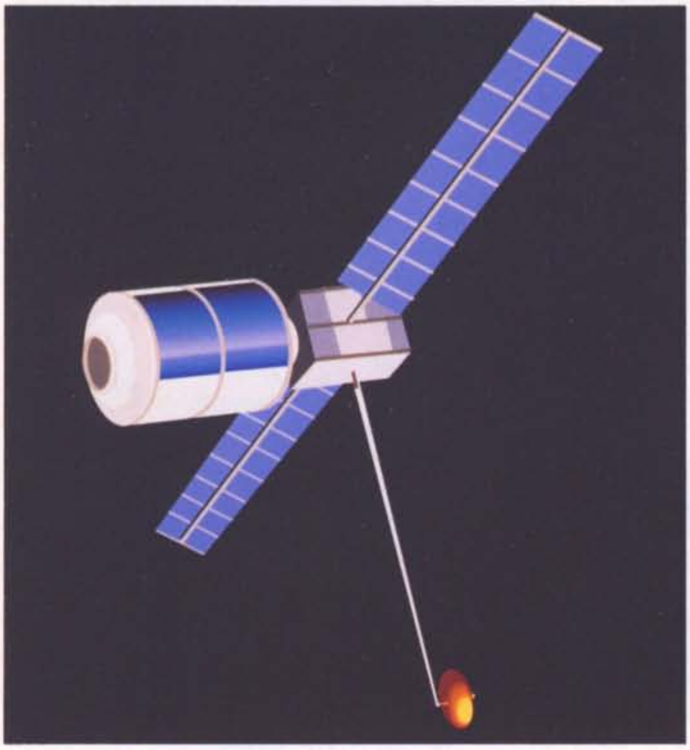
AOCS thrusters and propellants

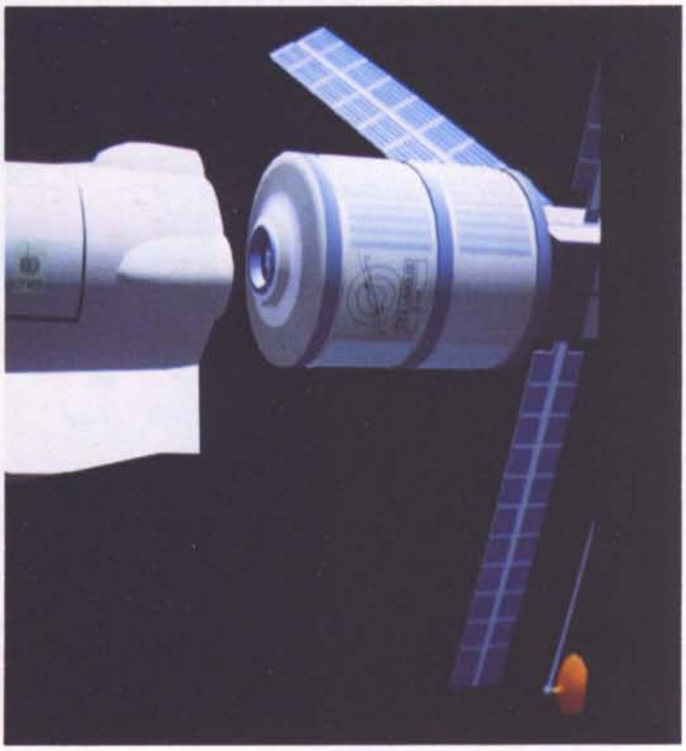
Characterisation in the real orbital environment of the plume impingement of attitude-control thrusters is urgently needed to verify the existing mathematical models, in view of the many rendezvous and docking

Figure 3 — The Columbus Man-Tended Free Flyer

Figure 4 — Rendezvous and docking: needed for Columbus and Hermes

Figure 5 — EVA: technology new to Europe requires in-orbit testing of critical components





manoeuvres to be carried out with the Space Station, Columbus, and Hermes.

Another area requiring study in orbit is the movement of propellants, particularly in the attitude-control tanks (sloshing), and how they affect the microgravity environment of the platform on which they are carried.

Support for development and utilisation of new programmes

Rendezvous and docking

In the context of the Columbus and Hermes programmes, rendezvous and docking will play a very important role (Fig. 4). To demonstrate such technology, a phased approach is envisaged which consists first of calibrating and demonstrating rendezvous sensors (i.e. long-range, short-range and proximity sensors) in-orbit, leading possibly to preparation of a complete in-orbit rendezvous demonstration using, for example, the Eureca platform and the Space Shuttle.

Fluid management

Fluid management is a key element in the servicing of the MTFF by Hermes. Demonstrations of the emptying and filling of surface-tension tanks in-orbit need to be carried out to improve fluid management under zero-gravity conditions. The results of these tests will have an important impact on the extent to which tanks may have to be replaced and how excess/contingency fluids aboard Hermes can be exploited by pumping them to the Space Station or Columbus MTFF.

EVA

Extra-Vehicular Activity (EVA) needed for the future manned systems will require several new technologies (Fig. 5), but the demonstration of life-support-subsystem components in orbit is particularly desirable.

Thermal control

Future multipurpose platforms call for significant advances in thermal-management technology. An important

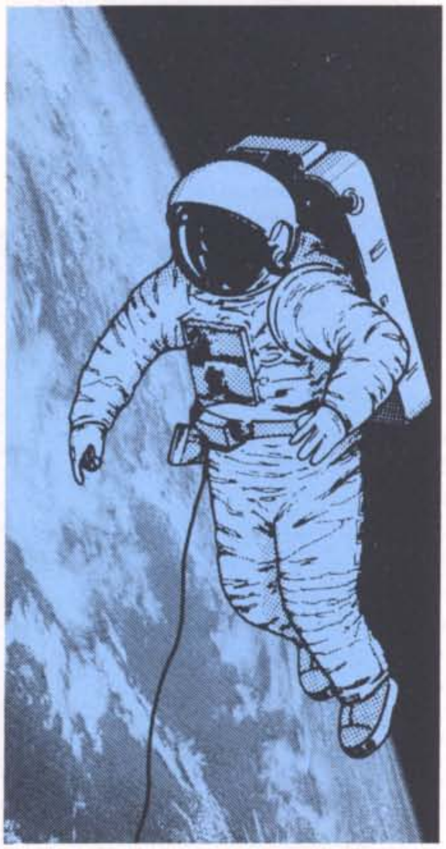


Figure 6 — The Hermes spaceplane: needs re-entry technology

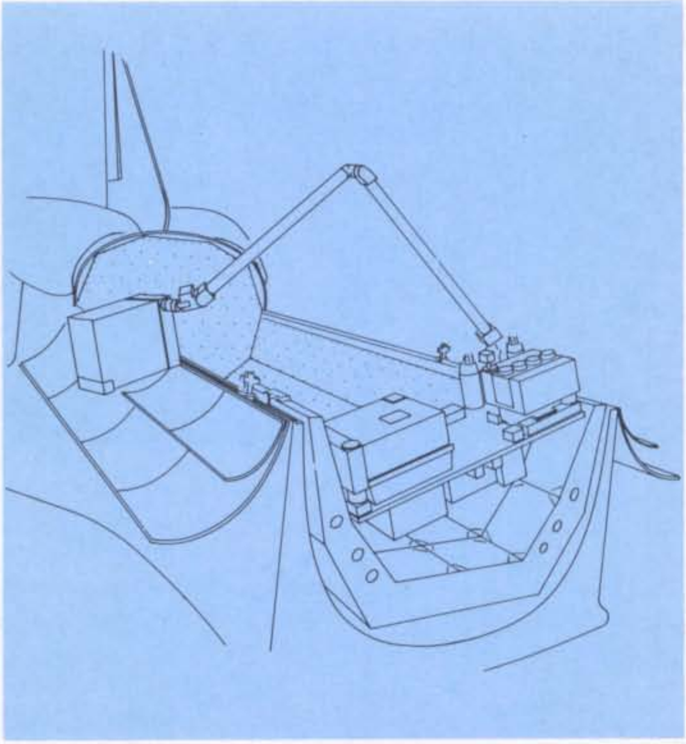


Figure 7 — Robotics technology: has a major role in future ESA infrastructures

technology will be two-phase heat-transport systems, which have great potential due to their high heat-rejection/mass ratio compared with more conventional systems. Capillary pumps, which will have a minimal impact on the microgravity environment compared with rotary fluid pumps, are another technology of high interest and one equally affected by the zero-gravity environment.

Data handling/compression
Columbus will carry a multitude of scientific instruments and large data streams will be generated. Optical storage disks and image-compression devices (e.g. CADISS) which can reduce the amount of data to be sent to the ground will be exploited.

In-orbit demonstration of these items is desirable by obtaining operational data through their preliminary use on Spacelab flights or on pre-operational satellites.

Re-entry
The Hermes Programme and some potential scientific programmes, such as the Comet-Nucleus Sample Return mission, will require the development of re-entry technology, which will be a new domain for Europe (Fig. 6).
Measurements of aerodynamic forces and of heating on a simple well-defined geometrical structure (blunt cone) in hypersonic flow are therefore needed to pave the way for more complex project-related verifications. Once Hermes itself is available, it could carry experimental packages to record aerodynamic data during re-entry, to enable a full understanding of the associated phenomena, and to prepare for future generations of launch vehicles.

Life support
Life-support technology is a fundamental element for Columbus and Hermes. The environmental-control support systems include waste-management equipment, the functioning of which is subject to strong zero-gravity influences. This is also a new technology for Europe and in-orbit testing of critical components before implementation in the programme is very important. Second-generation refrigerators and condensing heat-exchangers will both need in-orbit testing because of the influence of microgravity.

Power storage/fuel cells
Fuel-cell technology will be used for primary power storage onboard Hermes. This technology is new for Europe and in view of its criticality for Hermes, requires in-orbit testing of gravity-dependant components.

Robotics
Robotics technology will play an important role in the operation and servicing of the future infrastructure elements. In-orbit testing can verify the performance of equipment that cannot be adequately tested on the ground. One example is the Servicing-Vision Experiment, which requires realistic in-orbit illumination to verify the

Figure 8 — Inflatable space-rigidised antenna on the proposed scientific spacecraft 'Quasat'

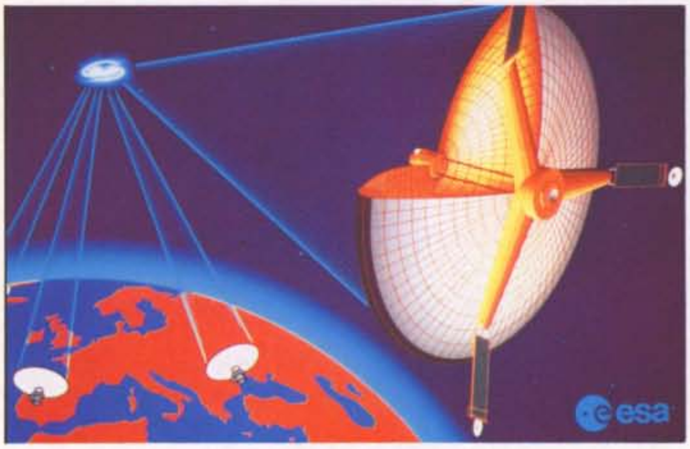
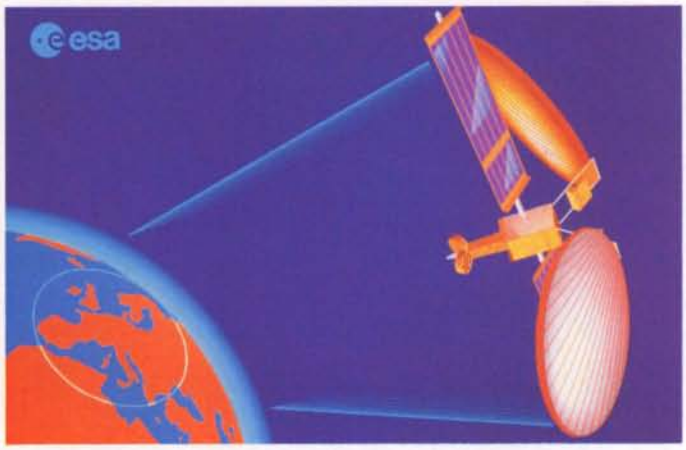


Figure 9 — Inflatable space-rigidised antenna on a telecommunications spacecraft



technology's effectiveness and range of application. In-orbit verification of a joint-drive design as part of the HERA remote manipulation system for Hermes is also being considered (Fig. 7).

Performance testing

Antennas

Large antenna reflectors are needed for the future scientific (e.g. Quasat, Fig. 8) and telecommunications (e.g. PSDE, Fig. 9) projects. Ground testing of large inflatable and unfurlable antenna reflectors, several metres in diameter, is very difficult. Moreover, the validity of the results obtained on the ground is conditioned by gravity effects. The inflatable space-rigidised (10 m-diameter) and the unfurlable antennas (6 m-diameter) currently being developed by the Agency are therefore being considered for in-orbit testing and possibly pre-operational use on experimental satellites.

The FIRST mission being considered as part of the Agency's Scientific Programme (Fig. 10) would require a very accurate reflector (surface accuracy of 8 microns for 8 m diameter) with active panel control. Pre-programme in-orbit calibration/demonstration of such technology on a small scale is being considered.

Sensors

Advanced sensors will be needed for future remote-sensing missions and for the Polar Platform. In some cases, they will require prior in-orbit calibration and testing of components.

Satellite optical links will also require orbital-environment testing at component level before operational use.

Laser-diode range finders for space-based metrology need in-orbit testing to allow calibration and demonstration of such new techniques.

Propulsion

Electrical propulsion will be required for making small corrections for the accurate in-orbit positioning of spacecraft and for deep-space propulsion. Testing of electrical thrusters in orbit is fundamental

Figure 10 — The Far-Infrared Space Telescope (FIRST), which would require active surface control

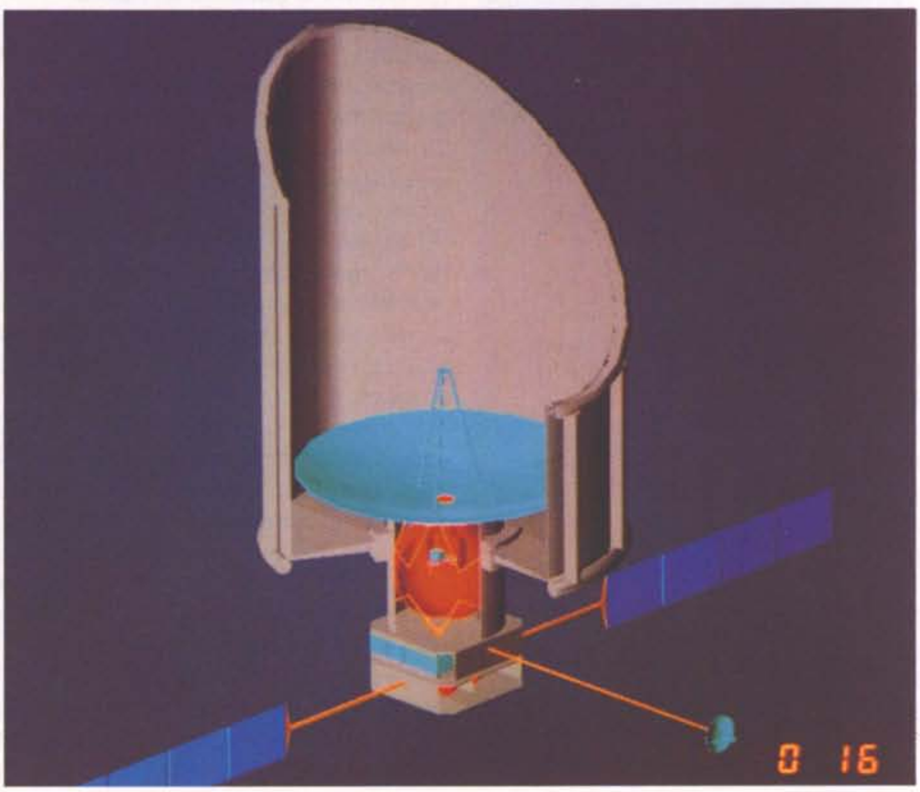
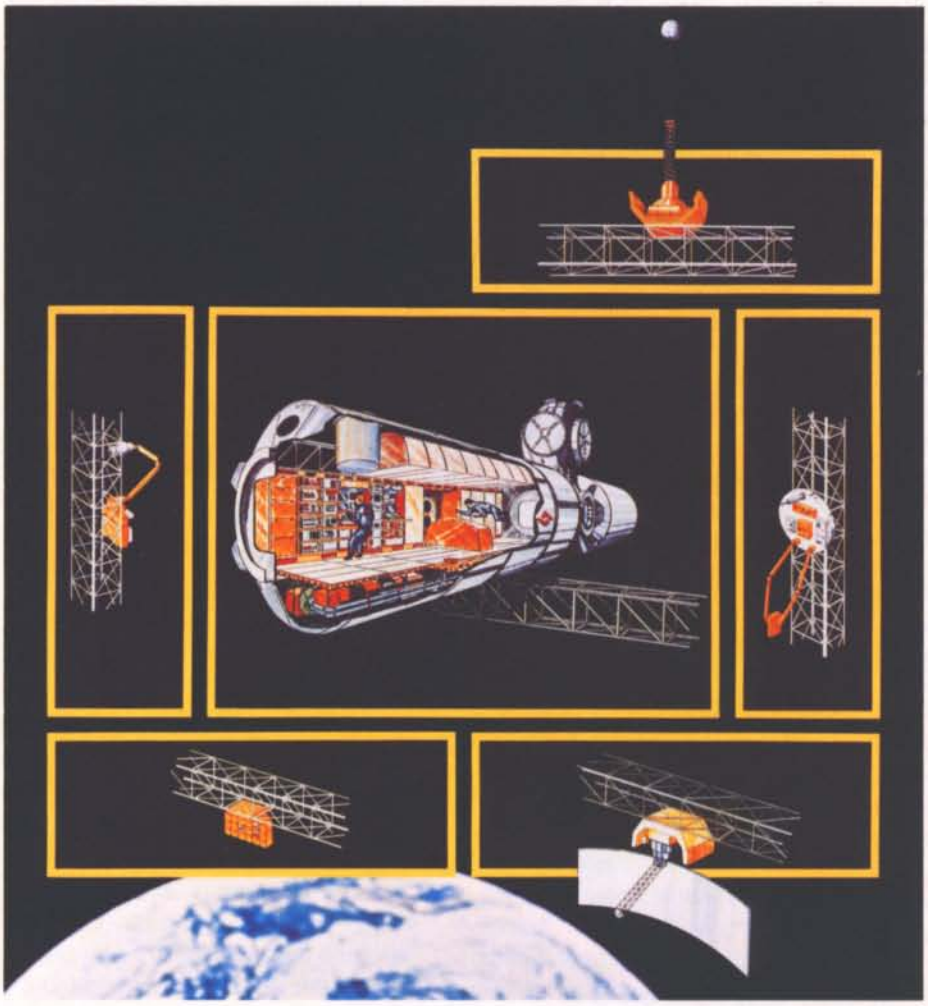


Figure 11 — Possible Columbus technology-demonstration facilities



to the demonstration of the technology's various applications.

Advanced photovoltaics
The power/mass/area ratios of solar arrays are critical spacecraft design parameters. New solar cells with higher efficiency (gallium arsenide) need to be tested in orbit to obtain performance data, as well as to investigate plasma-interaction effects. New types of concentrators such as the Sara louvre would also benefit from in-orbit calibration.

Microgravity measurement and isolation devices
Microgravity is a very important factor for material sciences in space. Advanced micro-accelerometers to measure the orbital microgravity environment accurately and isolation devices for damping out external vibrations from microgravity processing facilities need to be demonstrated and calibrated before their operational utilisation.

Columbus as a carrier for technology experiments

The new capabilities to be offered by Columbus will play a major role in future in-orbit technology development and testing. Approximately half of the technology payloads from the mid-nineties onwards can be flown on Columbus elements, given the availability of suitable accommodation for European attached payloads and acceptable costs.

Because of the unique availability of interactive experiment control and the possibility of in-orbit re-configuration, use of the Space Station for technology demonstration and development can lead in many cases to a considerable speeding up in the application of new space technologies. Hardly surprisingly, therefore, the Space Station is also a major element in the technology-development utilisation programmes of the USA, Japan and Canada.

Most of the experiments presently under consideration will be unpressurised payloads to be attached to the core Space Station and operated with some assistance from the crew in the attached module. A few experiments will be conducted on the Man-Tended Free Flyer.

The principle facilities envisaged for technology development and testing (Fig. 11) are:

- A permanent exposure and monitoring facility for studying the effects on test samples of long-term exposure to the space environment. Limited monitoring of important environmental data will be provided and exchange/reconfiguration of samples/experiment trays at regular times by robotics/EVA are possible.
- A technology work-bench that will provide the necessary internal and external equipment for experiments in the field of in-orbit servicing technologies.
- A technology test-bed for the verification of new technologies offering potential benefit in the long term, or needed to ensure an autonomous operational capability in space for Europe. The list of possible candidate technologies considered typical of this category and selected as a reference for current Columbus utilisation studies, include an advanced service manipulator system, a bi-liquid fluid-transfer management system, and large-structure assembly and tether experiments.

Table 1 — Technologies currently being assessed for in-orbit testing and their potential programme applicability

	Columbus*	Hermes	Telecom.	Science	Earth observ.**
Materials					
Atomic-oxygen interaction	X	X		X	X
UV degradation	X	X	X	X	X
Single-event upset	X	X	X	X	X
Micrometeoroid/debris	X	X			
Radiation environ. monit.	X	X			
Astronaut dosimetry	X	X			
Dynamics of Flexible Structures					
Verification of DCAP software	X	X	X	X	X
Attitude Control Systems					
Plume impingement	X	X	X	X	X
Liquid sloshing	X	X	X	X	X
Rendezvous					
Rendezvous sensors	X	X			X
Rendezvous demonstration	X	X		X	X
Fluid Management					
Demonstration	X	X		X	X
EVA					
Life-support-system components	X	X			
Thermal Control					
Two-phase heat transport system	X		X		X
Capillary pump	X		X		X
Data Handling/Compression					
Optical disk	X				
Data compression	X	X		X	X
Re-Entry					
Measurement of aerodynamic forces		X			
Re-entry guidance and control		X			
Life Support					
Second-generation refrigeration	X				
Components	X	X			
Habitability provisions	X	X			
Power Storage					
Fuel-cell technology	X	X			
Robotics					
Servicing-vision experiment	X	X			X
Robotics technology experiment	X	X			
Orbit replacement units	X	X		X	X
Remote manipulator comp. of Hermes		X			
Antennas					
Large inflatable, space-rigidised			X	X	
Unfurlable			X	X	
Multi-surface				X	
Sensors					
Satellite optical link	X		X		
Laser-diode range finder	X	X		X	X
Propulsion					
Electric propulsion	X		X	X	
Advanced photovoltaics					
Bi-facial solar cells/GaAs	X		X	X	X
Plasma interaction	X		X	X	
Microgravity					
Micro-accelerometer	X	X	X	X	X
Isolation mounts	X				

* Attached Pressurised Module (APM) and Man-Tended Free Flyer (MTFF) with predominantly microgravity payloads

** Polar Platform with predominantly Earth-observation payloads

Figure 12 — Ariane-5: proposed to carry secondary TDP payloads

Other flight opportunities and carriers

The next step in the TDP will be to match the diversity of in-orbit experiments proposed with the various carriers that could be used to accommodate them, the major selection criterion being the least-cost alternative to achieve 'the minimum experiment objective'.

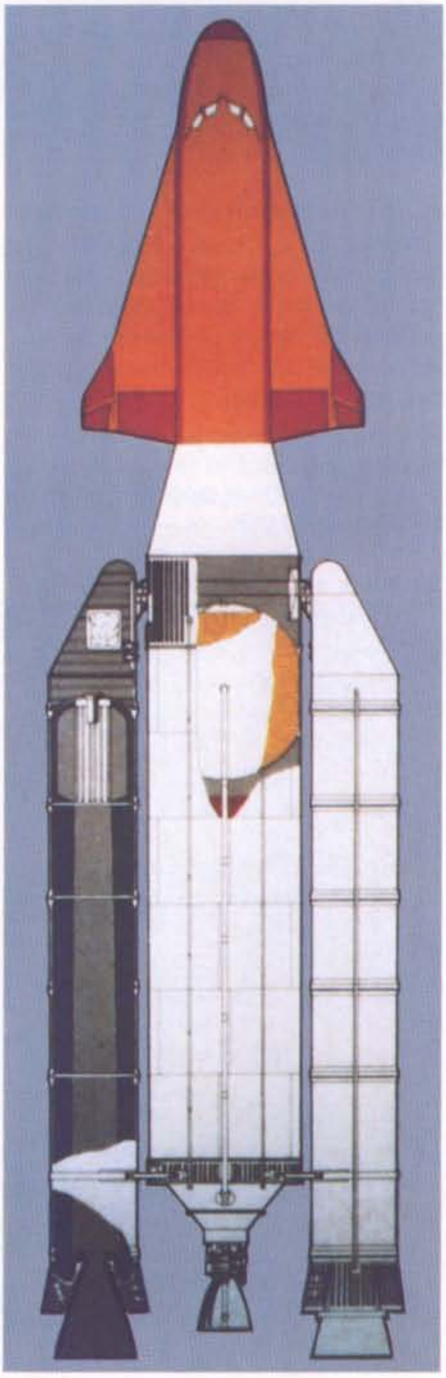
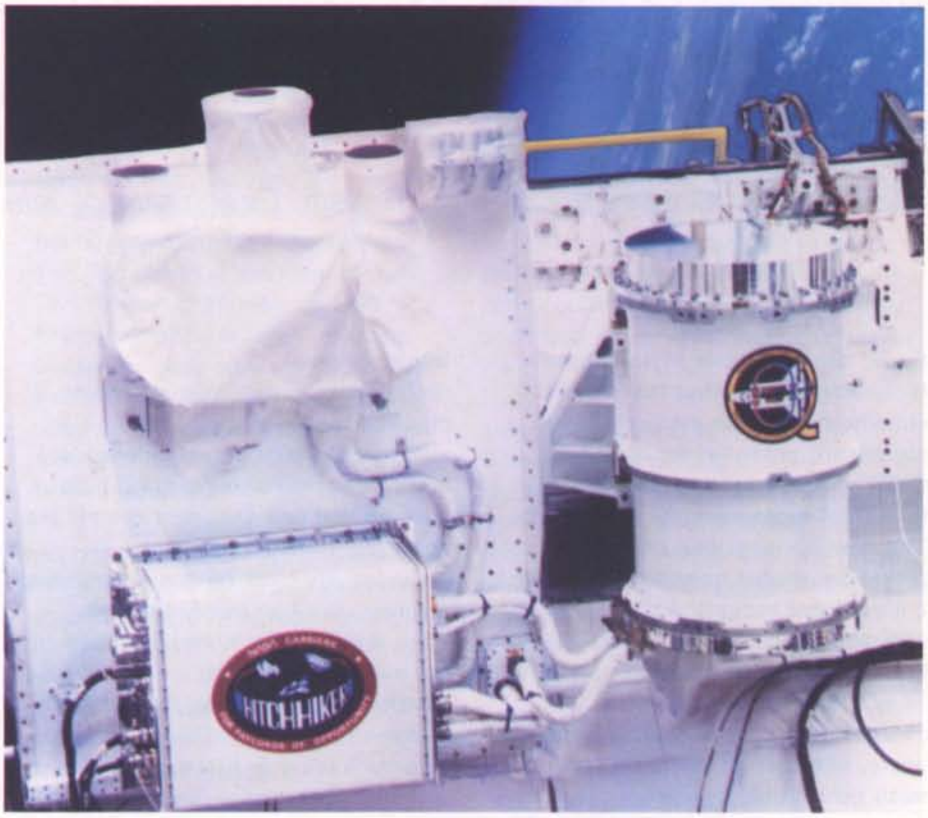


Figure 13 — Eureca: could accommodate long-exposure experiments

Figure 14 — NASA Hitch-hiker-G carrier aboard the Space Shuttle



Both Ariane-4, and later Ariane-5 (Fig. 12), can be used to carry individual TDP experiments, as well as small free-flyer satellites incorporating TDP experiments requiring long orbital exposure.

Eureca and Spacelab are also suitable vehicles for accommodating selected TDP experiments. The former (Fig. 13) offers long exposure and retrieval, while the latter permits manned intervention, which is important for some experiments from a cost point of view, or to allow in-orbit adjustments and modifications.

Shuttle-borne 'Hitch-hiker-G' payloads (Fig. 14) and 'GAS' carriers offer low-cost retrieval opportunities, and will find continuing application for TDP experiments, and also for cooperative flights with NASA, which has a very active in-orbit flight-test programme.

ESA satellites have already been used in the past to piggy-back experiments with the main payloads, and such opportunities will be further expanded for the subsequent TDP phases.

Hermes' ability to carry and/or bring back secondary technology experiments requiring return to Earth can also be exploited.

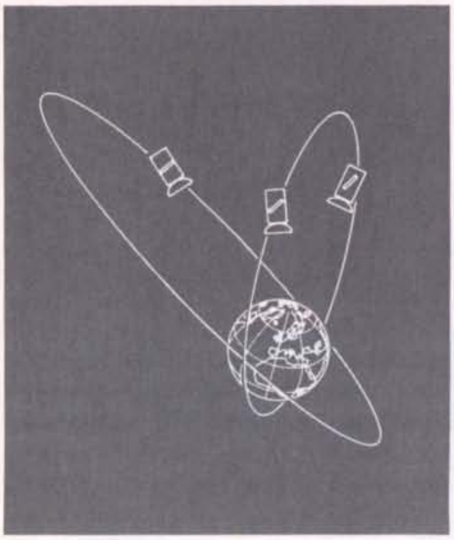
Schedule

The next phases of the In-Orbit Technology Demonstration Programme should start in 1989, and will continue throughout the 1990s. The relationships between the various technology experiments and the Agency's major future programmes are summarised in Table 1.

Conclusion

Implementation of the first phase of the in-orbit TDP is now in progress. In view of the Agency's long-term planning effort, first assessments of candidate technologies needing in-orbit testing have already been made. They cover a broad range, mirroring ESA's strong initiatives in many important programme areas, some of which involve very advanced technologies.

In-orbit TDP testing will continue to complement and support the development phases of these programmes, and will itself exploit the availability of the new Columbus infrastructure. In the 1990s, in-orbit technology testing will be a more common means of technology development and verification, contributing both to bringing new technologies on-line earlier and to reducing the risks associated with their application in the programmes under development.



The Concept of a Worldwide Satellite-Based Communications, Navigation and Surveillance System

C. Rosetti, Directorate of Telecommunications, ESA, Paris

Rapid developments in satellite technology mean that the latest satellite navigation systems have significant potential for replacing today's expensive and inefficient terrestrial radio-navigation networks. The new systems can offer high precision, global coverage and permit a significant reduction in the equipment that has to be carried on board mobiles, in particular aircraft. They can also serve several categories of user, thereby reducing costs, and can be integrated with such other functions as communications, surveillance, and search and rescue.

Introduction

Global radio navigation is at present characterised by a large and cumbersome profusion of independent and overlapping systems which have accumulated over the years to meet the specific and limited needs of comparatively small groups of the overall potential user population. Generally, these systems offer limited coverage and are available only along the more heavily travelled routes. Even so, the combined expense of maintaining these terrestrial infrastructures of limited capability is now very high. The cost to the user is also often unreasonably high because the individual shortcomings of each system mean that many underutilised items of equipment are frequently needed.

Historically, this has been the result of changing needs within the various groups of users, and of technological progress enabling radio-navigation aids to be adapted to new requirements. Most of these radio-navigation networks were initially developed by the military. The characteristics of many of these military systems were such that their use by the civilian community could not be prohibited. As a result of the very availability of such systems in fact, the civil community began making extensive use of them. Some of these systems subsequently became fully civilian, while others continued to be used by both the military and civilian communities (Loran-C; VLF/Omega).

Over the last twenty years, this picture started to change, in particular since the advent of navigation satellite technology. The new satellite navigation systems can be protected by the military against unauthorised use. In cases where their utilisation by the civilian community is authorised, the precision offered can be degraded, and availability made dependent on military criteria.

At the same time, however, the civilian user community and its requirements for better navigational capability and mobile communications are growing at a rapid pace. In the future there will be a need for more precise navigation over a much larger area of the globe. For aircraft, economic and operational considerations require a reduction in horizontal, and more particularly vertical, separation at high altitude. Moreover, there is a pressing need for better air-traffic-control and collision-avoidance schemes than are currently available, schemes which may rely in turn on more accurate navigational information. Similarly, increased emphasis on safety and environmental impact in coastal confluences and harbour areas produces a requirement for more precise and reliable radio navaids for maritime navigation. There is also a large and rapidly growing land-mobile community which requires better means of position determination than those at present available.

Finally, there are a wide range of existing and potential specialist applications that current navigation systems either ignore or serve inadequately. These include geodetic mapping, precision location for offshore oil exploration and production and sea-bed mining, research related to earthquake prediction, and position determination for low-altitude (e.g. Earth-resource-monitoring) satellites.

Taken individually or in combination, none of the terrestrial radio navigation systems in use today are capable of adequately meeting these future requirements. Most systems offer only limited coverage and can be expanded to global proportions only at enormous cost. Even so, navigation accuracy is at best usually only modest. Some systems are sensitive to siting and terrain (e.g. VOR/DME) and provide inadequate low-altitude coverage (needed particularly for helicopter operations and land-mobile users). Finally, some systems such as Omega entail a very high avionics cost, because a complex area navigation computer is needed to offset the system's basic ambiguity and the low data rate.

In some cases, self-contained navigation aids such as inertial navigation systems ease this situation somewhat, but until recently (i.e. the introduction of the ring-laser gyro) were extremely expensive. Furthermore, inertial navigation systems require periodic updates from other navigation systems in order to be precise and, as noted earlier, most navigation systems currently offer only very limited coverage and relatively poor accuracy.

For the above reasons, the setting up of a worldwide civil navigation-satellite system could, under certain circumstances, be an efficient and economical way of meeting existing and, more particularly, future needs. The requirements generated by the different mobile activities might, however, be very different in terms of availability, precision, integrity, coverage, etc. Moreover, the organisational/legal setup needed to satisfy these requirements also differs very much from one type of activity to another. For example,

- Land-mobile activities are low-cost and mostly commercial in nature. Safety of navigation is not a primary requirement.
- Aeronautical activities, on the other hand, require the highest degree of precision, availability and systems integrity. Safety of navigation is of primary concern. States are responsible for providing the necessary infrastructure, and are bound by international agreements. The Convention of the International Civil Aviation Organisation (ICAO, Chicago 1948) is a typical example. States also have sovereign rights over their air space. Air space outside national boundaries is organised and managed by international agreements between States.

When designing a new system with the aim of satisfying present and future needs, a multitude of aspects have to be taken into account:

The size of the user population
The primary requirement for land-mobile activities is an acceptable communications/position-determination capability at the lowest possible cost.

The evolution of given user groups
The fastest changing needs are to be found in the area of aviation, where operational efficiency becomes the major driver. Efficiency of operations and safety of navigation may, however, be in conflict, unless much better communications, navigation and surveillance capabilities are available.

The present picture might change fundamentally in the next 20—30 years. Today's mix of low-speed (general aviation, helicopter) and medium-speed (subsonic) aircraft will become much more difficult to manage with the advent of very slow, very large, lighter than air heavy load carriers at one end of the scale, and supersonic/hypersonic aircraft at the other. This means that the designer of a future system has not only to try to find an economically viable solution, but also to build enough flexibility into the system design to make it adaptable to the changing needs.

The least predictable evolution is to be found in the area of land-mobile users, as this market is less well defined than the maritime or aeronautical one. Moreover, although the land-mobile satellite market can be categorised as potentially rather large, it might be seriously eroded by competitive systems and technologies like cellular radio networks (with the exception of sparsely populated areas, which are rather few in the European context).

It should be added that cellular radio systems do not provide a position-determination (fleet surveying) capability, which satellites can. Obviously, the evolution of this land-mobile user group, from the satellite-technology point of view, will depend more heavily on the cost/benefit relationship than for other user groups.

The standardisation of system characteristics
In the case of land-mobile communications and position determination, global standardisation may not be of primary concern, since it can be supposed that such systems will be implemented regionally and that inter-regional traffic (e.g. US/Europe) will be negligible. Moreover, such systems being primarily commercial by nature, ownership might differ from one region to another. Requirements deriving from industrial protection or intellectual property rights might even drive the regional systems towards non-standardisation in this particular case. This picture could, of course, change if an international body were to be charged with providing land-mobile services globally, but this is unlikely.

The situation in the area of maritime and aeronautical activities is quite different. It would be very uneconomical if a ship or aircraft were not able to travel the world with equipment that can be used anywhere, with the same quality of service.

In contrast to the land-mobile situation, operation of such systems presupposes a broad cooperative effort among States, including perhaps joint ownership, in order to make sure that its operation and control is compatible with problems related to national sovereignty.

This last aspect is very important in the sense that it draws the line between systems that can be regarded as purely commercial, when private ownership is practicable, and systems where responsibility has to remain with the States involved.

This article attempts to document the major developments undertaken in these areas throughout the world, their relative merits, and the work being carried out by ESA.

Satellite navigation and mobile communications systems under study/development

From the technical point of view, the systems considered fall into two categories:

- Systems where the user terminal is active. Here the terminal communicates via satellites with a central ground station, where the position calculations are performed and transmitted back to the user. Most of the commercial systems proposed intend to use this method.
- Systems where the user terminal is passive. The user determines his own position from data broadcast by the satellites. Practically all military systems, and the civil ones designed to provide safety of navigation, fall into this category.

Commercial systems

A number of private operators in the USA have already applied to the Federal Communications Commission (FCC) for frequency-spectrum allocation and a licence for the operation of a Radio Determination Satellite Service (RDSS) to offer position-determination and a low-speed data-communication capability to licensed users.

A problem that all of these proposed systems have in common is that there are no official frequencies allocated for such a satellite service. Most of them hope to see such spectrum allocated at the forthcoming World Administrative Mobile Radio Conference (1987).

The FCC has so far only authorised GEOSTAR to operate an RDSS service and granted, by exception, frequency spectrum utilisation for this purpose. It should be emphasised that the frequencies in question are not allocated to such a service, but the FCC felt able to give its approval because the initial GEOSTAR system plans to cover only the US territories and hence will not cause harmful interference to radio services outside those regions. As far as other applicants are concerned, the FCC recognises that, for the time being, only one operator could be authorised, since existing and incipient satellite technology does not allow discrimination between two or more mobile satellite systems using the same frequencies.

The FCC also considers that the projections shown by applicants are based on cost and service assumptions that may prove to be too optimistic, particularly since in many instances terrestrial cellular radio networks enjoy strong competitive advantages over satellites in terms of cost and spectrum economy.

The GEOSTAR system concept has three parts: a ground station with a complex and powerful computer facility, three satellites in geostationary orbit, and a transceiver with display carried by the user. The ground station will interrogate (by using digital messages) the user terminal through a central satellite and will receive the transceiver reply via all the satellites. By measuring the differences in the propagation times of the messages between the user terminal and the satellites and combining these with digital data on altitude sent by the user terminal, the user's position will be determined at the ground station and transmitted back to the user.

A simplified GEOSTAR communications payload was launched in 1986 on a G-STAR satellite, but it failed shortly after reaching orbit. Mobiles (e.g. trucks) equipped with independent terrestrial navigation equipment (Loran-C) would have been able to transmit their data via the satellite to the GEOSTAR ground station in Princetown, where their position would have been displayed. There was no return link foreseen from the station to the mobile. This setup therefore does not demonstrate the full GEOSTAR system characteristics. It is a simple, unidirectional communications link from a mobile user to a central point.

An agreement has been signed between the GEOSTAR Corporation and the French National Space Agency (CNES) to study the possibility of setting-up a GEOSTAR-derived system called 'LOCSTAR' in Europe, Africa and the Middle-East. Legal problems face this type of system in this region, however, because:

- there is, as yet, no frequency-spectrum allocation (this might be resolved at the Mobile WARC, 1987), and
- there are, at present, restrictive regulations concerning use of two-way mobile radio equipment and its carriage across national borders.

Military systems

Two military systems are presently under deployment: the USA's GPS-Navstar and the USSR's Glonas.

When fully deployed, GPS will be a continuous, global-coverage satellite navigation system. The system will have the ability to offer three-dimensional position and velocity information, plus highly accurate time data. The final space-segment configuration will consist

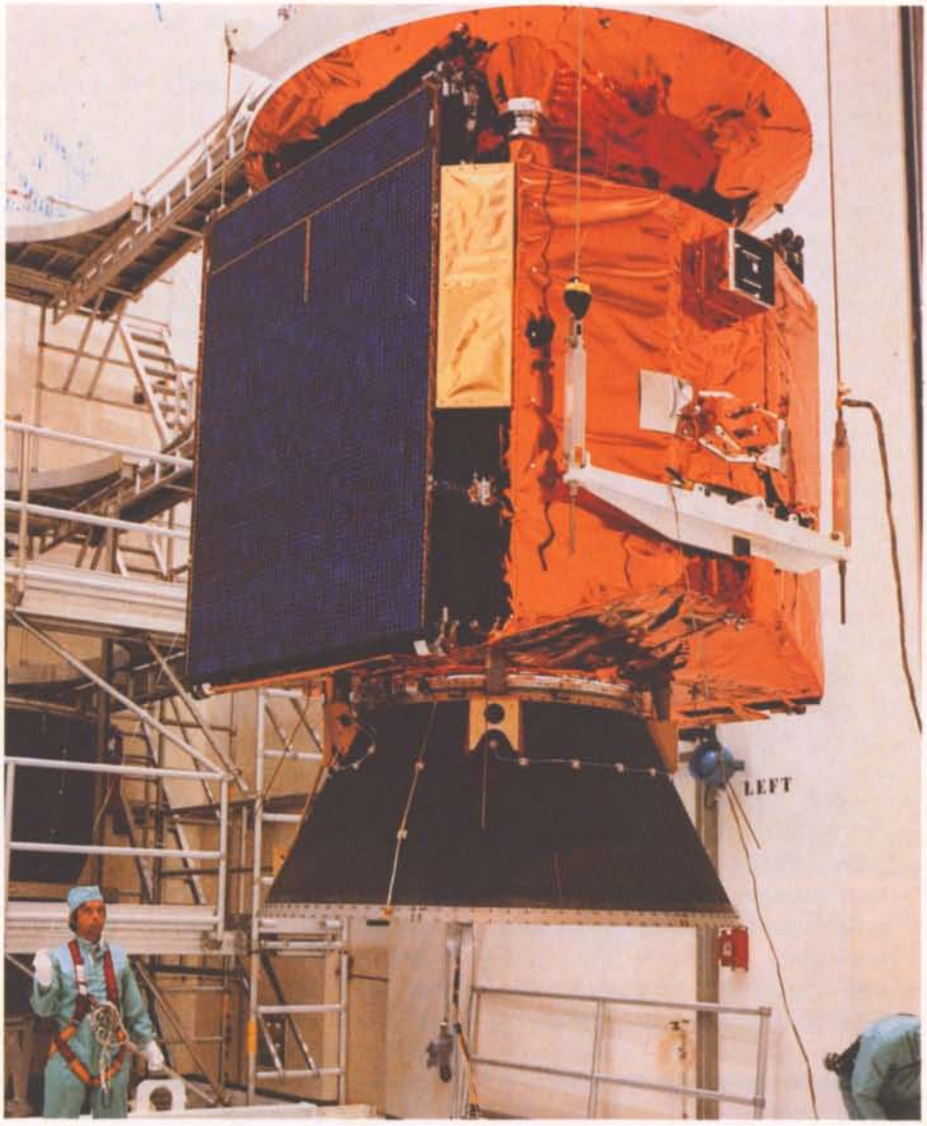


Figure 1 – The ESA Marecs-B2 maritime communications spacecraft, currently operated by INMARSAT, being readied for launch in November 1984

of 18 active satellites plus three working spares, divided over six orbits with a 12 h period and 55° inclination.

The GPS user determines his position by measuring pseudo-ranges to four satellites, and computing the satellite positions by using ephemeride data received from them.

Two levels of precision can be offered: an encrypted precision code (P-code) and a coarse acquistion code (C/A code). The accuracy of the P-code system is of the order of about 20 m with 95% probability, while the C/A-code will offer 100—150 m accuracy (also 95% probability).

The current policy of the US Department of Defence (DOD) is that the P-code will be available to military users only, while the C/A code will be accessible to civil users free of charge, unless the US Congress directs the DOD to charge a utilisation fee. There is also talk of restricting use if US security interests are threatened.

Since 1973, ten satellites have been launched, of which only seven are still operational. The Space-Shuttle accident will probably delay the reaching of full GPS operational capability, which was initially planned for 1989.

The USSR's Glonas system is much less documented. The satellites are in three 12 h orbits inclined at 63°. There may eventually be a total of perhaps 12 satellites, transmitting in similar frequency bands to GPS-Navstar using spread-spectrum techniques.

Work done by ESA
The Agency has been involved for many years in R&D work related to mobile satellite communications systems. Its most successful programme is Marecs (Fig. 1) currently operated by the International Maritime Satellite Organisation INMARSAT. Another, less successful, programme was the aeronautical-communications mission Aerosat. After it was abandoned, the participants — ESA, the Federal Aviation Administration and Canada — created an Aviation Review Committee (ARC) with enlarged participation. This Committee has since analysed the needs of civil aviation, as well as the technical options for fulfilling them. It completed its work by submitting its findings and recommendations to the International Civil Aviation Organisation (ICAO). The ICAO Council then created a special 'Future Air Navigation System (FANS)' Committee, which has the task of analysing the needs of civil aviation up to the year 2020, and making the necessary recommendations regarding operational, technical and institutional matters to the ICAO Council. ESA has observer status on this Committee.

It is already recognised that the most cost-effective means of improving operational efficiency in a manner compatible with requirements deriving from safety of navigation is to integrate the functions of communications, navigation and surveillance into one system, to adopt satellite techniques and to design a multi-user-oriented system.

The system design work being carried out by ESA therefore takes into account a number of important facts and requirements defined by the international user communities:

- The present aeronautical navigation and communications infrastructure will have to be improved, but this will be an evolutionary process. There will therefore be a (long) transition period between the present systems and those of the future.
- Under the Chicago (ICAO) Convention, States have rights (sovereignty over their airspace) and obligations (respect of ICAO standards, liability in the case of network malfunction).
- The civil mobile community cannot afford to spend billions of dollars on a system that has to be fully deployed over a long period in order to offer an operational capability, particularly in view of the transition period mentioned earlier.
- The system has to be designed in such a way as to gain technical/economic as well as political acceptance by the international user community.
- Last but not least, the existance of INMARSAT and its space system.

Moreover, the system has to offer the following features:

- Global coverage (when fully deployed)
- Possibility of gradual implementation (region by region)
- Unrestricted access
- High integrity (super-redundancy)
- 100% availability
- Invulnerability (decentralisation)
- Graceful degradation (in the event of partial failures)
- Non-saturable (unlimited number of users)
- Economic efficiency both for the provider and for the user (common system for any type of user; combination with other functions such as mobile communications, search and rescue)
- Multi-user orientation (aviation, marine, geodetic, etc.).

The studies carried out under ESA contracts have led to a system concept known as 'Navsat'. Similar work initiated in parallel in the Federal Republic of Germany has been known under the name 'Granas'. In 1986/87 a harmonisation study was carried out which took the best features of Navsat and Granas and merged them into a single, consolidated European concept.

The user segment

As in the case of the US GPS/Navstar system, the Navsat/Granas user determines his position by measuring the pseudo-range to at least three (two-dimensional navigation) or four (three-dimensional navigation) satellites using a passive navigation receiver.

There is an important difference, however, in the signal structure broadcast by the two systems. While all GPS satellites transmit at the same time and the navigation receiver distinguishes one from the other by individual coding of the transmission, in the European approach the satellites transmit in time sequence, in a well-defined time slot. This offers a number of advantages, both for the satellite and for the navigation receiver. Since the signals are transmitted in a short (140 ms) high-power burst, each lasting 2.4 s, the average power requirement onboard the satellite can be low. On the receiver side, it is easier to process the signals sequentially than in parallel.

Another difference is to be found in the way the satellite position is presented to the navigation receiver.

GPS/Navstar satellites broadcast the ephemeris of the satellite orbit, while in the European concept the satellite broadcasts the satellite coordinates (at the moment of transmission) in a geocentric coordinate system. As in GPS, the signal is transmitted on two different frequencies, in order to permit correction of errors induced by ionospheric perturbation. The precision of the position determined is comparable with the precision of the GPS 'P' code.

The space segment

One of the most important constraints of a future civil satellite-navigation system is its cost. This applies not only to the fully operational, global system, but more importantly even to the timing of its deployment. It was noted earlier that a long period will elapse before such a system is in use globally on a large scale. Civil users cannot afford to pay the high costs of an underutilised system, redundant to the terrestrial networks being used today.

For this reason, particular attention has been paid to reducing the cost of the overall system, while at the same time defining a space segment that will permit a gradual implementation, starting with the regions where such a system is most urgently needed and, as the user population increases, expanding it until global coverage is attained.

To achieve this goal, the space segment consists of a geostationary part and a part in which the satellite orbits are elliptical with an inclination of 63.4°. The geostationary part has been selected because navigation payloads could be integrated as passengers onboard satellites belonging to other mobile services, thereby reducing the overall system cost. The elliptical part and its characteristics have been chosen to allow coverage of a selected region with a small number of satellites, but offering a full operational capability.

The full space segment and its characteristics are summarised in Figure 2 and in Table 1. The reduced, regional constellation is illustrated in Figures 3 and 4.

Figure 2 — Navsat space-segment constellation

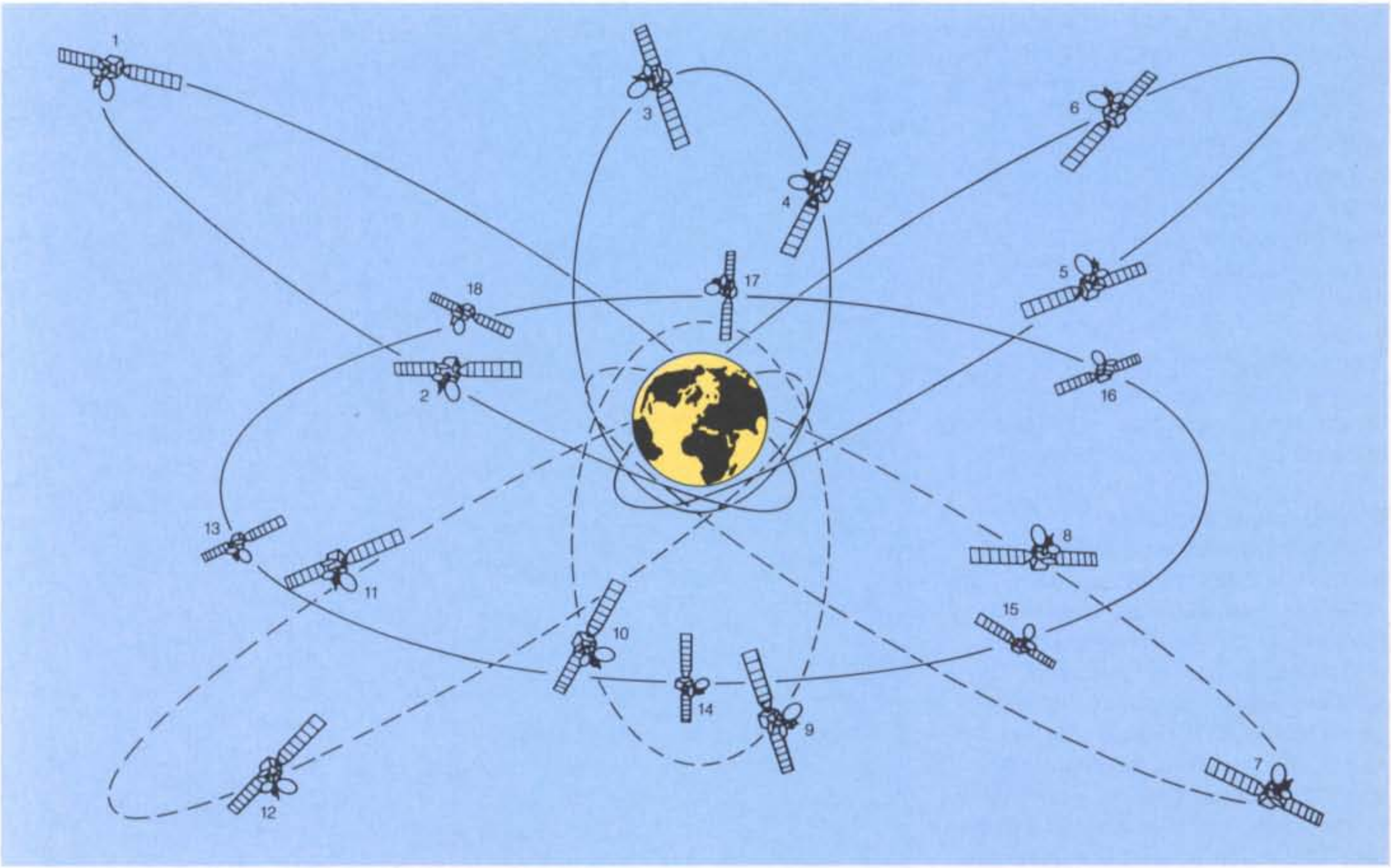


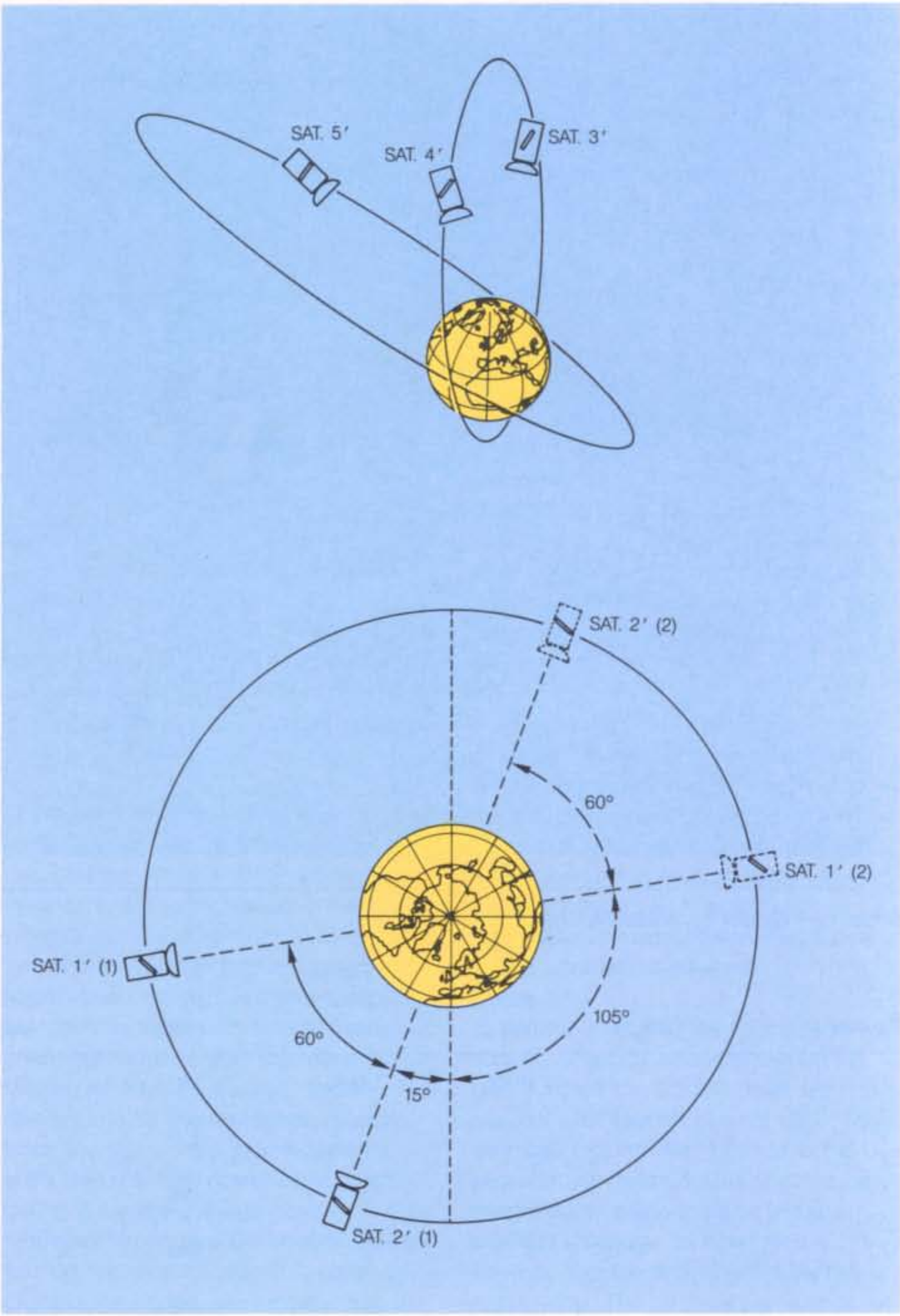
Table 1 — Navsat constellation characteristics

Satellite	Orbit type	Apogee altitude (km)	Perigee altitude (km)	RAAN (*) (deg)	Inclination (deg)	Argument of perigee (deg)	Initial true anomaly (deg)
1	HEO	39105	1250	340	63.45	270	180
2	"	"	"	"	"	"	240
3	"	"	"	100	"	"	168
4	"	"	"	"	"	"	206
5	"	"	"	220	"	"	154
6	"	"	"	"	"	"	192
7	"	"	"	340	"	90	180
8	"	"	"	"	"	"	240
9	"	"	"	180	"	"	168
10	"	"	"	"	"	"	206
11	"	"	"	220	"	"	154
12	"	"	"	"	"	"	192
13	GEO	35786	35786	0	0	0	285
14	"	"	"	0	0	0	345
15	"	"	"	0	0	0	45
16	"	"	"	0	0	0	105
17	"	"	"	0	0	0	165
18	"	"	"	0	0	0	225

* RAAN = Right Ascension of Ascending Node

Figure 3a — Spacecraft in elliptical orbits in the reduced configuration

Figure 3b — Spacecraft in geostationary orbits



Several types of elliptical orbits are posible. A Molnyia-type orbit would offer (in the reduced constellation) a service in two regions separated by 180° in longitude, but only in the Northern Hemisphere. A Tundra-type orbit would, with the same reduced configuration, serve only one longitudinal region, but in both hemispheres, taking in both the Arctic and Antarctic.

These orbit-selection options are being left open for the time being, the final choice depending in part on the priorities to be set by the user communities.

Ground control segment

Navsat and Granas used two different methods to determine the positions of the navigation satellites to be broadcast to the users. In the Navsat concept, the satellite transponder is transparent. The satellite position is determined at the ground station to which the satellite is visible. The position is then transmitted with the necessary time-delay correction to the satellite, which retransmits it to the user, as if it would have been generated onboard. Most of the complexity is therefore contained in the ground stations. For a global system, six are required plus a mission centre having the task of coordinating all ground stations.

In the Granas concept, the satellite proceeds to pseudo-range measurements to four relatively simple ground stations in view, calculates its position, and broadcasts it to the user. In this approach, the satellite transponder is 'intelligent' and the ground station is kept simple. About 15 such ground stations would be required, plus a master station with, interalia, a coordination function.

In both approaches the feeder link from ground to the satellites uses the 5 GHz frequency band.

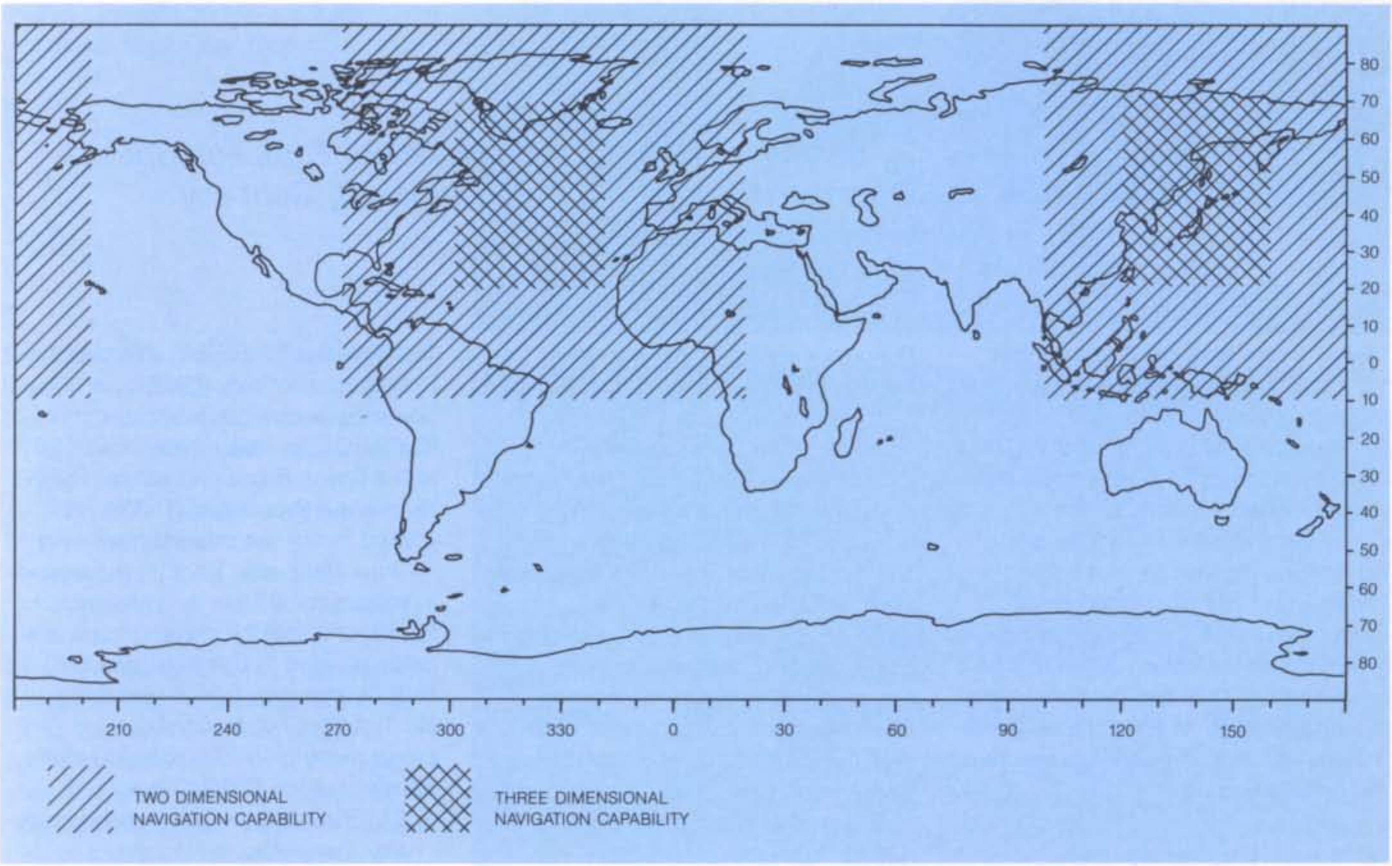
In the harmonised Navsat/Granas concept, both approaches are being retained, pending a detailed technical/economic analysis.

The communications function

It has been said that the geostationary part of the satellite navigation system could be carried as a passenger aboard satellites belonging to the mobile services. In this case, the communications function required, in particular by civil aviation, is automatically provided. The coverage of these satellites is, however, limited both to the north and the south at higher latitudes. The regions out of sight of the geostationary orbit have to be served by the non-geostationary element of the navigation system.

It is forseeable that the demand in terms of communications capacity will be lower

Figure 4 — Selected geographical areas appropriate for an initial partial system



in these regions compared with the rest of the world. Moreover, since a mobile will always have at least three satellites in view at any moment, the capacity required can be spread over a number of satellites. This means that, while for the geostationary element of the system, the navigation package will be carried as passenger, the opposite is true for the non-geostationary part, where the communications package, being small, will be passenger onboard the navigation satellite.

Conclusion

The adoption of the new system implies the meeting of a number of conditions:

- That the necessary technologies are developed to meet the specific needs of both users and system providers.
- That these techniques are introduced in a phased, evolutionary way, serving initially those regions where they are mostly needed.
- That one of the major results of their adoption is to reduce the complement of avionics required to operate the system and the cost to the provider operating them.
- That States providing today's services are in a position to phase out the terrestrial networks that will eventually become redundant. This will only be possible if the new system is developed with the broadest international cooperation and operated by an internationally recognised organisation.

ESA has no intention — nor do its terms of reference allow it — to operate such a system. ESA's task is to define the technical concept for such a satellite system, submit it to the scrutiny and acceptance of the international community, and to preserve a role for European industry when such a system is eventually implemented in that framework of broad international cooperation.

Nevertheless, this does not exclude the possibility that ESA could develop the required technologies and set up an experimental/pre-operational partial system, hopefully in a cooperative venture with other parties, which could later be taken over and operated by an appropriate international organisation.

Twenty Years of ESOC

H. Schramm, Head of Administration, European Space Operations Centre (ESOC), Darmstadt, Germany

Twenty years ago, on 8 September 1967, the Bundesminister für Wissenschaftliche Forschung, Dr. Gerhard Stoltenberg, and the first Director General of ESRO, Prof. Pierre Auger, signed an 'Agreement Concerning the European Space Operations Centre' between the Government of the Federal Republic of Germany and the European Space Research Organisation (ESRO), ESA's predecessor. This can be considered the official birth of ESOC, though its 'labour pains' had started more than six years earlier.

What were the reasons for establishing ESOC? Why was Darmstadt selected? What were the major milestones in its development? This brief historical review is intended to provide some of the answers.

During a meeting of representatives from European States in Meyrin, Switzerland, at the end of November 1960, an Agreement was signed concerning the establishment of a European Preparatory Commission for Space Research, to be known as 'COPERS'. This Agreement entered into force at the end of February 1961. The main task for COPERS was to agree on a European Space Programme and to establish the legal and organisational framework needed to implement such a programme, i.e. to draft the ESRO Convention, the relevant Statutes and Regulations, and to decide, amongst other things, on the locations for the Organisation's establishments.

Four establishments, in addition to ESRO's Headquarters in Paris, were deemed to be necessary at that time: a Technical Centre (ESTEC) including a Research Laboratory (ESLAB), a Sounding-Rocket Launching Facility (ESRANGE), a Data Centre (ESDAC), and a Space Research Institute (ESRIN). Various member States of COPERS applied to host an establishment, and on 14 June 1962, after lengthy discussions in various committees and after visits to the relevant sites by expert groups, it was finally decided to distribute the ESRO Establishments as follows (Resolution No. 1 of the Conference of Plenipotentiaries on the occasion of the signature of the ESRO Convention):

- ESTEC/ESLAB in Delft (Netherlands), later transferred to Noordwijk;
- ESDAC in Darmstadt (Germany);
- ESRANGE in Kiruna (Sweden);
- ESRIN in Italy (Frascati was selected later).

Figure 1 — Foundation-stone-laying ceremony at ESDAC on 12 November 1965, with Dr. Alexander Hocker, Chairman of ESRO's Council, and Dr. Stig Comet, Director of ESDAC, presiding

Figure 2 — Signature on 8 September 1967 of the ESOC Host Agreement by Bundesminister Dr. Gerhard Stoltenberg and Prof. Pierre Auger, Director General of ESRO

Figure 3 — The ESDAC buildings, photographed shortly after completion

Figure 4 — The ESDAC computer room, showing the IBM 360/50 computer installed in September 1966

The three main criteria in choosing the location for ESDAC were:

- that it was to be a computer centre, which could be used in the build-up phase
- it should be close to a university and to an international airport
- there should be a world-wide communications network available.

These requirements were considered to be best met by the proposal put forward by the German Delegation. With the Deutsche Rechenzentrum in Darmstadt, it offered computer facilities and offices where staff could start work immediately. It could also claim proximity to the Technische Hochschule Darmstadt, which already had a very good academic reputation. Excellent connections to a world-wide communications network already existed, and the site was no more than twenty minutes by car from Frankfurt international airport.

The German Government's proposal was also strongly supported by the Land Hesse and the Magistrat der Stadt Darmstadt, who welcomed the decision in favour of their town and participated actively in solving local problems, such as the selection of the final site, provision of temporary accommodation for staff, etc.

The first ESDAC staff member took up duty on 1 December 1963. He was its first Director, Dr. Stig Comet. In 1964, the Heads of ESDAC's three Departments were appointed. Dr. Bengeser, ESOC's first Head of Administration, was faced with a diversity of administrative tasks

Figure 5 — The Main Control Room at ESOC today, photographed in September 1987 during the ECS-4 launch rehearsal

picture report

associated with the build-up of such a centre. Mrs Lloyd, Head of the Data Processing Department, and Dr. Walter, Head of the Data Analysis Department, initiated the first steps in making ESDAC operational, including selection of the first computers, and the provision of programming and mathematical services to meet the requirements of ESRO's first satellite and sounding rockets. By the end of 1964, ESDAC had a total of 18 staff.

The initial idea of erecting a building of approximately 2000 m^2 for ESDAC on the site of the Deutsche Rechenzentrum was abandoned very early on. Instead, the German Government bought a piece of land covering nearly 42 000 m^2 from the Land Hesse. 20 000 m^2 of this were initially given to ESRO for the establishment of ESDAC, in parallel with completion of the relevant legal arrangements. This allowed site preparation and the planning of the building, the roads and the necessary connections to public utilities to be commenced immediately.

During this period, the ESDAC staff were temporarily accommodated in two stories of a rented building in Darmstadt, at Havelstraße 16. The new ESDAC building was completed at the end of 1966 and the staff, which by then had increased to 50, moved in.

However, these early ESDAC staff had virtually no time to concentrate on their original tasks, because the essential role of the Centre was changed by a decision of the ESRO Council in April 1967 to create a new Directorate, the European Space Operations Centre (ESOC). ESOC would be responsible for the Data Centre, for the ESTRACK network (whose Control Centre had to be moved from ESTEC in Noordwijk to Darmstadt), and for ESRANGE in Kiruna.

This Council decision was taken on the basis of recommendations made in the so-called 'Bannier-Report'. Mr. J.H. Bannier, Director of the Netherlands Research Organisation ZWO, was the Chairman of a group of six international experts who had been charged 'to study the internal structure, procedures and methods of work of ESRO'.

Following this decision, the Agreement between the German Government and ESRO, which was then ready for signature, was renegotiated over a four-month period. The official ceremony for the signature of the ESOC Agreement by Bundesminister Dr. Gerhard Stoltenberg and Prof. Pierre Auger in the presence of high-level representatives from the Member States, universities, scientific institutes and industry, subsequently took place on 8 September 1967.

The additional ground needed for extension of the site — approx. another 20 000 m^2 — was again made available by the German Government, and planning and construction of the Satellite Control Centre could start immediately. By May 1968, ESOC and its space tracking network, with stations in Redu (Belgium), Fairbanks (Alaska/USA), Spitzbergen (Norway) and the Falkland Islands (UK), were fully operational.

The first Director of ESOC was Mr. Umberto Montalenti. He was followed, in 1973, by Prof. Gianni Formica, who was succeeded by Dr. Reinhold Steiner in 1979. The current Director of ESOC, Mr. Kurt Heftman, ESA's Director of Operations, has been in post since 1983.

ESRO's first satellite in orbit, ESRO-II, launched on 17 May 1968, was supported by ESOC. Thirteen further scientific satellites have since been operated successfully from ESOC, the last of these tasks culiminating in the spectacular encounter in March 1986 between the Giotto spacecraft, ESA's first deep-space mission, and Comet Halley. These fourteen missions have spanned a wide range of space-research activities and have produced excellent scientific results, reflected in the wealth of papers published by scientists.

With the launch of Meteosat-1 in November 1977, ESOC supported the Agency's first applications satellite. It was to provide one of the most exciting events in ESOC's short history when, on 9 December 1977, the first image of the Earth was received in the Centre's Control Room. Since 1977, ESOC has received, processed and disseminated

Figure 6 — The Meteosat Control Room at ESOC, photographed in September 1987

picture report

Meteosat images and meteorological data for meteorological services around the world. Every day, at half-hourly intervals, the Centre receives three images in the visible (restricted to daylight), infrared and water-vapour channels, i.e. approximately 120 images per day. Almost half a million images have therefore been handled over the last ten years. The great interest that Meteosat holds for the public is demonstrated by the fact that millions of television viewers are able to watch animated sequences of Meteosat images during the majority of the daily weather forecasts broadcast by European TV companies.

Since January 1987, the Meteosat Programme has been run by ESA/ESOC on behalf of EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites.

ESOC's role as a controller of communications satellites began with the Orbital Test Satellite (OTS), launched in May 1978. It continued with the European Communication Satellites ECS-1, -2 and -4, launched in June 1983, August 1984 and September 1987 respectively, and the maritime satellites Marecs-A and -B2, launched in December 1981 and November 1984. The ECS satellites are used by EUTELSAT, the European Communications Satellite Organisation, and the Marecs satellites by INMARSAT, the International Maritime Satellite Organisation.

In addition to the fourteen scientific and eight applications satellites supported to date by the Centre, ESOC has also provided support to some non-ESA satellites, such as the Dutch scientific satellite ANS and the Indian applications satellite APPLE. All have been supported successfully by ESOC's experts, with excellent cooperation from other organisations and institutes both within and outside ESA's Member States.

The enormous increase in ESOC's responsibilities and tasks that has taken place over the past twenty years is also reflected in the figures regarding staff, facilities and equipment. At the end of 1967, ESOC had a total of 95 permanent staff. Today there are approximately 600 staff, including contract staff, working at the Centre.

The effective working area of the first building on the site, including the computer wing, staff accommodation and operational facilities, was a total of 3200 m^2; today that area is in the order of 17 600 m^2.

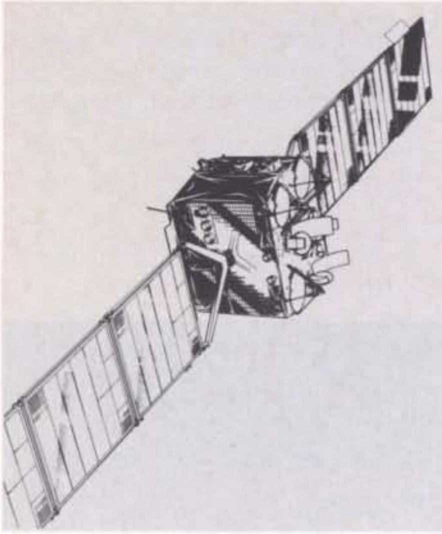
The network of ground stations has also been enlarged over the years and now comprises connections to Michelstadt (Germany), Redu (Belgium), Villafranca (Spain) and Maspalomas (Canary Islands), Fucino (Italy), Kiruna (Sweden), Kourou (French Guiana), Perth (Australia), Malindi (Kenya) and Ibaraki (Japan).

Another interesting comparison is provided by the increase in computer capacity that has taken place. The first computer used by ESDAC was an IBM 7090 with a computing capacity of 0.4 MIPS (million instructions per second). The total computing capacity presently under ESOC's control can handle 300 times more information every second. Developments in the areas of main memory and peripheral disk storage have been even more impressive, exceeding the MIPS comparison many times over.

Conclusion

Looking to the future, ESOC will doubtless continue to be charged with so-called 'classical missions', operating both scientific and applications satellites and dealing with more and more advanced spacecraft and control technologies. As the most experienced operations centre in Europe, it can also be expected to play an important role in ESA's manned space missions. Its exact role in this respect has still to be defined in the context of the on-going discussions on the future Ground Facilities Concept for the operation of the in-orbit infrastructure elements.

The ESOC staff are looking forward to the challenge of ESA's future space programme and the opportunity to contribute, as in the past, to its success, in close collaboration with their colleagues at the other Establishments.



Orbital Control of Geostationary Spacecraft from Dedicated Control Centres

E.M. Soop, Spacecraft Trajectory Branch, Orbit Attitude Division, ESA Computer Department, ESOC, Darmstadt, Germany

Routine operations for the European Communications Satellites (ECS) are performed by a dedicated ESA Control Centre at Redu in Belgium. Since 1983, orbit control has been carried out using a small portable software system called 'PEPSOC', specially designed for geostationary missions. The Meteosat and Olympus satellites, as well as several non-ESA missions, are now benefitting from the availability of PEPSOC.

Historical background

The trend in the in-orbit control of a geostationary mission is to operate the spacecraft during the routine phase from a dedicated control centre. This mode of operation was first implemented by ESA with the establishment of a Control Centre at Redu in Belgium dedicated to routine operation of the European Communications Satellites (ECS).

In the original design of the Redu Centre, it was assumed that orbit control would be carried out remotely from ESOC in Darmstadt, as it was considered impractical to retain the necessary orbit experts at such a small control centre. Moreover, the computer system at Redu was assumed to be too small to be able to support the relatively demanding programs previously used for orbit determination and manoeuvre preparation.

At a later stage, however, it was realised that there would be a great advantage in creating a completely self-supporting Control Centre, where not only the normal spacecraft control functions could be carried out, but also the more specialised task of orbit control. This could subsequently serve as a prototype for designing the ground segment for future geostationary communications missions.

In 1980, the Spacecraft Trajectory Branch at ESOC undertook to study the feasibility of producing a small set of orbit-control programs that would be both easy to use and small enough to be accommodated on the offline computer at Redu. The study had a positive outcome and resulted in the program package called 'PEPSOC': Portable ESOC Package for Synchronous Orbit Control (see ESA Bulletin 32, November 1982).

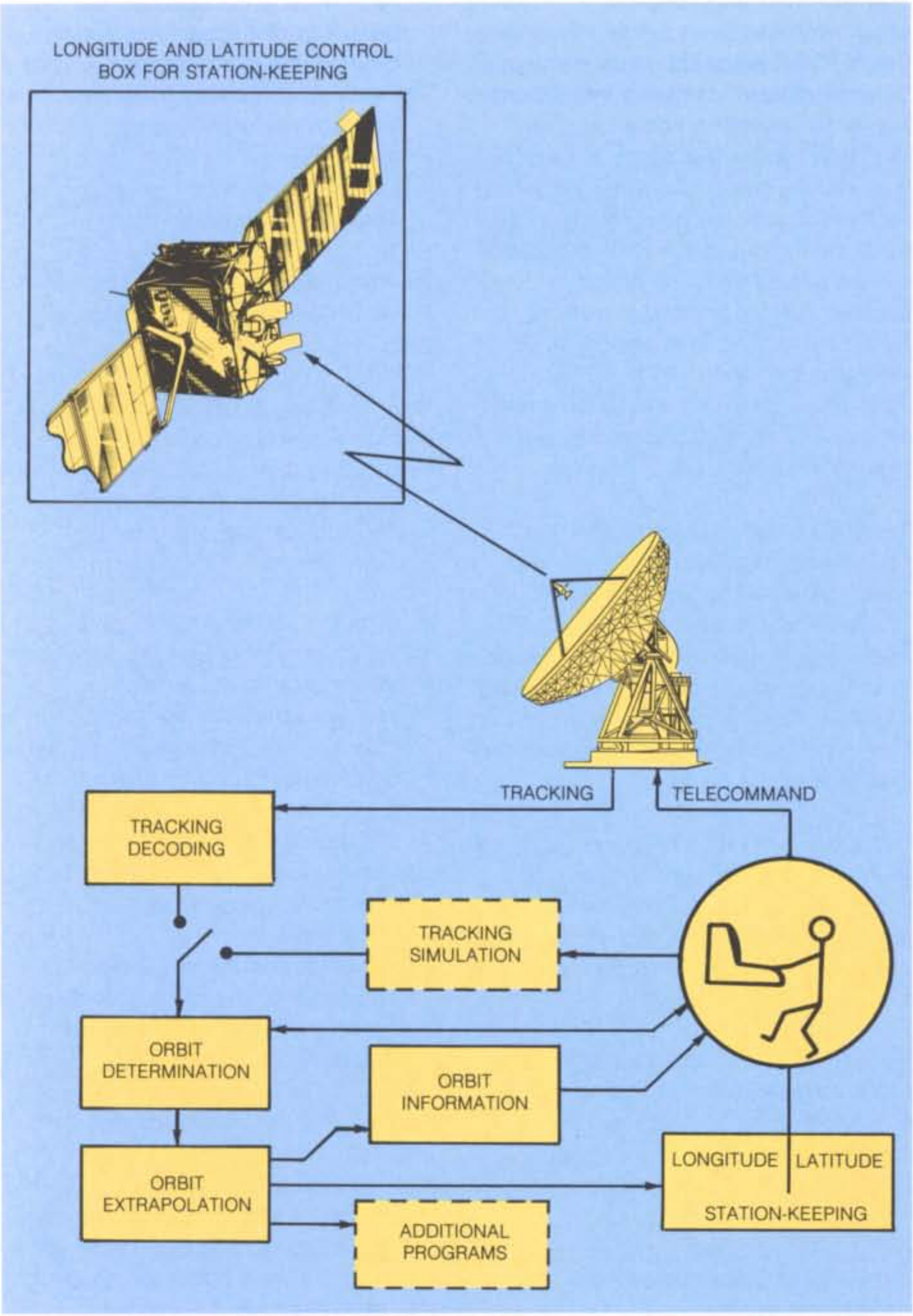
The routine-phase orbit-control operations for ECS-1 have been successfully performed from Redu using PEPSOC since they began in August 1983. A year later, the PEPSOC system was extended to support the ECS-2 launch. During the renewal of the computer system at Redu (now SEL-Gould machines) in early 1987, each PEPSOC module was revised slightly, but without changing the basic design. At the same time, the system was extended to support four ECS spacecraft in orbit simultaneously, plus a simulated fifth spacecraft for training purposes.

Since mid-1987, PEPSOC has also been used on the Meteosat computers at ESOC to support the orbital operation of Meteosat-F2. The system is now ready to operate the future Meteosat-P2 and the MOP-series of meteorological satellites. PEPSOC is also presently being installed on a SEL-Gould computer in a Control Centre at Fucino in Italy ready to support the routine operational phase of the Agency's Olympus communications spacecraft in 1989.

PEPSOC is available under licence to both national institutes and private industry in ESA's Member States, since it is a facility paid for from ESA's budget. No licence fee is normally charged, just a small sum to cover direct transfer

Figure 1 — The PEPSOC orbital-control loop, highlighting the spacecraft operator's role

costs and, when applicable, consultancy support by ESOC experts. So far, PEPSOC has been acquired and implemented on VAX computers by Science Systems Ltd. (GB) in 1984 and by Logica Ltd. (GB) in 1987. The latter company will use PEPSOC in a Control Centre it is providing for the new 'Eutelsat-II' generation of communications spacecraft, which will progressively replace the ECS generation in the 1990s.



Design principles

The PEPSOC design was based upon many years of experience at ESOC in operating geostationary missions. The coding used existing software modules which were reduced in size and complexity. The reduction and simplification were achieved by limiting the scope of the programs to handle only the routine operations of geostationary missions. In contrast, the general-purpose orbit programs at ESOC can be used to support many types of missions, including the transfer phase and the injection into geostationary orbit. They can also be used for analysis and evaluation of several aspects of a space mission.

The purpose of PEPSOC is to support the orbit-control task, as shown in Figure 1. The state to be controlled is the spacecraft's position inside a control box of specified size in terms of longitude and latitude (not necessarily equal-sided). The third element of the the spacecraft's position, its height above the Earth, has no explicit control requirement. Implicitly, however, the need to keep the longitude drift rate low constrains the spacecraft height to close to the geosynchronous value of 35 786 km. Perturbations in orbital state are caused by the gravitational attraction of the Sun and the Moon, solar radiation pressure, the small asymmetry in the Earth's gravitational field, and attitude control thrusts.

The input to the control loop consists of tracking data: measurements by means of radio signals of the spacecraft's distance and direction from the antenna(s) of one or more ground stations. The output from the control loop supplies the operator with information about the spacecraft's orbital position and also provides recommendations regarding station-keeping manoeuvres to be performed to prevent the spacecraft from leaving the specified control box. The feedback to the spacecraft consists of manoeuvres with the low-thrust onboard propulsion system, which are manually commanded by the operator.

The ECS spacecraft are maintained inside 0.2°wide control boxes in longitude and latitude, centred on the longitudes of 13°E and 7°E, respectively. This is achieved by means of a longitude manoeuvre once every two weeks, and a latitude manoeuvre once every four weeks.

Of late, however, the ECS-1 latitude manoeuvres must be performed as two thrusts separated by 24 h because of a switch-over to the back-up thruster system. The manoeuvres for the Meteosat missions are performed at intervals of several months, because a wider control box is allowed. On the other hand, the programs that process the Meteosat weather pictures require the orbital position inside the control box itself to be determined with a high accuracy.

Because of the relatively long time interval between station-keeping manoeuvres, the response time of the orbit-control system is not critical. This is an important consideration for PEPSOC, since it implies that the computer programs do not need to operate in real time. PEPSOC therefore relies on batch programs, with manual intervention by the spacecraft operator or the operations engineer in the control loop. PEPSOC operations for a single spacecraft require between 10% and 20% of a full-time employee's time, depending on the frequency of manoeuvring.

The manual mode of operation that has been selected implies that decisions concerning the time-lining and the logistics of operation are not programmed into PEPSOC, but are the responsibility of the spacecraft operator. PEPSOC essentially performs the numerical calculations and delivers the information needed to make the decisions. In this way, it can be used to support a wide range of different station-keeping strategies. Once a strategy has been established, only a small amount of PEPSOC input data needs to be updated during routine operations.

Because of this manual mode of operation, however, the spacecraft operator must have a basic understanding of the relevant areas of celestial mechanics. A survey of the available celestial-mechanics literature showed that there was no appropriate introductory guide to the geostationary orbit available commercially. A suitable guide was therefore written at ESOC*.

The PEPSOC programs

Much effort has been devoted to making the PEPSOC programs easily portable between different computer installations, largely by relying on Fortran and an operating system that supports batch operations. The operator uses the editing facility of a standard computer terminal for data input. Output from the programs can be printed on a line printer or displayed on the terminal screen. At Redu, the existing work stations have been programmed to allow PEPSOC input without any changes to the actual programs. The same approach will be used at the Fucino Control Centre.

There is no general standard for the coding and transmission of tracking measurements. The part of the PEPSOC program that retrieves and decodes the tracking data must therefore be adapted to each new space mission. The plotting program is also installation-dependent due to the lack of software standards for graphical output devices.

The orbit-control loop is supported by six PEPSOC computer programs which together involve 9000 Fortran statements (about 40% are comments). Each program module performs one of the following functions (Fig. 1):

- Retrieval of tracking measurements followed by decoding, smoothing and correcting for calibrations.
- Orbit determination from tracking measurements collected during a time interval of typically between 1 and 30 d. The parameters determined include tracking biases, solar radiation pressure and thruster performance.
- Extrapolation of the orbit determined for between one and three months into the future by numerical integration, taking into account the effect of planned manoeuvres.
- Printout of orbital and auxiliary information to the operator, e.g. prediction of eclipses and sensor blindings by Sun or Moon.
- Preparation of manoeuvres for longitudinal station-keeping, shift or re-acquisition.
- Preparation of manoeuvres for latitudinal station-keeping.

The extrapolated orbit is stored as a data file, which can be read by additional programs that may be added to the PEPSOC system in a modular manner. Such programs could, for example, support a new type of station-keeping strategy or produce auxiliary information for the operator or for external users. Several such programs are already available, which:

- output predicted pointing directions to the spacecraft for steering a ground-station antenna via a data link
- print predicted directions to the spacecraft for manually pointing any payload user's ground antenna
- archive the orbit history
- plot the orbit history for, for example, annual reporting (Fig. 2)
- print orbital elements as a telefacsimile
- transmit a data file with orbital information to the image-processing system for the Meteosat weather picture.

A recent PEPSOC extension is a program that produces simulated tracking data as input to the orbit-determination process. This serves as a training tool for PEPSOC operators for a new control centre before the spacecraft has been launched.

*ESA SP-1053, available from ESA Publications Division.

Figure 2 — Longitude evolution for ECS-1 and ECS-2 (daily maxima and minima) for the year 1985/86. Each peak in the curve is caused by a longitude station-keeping manoeuvre

Future implementations

It is possible to implement PEPSOC on a personal computer. A relatively powerful model would be needed as regards disk and core storage, programmable in Fortran to perform arithmetic operations with floating-point double precision. This is just one of many possible future implementations of PEPSOC currently under consideration.

An obvious development for all control systems is the trend to automate them. This is also true for the orbit-control loop of a geostationary spacecraft. Automation implies creating a new system around the existing PEPSOC suite to make the decisions and take the actions that have so far been the responsibility of the operator. There are plans at ESOC to do this at some time in the future, but only in the context of the automation of other spacecraft-operator tasks, since PEPSOC constitutes only a small part of the operator's total workload.

Another possibility might be to automate the orbit-control function in a computer onboard the spacecraft. In the late 1970s, ESA study contracts were placed to investigate methods for autonomous spacecraft station-keeping. This line of development turned out to be a dead end, because the input for the control loop, namely the measurements of distance and direction to the spacecraft from ground-station antennas, is obtained on the ground. The methods of measuring spacecraft position available onboard, namely via the directions to stars and to the Earth and Sun by means of sensors, do not provide anywhere

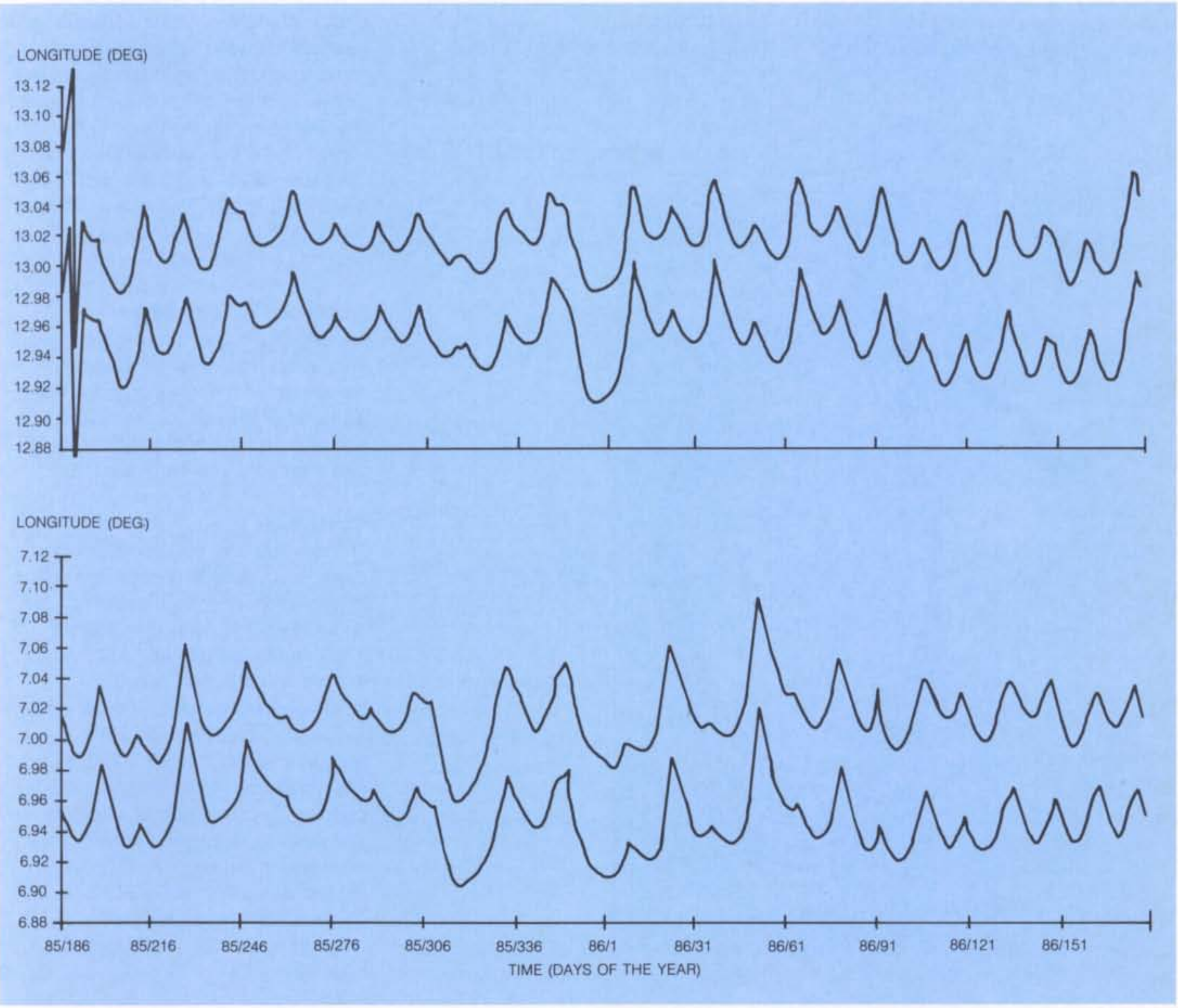


Figure 3 — Projection onto the equatorial plane of spacecraft motion during the free-drift phase of a 14-day station-keeping cycle inside a 100 km-long control box

near the accuracy needed for the precise orbit control of future geostationary missions. There is therefore no advantage in putting the control loop onboard the spacecraft.

Coordinated station-keeping

Recently, a possible future task for PEPSOC has been identified in the support of coordinated station-keeping by several spacecraft that share the same longitudinal position, but are operated from different control centres. To eliminate the risk of collision between the spacecraft, their orbital control should be coordinated such that the station-keeping manoeuvres are executed according to an agreed schedule with the same strategy. It is desirable that the same software system be operated by the different control centres, to ensure agreement between the orbit-determination methods, the physical models and the strategy definitions. A coordinated-station-keeping feature can be added to PEPSOC as a new software module.

One example of a shared longitude is the position of 19°W, which is allocated to about ten prospective or future missions including Olympus. The proposed size of the control box is 0.14° in longitude and latitude, which is equivalent to about 100 km at the geosynchronous orbit. Without coordinated station-keeping, the statistical risk of collision would not be negligible, partly because the satellites would not be uniformly distributed inside the control box. They would orbit in close proximity since they follow the same equation of orbital motion and have similar station-keeping requirements. The regular station-keeping manoeuvres needed to ensure a predefined safe minimum distance between spacecraft can be performed using PEPSOC.

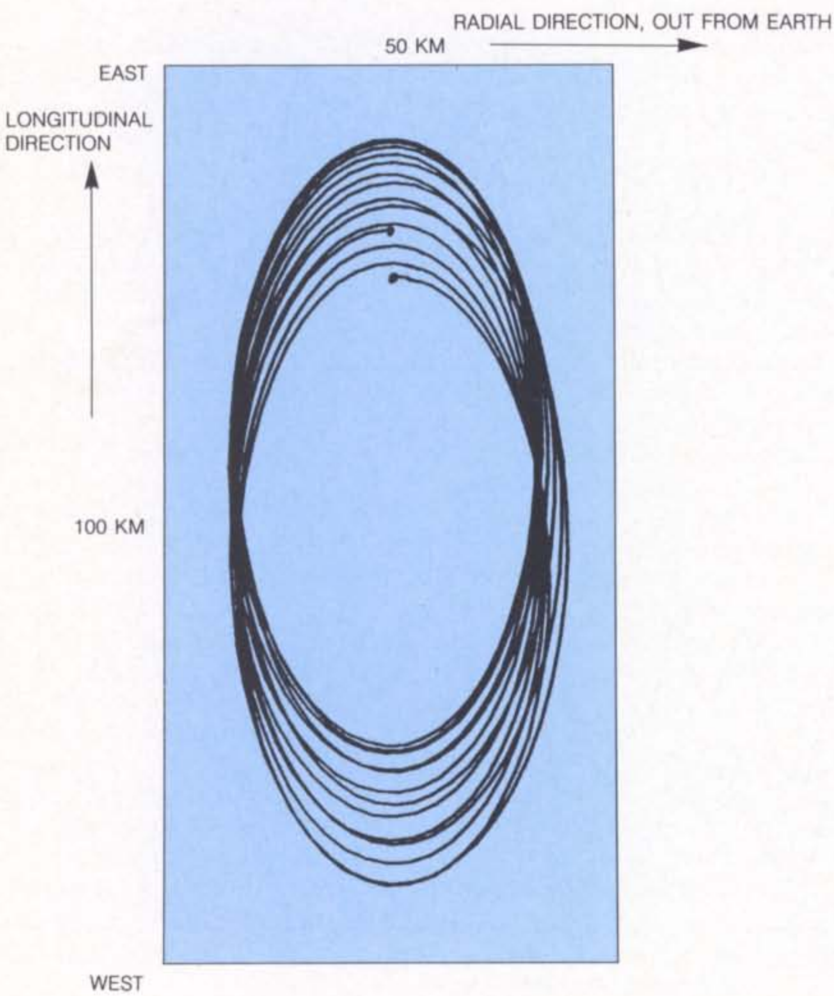


Figure 3 shows a projection into the equatorial plane of a free-flight spacecraft trajectory between station-keeping manoeuvres. The spacecraft moves in a clockwise spiral, completing one loop per day. Not shown in the graph is the libration in latitude, outside the plane of the paper, which also has a period of one cycle per day. The relative phase between the two oscillatory motions depends on the time of the year. It is not practical to divide the station-keeping control box into even smaller portions and allocate one part to each spacecraft. This would require very frequent manoeuvring, thereby increasing the workload of the control centre and accelerating the consumption of thruster propellant to unrealistic levels.

Conclusion

The development of a portable software system dedicated to controlling satellites in geostationary orbit is justified by the large number of present and future missions that will use this orbit. In fact, there is no other field of celestial mechanics where such a limited orbital region of space finds such wide application. With PEPSOC, the trained spacecraft operator or engineer can perform the orbital control tasks that were previously the exclusive domain of the orbit expert. Moreover, many new and interesting applications of PEPSOC can be visualised for handling the challenging orbital-control tasks of the future.

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

In Orbit / En orbite

	PROJECT	1987–1993 (JFMAMJJASOND)	COMMENTS
SCIENT. PROG.	ISEE-2		RE-ENTRY SEPT. 1987
	IUE		
APPLICATIONS PROGRAMME	MARECS-1		
	MARECS-2		LIFETIME 5 YEARS
	METEOSAT-2		
	ECS-1		LIFETIME 7 YEARS
	ECS-2		LIFETIME 7 YEARS

Under Development / En cours de réalisation

	PROJECT	1987–1993 (JFMAMJJASOND)	COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE		LIFETIME 11 YEARS
	ULYSSES		MISSION DURATION 4.5 YEARS
	STSP		LAUNCHES 1994 AND 1995
	HIPPARCOS		
	ISO		LAUNCH 1992/93
TELECOM. PROG.	ECS-4 & 5	ECS-4, ECS-5	
	OLYMPUS-1		LIFETIME 5 YEARS
EARTH OBSERV. & MICROGRAVITY PROGS	ERS-1		
	EOPP		
	METEOSAT-P2/LASSO		OPS. PERIOD DEPENDS ON MOP
	METEOSAT OPS. PROG.	MO 1, MO 2, MO 3	
	MICROGRAVITY	IML-1, SPACELAB D2	IML LAUNCH DATE UNDER REVIEW
SPACE ST. & PLATFMS. PROG.	EURECA		
	COLUMBUS		
SPACE TRANSPORTATION PROGRAMME	ARIANE LAUNCHES	V19, V20, V21	
	ARIANE-4		
	ARIANE-5 PREP. PROG.		START DEVELOPMENT PROG. JANUARY 1988
	HERMES PREP. PROG.		START DEVELOPMENT PROGRAMME JANUARY 1988

= DEFINITION PHASE · > PREPARATORY PHASE · ▨ MAIN DEVELOPMENT PHASE · ▪ STORAGE · ◇ HARDWARE DELIVERIES

~ INTEGRATION · ✝ LAUNCH/READY FOR LAUNCH · * OPERATIONS · - ADDITIONAL LIFE POSSIBLE · ⸸ RETRIEVAL

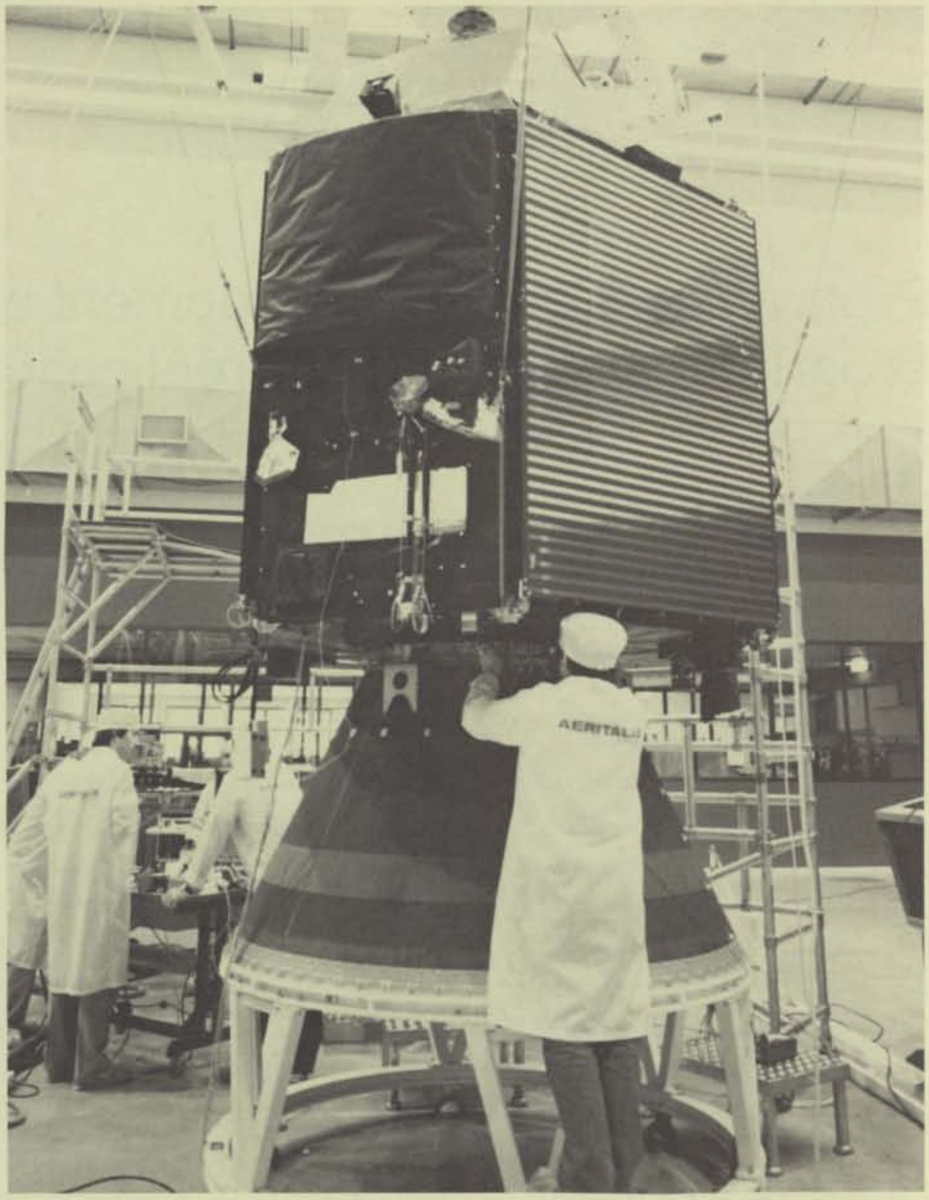
Météosat

Programme pré-opérationnel
Le satellite Météosat P2 reste entreposé chez le maître d'oeuvre à Cannes. Le lancement est prévu pour le début de 1988.

Programme Météosat opérationnel (MOP)
La construction du matériel de vol et les essais des systèmes se déroulent conformément aux prévisions à l'Aérospatiale, pour les trois unités au programme. Les principales causes d'incertitude du programme sont liées aux dates de lancement de MOP-1 et de MOP-2.

Secteur terrien
Les travaux de réaménagement et d'amélioration du matériel existant se poursuivent, en prévision de l'exploitation des nouveaux satellites du programme opérationnel.

Les principaux domaines de travail sont les suivants:
- *Système d'acquisition de données, de télécommande et de poursuite (DATTS)*
- *Réseau assurant les liaisons avec les orbites de transfert géostationnaire*
- *Système de mesure de distance*
- *Système de collecte de données*
- *Centre de contrôle opérationnel Météosat.*



Hipparcos engineering-model spacecraft undergoing shock separation testing with the Ariane adapter, at Aeritalia (Italy)

Essai de séparation/choc entre le modèle technologique d'Hipparcos et l'adapteur d'Ariane chez Aeritalia (Italie)

Hipparcos

Le programme d'essais du modèle d'identification du satellite a pris fin avec l'achèvement de l'essai B du système intégré. Les résultats de tous les essais, notamment les performances réelles enregistrées, vont être comparés aux exigences et paramètres relatifs à la définition au niveau du système. Ils seront analysés, en même temps que les données provenant des autres essais de qualification, lors de la revue des résultats de la qualification au niveau du système, qui aura eu lieu à la mi-septembre. L'examen en continu auquel ont déjà été soumis tous les résultats de chacun de ces essais a donné satisfaction et permet ainsi d'envisager la qualification définitive au niveau du satellite intégré.

Les essais du prototype-modèle de vol de la charge utile ont fait apparaître un problème de défocalisation différentielle. On a établi qu'il était imputable au miroir plan de renvoi, dont la colle avait subi des effets de fluage sous l'action antérieure d'une exposition à des températures et à des taux d'humidité élevés. On l'a remplacé par le miroir de rechange, dont la colle était restée stable en raison d'un entreposage dans de meilleures conditions. Le remplacement du miroir, puis de nouveaux essais et de longs travaux d'étalonnage ont quelque peu retardé la livraison de la charge utile et son intégration au satellite, prévue pour octobre.

L'intégration des sous-systèmes et les essais du prototype de vol du véhicule progressent à grands pas. La majorité des sous-systèmes ont été installés et leurs essais ont donné satisfaction. Quant au sous-système de correction d'attitude et d'orbite, son installation et ses essais auront lieu prochainement. Au terme de ce processus relativement long, la plate-forme sera prête à recevoir la charge utile.

Les activités inhérentes à la maintenance du satellite pendant son entreposage et à sa réactivation avant le début de la campagne de tir sont encore à l'étude à l'Agence et chez les constructeurs. Ces derniers devaient soumettre à cet effet une proposition en bonne et due forme courant septembre, pour qu'un contrat puisse être passé avant la fin de l'année.

Meteosat

Preoperational programme
The Meteosat-P2 spacecraft is still in storage at the Prime Contractor's facility in Cannes, with launch currently scheduled for the beginning of 1988.

Meteosat Operational Programme (MOP)
Flight hardware manufacturing and system testing for the three MOP spacecraft is progressing according to plan at Aerospatiale. The most critical aspect in the programme concerns the launch dates for MOP-1 and -2.

Ground segment
The refurbishment and improvement of existing equipment is continuing in preparation for the operation of the new MOP satellites. The main areas of activity are:
- Data Acquisition Telecommand & Tracking System (DATTS)
- Geostationary Transfer Orbit Network (GTO)
- Ranging System
- Data Collection System
- Meteosat Operations Control Centre.

Hipparcos

With the termination of the Integrated System Test B, the engineering model satellite test programme was completed. The results of all the tests, particularly the actual recorded performances, will be compared with system level design parameters and requirements, and will, together with other qualification test data, be scrutinised at the system level Qualification Results Review (QRR) scheduled for mid-September. The results of each of the separate tests have already been examined individually and confirmed as satisfactory, adding considerably to confidence that full qualification status at integrated satellite level will be declared.

During the course of the Proto-Flight Model (PFM) payload tests a problem of differential defocussing was observed. This problem was traced to the flat folding mirror that had experienced both elevated temperatures and humidities, causing creep effects in the mirror glue. The mirror was exchanged with the spare, which, not having experienced these adverse conditions during storage, has stable glue. In conjunction with the mirror exchange, retesting and extended calibration activities, the payload programme has stretched somewhat and delivery of the payload for satellite integration is now expected in October.

Subsystem integration and test of the protoflight spacecraft is proceeding at full speed. The majority of the subsystems have been installed and been satisfactorily tested. The Attitude and Orbit Control Subsystem (AOCS) will shortly be installed and tested. At the end of this comparatively lengthy process, the spacecraft will be ready for integration with the payload.

The activities required for satellite maintenance during storage and for its reactivation prior to the beginning of the launch campaign are still being investigated by both ESA and industry. It is planned that industry will submit a formal proposal for these tasks in the course of September, with the objective of concluding a contract before the end of the year.

Olympus

The Flight-1 spacecraft arrived at the Jet Propulsion Laboratory, Pasadena, California on 29 May after special air shipment from British Aerospace at Stevenage. The solar simulation test sequence involving a number of individual test phases, was completed successfully. The spacecraft was then transferred to the David Florida Laboratories (DFL) in Ottawa, arriving on 22 June. Initial assessment of the measurements made during the thermal test showed them to be satisfactory and a full analysis of the results is now under way.

At DFL preparations for the start of the main electrical testing at system level are in progress in parallel with the retrofitting of certain equipment items. These system tests precede the environmental testing of the spacecraft and the first, concerned with the radio-frequency sensing system associated with the broadcast payload, is planned to be conducted in the anechoic chamber starting in early September.

The Ariane manifest now shows Olympus-1 on V-30, planned for launch in January 1989.

The construction of earth stations is continuing in a number of European countries and in Canada while the ESA earth stations are nearly complete. Applications to use the satellite capacity have now been received from over one hundred organisations and include a number of major experiments e.g. SSTDMA, videoconferencing, distance learning, and computer-computer communication.

Various alternative missions for Olympus-2 were presented to participating Member Countries in the course of July. Mission study work is continuing and an RFQ for a study proposal is being prepared.

ERS

Equipment and sub-system Critical Design Reviews are in progress and will extend over the next months until the System Critical Design Review scheduled for October/November.

Mechanical qualification in line with the latest, somewhat enhanced, data obtained from the Launcher Authority has been completed successfully, thus ending the vibration and acoustic tests of the satellite structural model and centrifuge testing of the payload structural model.

Engineering-model manufacturing has been completed in nearly all areas and integration and tests of the sub-systems are in progress. These tests in general confirm the performance predictions. There have, however, been occasional test failures affecting the delivery forecasts for payload elements. Plans are being developed to advance software compatibility testing in order to minimise the delay in the completion of engineering model payload testing, notwithstanding current delays in engineering model payload deliveries.

Flight model manufacturing has started in many areas, but risks in the schedule of completion of the flight model payload due to late deliveries of Hi-Rel components and delays in the engineering model programme remain.

Work on the Kiruna Station development, the Mission Management and Control Centre and the Earthnet ERS-1 elements

Olympus

Transport of the Olympus flight spacecraft to JPL (USA)

Transport du modèle de vol d'Olympus au JPL (Etats-Unis)

L'exemplaire de vol no 1 en provenance de British Aerospace est arrivé le 29 mai au Jet Propulsion Laboratory de Pasadena, en Californie, transporté par avion-cargo spécial depuis Stevenage. La série d'essais de simulation solaire, comportant différentes phases, a été couronnée de succès. Le satellite a ensuite été transféré aux laboratoires David Florida d'Ottawa, où il est arrivé le 29 juin. L'évaluation initiale des mesures effectuées pendant l'essai thermique s'est révélée concluante et l'analyse complète des résultats est en cours.

Les préparatifs se poursuivent à Ottawa en vue du démarrage de l'essai électrique principal au niveau système, parallèlement au montage en rattrapage de certains matériels. Ces essais système, qui seront suivis d'essais du satellite en ambiance spatiale, devaient commencer début septembre. Ils sont effectués en chambre anéchoïque et portent sur le système d'écartométrie radioélectrique associé à la charge utile de radiodiffusion.

Le dernier calendrier des tirs d'Ariane mentionne janvier 1989 comme date de lancement d'Olympus-1, sur le vol V-30.

La construction des stations terriennes se poursuit dans divers pays européens et au Canada, celles de l'ESA étant en voie d'achèvement. Plus de cent organisations ont soumis des demandes d'exploitation du potentiel du satellite après sa mise en orbite, dont certaines portent sur des expériences de grande envergure (AMRT avec commutation à bord, visioconférences, télé-enseignement, liaisons entre ordinateurs).

Courant juin, diverses options ont été soumises aux pays membres quant à la mission d'Olympus-2, dont l'étude se poursuit. Une demande de prix consécutive à une proposition d'étude est en cours d'élaboration.

ERS

Les revues critiques de conception du matériel et des sous-systèmes se poursuivront jusqu'en octobre-novembre, période prévue pour celle du système.

Le résultat concluant des qualifications mécaniques effectuées en fonction des données les plus récentes, sensiblement affinées, communiquées par l'autorité responsable du lanceur, a marqué l'achèvement des essais acoustiques et de vibration du modèle mécanique du satellite, et des essais de centrifugation de celui de la charge utile.

La construction du modèle d'identification est achevée à presque tous les niveaux, tandis que l'intégration et les essais des sous-systèmes se poursuivent. Ces essais confirment dans l'ensemble les performances calculées, mais certains échecs sont toutefois venus modifier les dates prévues pour la livraison des éléments en question de la charge utile. On envisage d'avancer la date des essais de compatibilité du logiciel pour réduire le plus possible le retard final des essais du modèle d'identification de la charge utile, auquel s'ajouteront toutefois les actuels retards de livraison du matériel requis pour sa réalisation.

La construction du modèle de vol a commencé à divers niveaux, mais des incertitudes subsistent quant à la date d'achèvement du modèle de vol de la charge utile, en raison des retards de livraison des composants à haute fiabilité et du retard accumulé au cours du programme de réalisation du modèle d'identification.

En ce qui concerne la mise au point de la station de Kiruna, le centre de gestion et de commande de la mission et les éléments ERS-1 d'Earthnet, les travaux progressent normalement. Les préparatifs se poursuivent en vue de la phase de démarrage et de l'étalonnage en orbite, et en vue de la campagne Toscane-2.

L'évaluation finale des réponses à l'offre de participation ERS est en cours, de même que le choix officiel des propositions qui seront présentées au Conseil directeur du programme d'observation de la terre, qui se réunira en octobre.

ERS-2

Des négociations ont été entamées avec les constructeurs en vue de l'acquisition d'une deuxième unité de vol, identique dans toute la mesure du possible à ERS-1.

is proceeding nominally. Preparation for the in-orbit commissioning phase and calibration, as well as the Toscane-2 campaign, is in progress.

The responses to the ERS Announcement of Opportunity are now under final evaluation and formal selection of proposals for presentation at the Earth Observation Programme Board to be held in October is underway.

ERS-2

Negotiations with industry are continuing for the procurement of a second Flight Unit as far as possible identical to ERS-1.

EOPP

The Earth Observation Preparatory Programme (EOPP) activities have concentrated on the definition of a Solid Earth mission, continued international contacts on Polar Platforms and the initiation of a number of contracts with industry for Polar Orbit Instrumentation or Second Generation Meteosat.

Solid Earth

At the June meeting of the Earth Observation Programme Board the go-ahead was given for the feasibility study (Phase-A) on a Solid Earth Mission with the prime aim of mapping the Earth's Gravity Field by means of a single low-orbit satellite, planned to be launched together with ERS-2 in 1993. At the end of July a competitive request for tender was issued to industry, with responses requested by mid-September.

Second-Generation Meteosat

A Workshop devoted to the Second-Generation Meteosat was held in Spain at the end of May. It brought together some 30 participants from eight European countries and representatives of Eumetsat, the World Meteorological Organisation (WMO) and the European Centre for Medium-Range Weather Forecast (ECMWF).

The Workshop dealt exhaustively with data circulation using information generated by satellite (images, soundings) or relayed by them (data collection platforms, images from other satellites or data transmitted within the WMO's global telecommunication system). Industrial studies on main microwave or optical instruments and scientific packages are proceeding according to schedule.

Polar Orbit Earth Observation

The schedule of activities and the specifications for instruments have been presented to the Earth Observation Advisory Group. Tender actions have been initiated for studies on radar altimeters, imagery spectrometers and synthetic-aperture radar, and others are in the course of preparation.

Scientific consultant groups have been established to advise on requirements for ATLID, which will detect cloud and aerosol particles, and Limb Sounders, which will study the chemical composition of the upper atmosphere.

Microgravity

Work on the microgravity multi-user facilities is progressing in industry. These facilities, consisting of Anthrorack, the Critical Point Facility and the Advanced Fluid Physics Module (AFPM) will form part of the German D2 Spacelab payload which is currently planned to be launched in 1991. Phase-B, the feasibility study of the Gradient Heating Facility, is nearing completion and the contractor has been requested to prepare an offer for the Development Phase C/D. Phase C/D of the Bubble, Drop and Particle Unit is already underway.

Concerning the NASA-managed International Microgravity Laboratory (IML-1) on which ESA's Biorack will be flown for a second time, a meeting of all investigators was held in ESTEC in early September to review the progress of work and the status of the experiment.

A small European passive experiment of the Biorack type will be carried on board the USSR's Biosatellite mission to be launched in late September.

Preparations are proceeding for the next sounding rocket flights carrying microgravity experiments. A Texus campaign is planned for November of this year and a Maser-2 launch in March 1988.

Following the parabolic airplane flights made earlier in the year, which concentrated mainly on combustion under microgravity conditions, preparations are being made for a parabolic flight campaign mainly dedicated to Life Sciences to be held in October.

The Third European Symposium on Life Sciences Research in Space, organised by ESA and co-sponsored by the Austrian Solar & Space Agency (ASSA) was held in mid-September.

On the Eureca Microgravity Payload developed by ESA, the tests on the Engineering Model of the Automatic Mirror Furnace have successfully been completed. The model was subsequently installed in the Microgravity User Support Centre (MUSC) at DFVLR.

Eureca

Eureca-A

Design and development of Eureca-A is proceeding according to the re-aligned Eureca-A schedule aiming for launch in April 1990. Integration of the Orbit Transfer Assembly and thermal control freon lines into the flight structure is in progress at BPD. Subsequently, the spacecraft will be moved to MBB/ERNO, Bremen, for further integration activities. The second Overall Checkout Equipment (OCOE) software delivery from ESA to MBB/ERNO has slipped from August to December due to late delivery. However, already available software does support the ongoing payload interface tests at the Payload Test Facility (PTF).

On the critical list are: the thermal control system with problems in the Thermal Control Unit (TCU) schedule, radiator welding, and the necessity to implement a radiator bypass due to lack of sufficient power for thermal control by heaters; and the Attitude and Orbit Control System (AOCS) which completed its critical design review late.

The second ESA/NASA Payload Safety Review was successfully completed for eleven of the fifteen instruments in July.

Eureca-B

The Eureca-B Phase-B2 Extension study is progressing satisfactorily as part of the Columbus Phase-B2 Extension, based on a negotiated and finalised Statement of Work, Document Requirements List and contract.

EOPP

Les activités du Programme préparatoire d'observation de la terre sont axées sur la définition de la mission 'solide terrestre', sur le maintien de contacts internationaux dans le domaine des plates-formes en orbite méridienne et sur l'amorce de divers contacts avec l'industrie, relatifs à des équipements pour orbite méridienne ou à un Météosat de seconde génération.

Solide terrestre
A sa réunion de juin, le Conseil directeur du programme d'observation de la terre a autorisé l'étude de faisabilité (phase A) d'une mission 'solide terrestre', dont le principal objectif sera d'établir la carte du champ de gravité terrestre à partir d'un satellite unique sur orbite basse, qu'il est prévu de lancer en même temps qu'ERS-2 en 1993. Un appel d'offres a été lancé fin juillet et les constructeurs devaient remettre leurs soumissions avant la mi-septembre.

Météosat de seconde génération
Un atelier consacré au Météosat de seconde génération s'est tenu fin mai en Espagne. Il a réuni une trentaine de participants venus de huit pays européens, ainsi que des représentants d'Eumetsat, de l'Organisation météorologique mondiale (OMM) et du Centre européen pour les prévisions météorologiques à moyen terme (ECMWF).

Cet atelier a examiné de manière approfondie la diffusion des données à partir des informations produites par le satellite (images, données en provenance de sondes) ou retransmises par ce dernier (plates-formes de collecte de données, images en provenance d'autres satellites ou données transmises au sein du système global de télécommunications de l'OMM). Les études industrielles des principaux appareils optiques et à hyperfréquences et des principaux ensembles scientifiques se déroulent conformément aux prévisions.

Observation de la terre en orbite méridienne
Le calendrier des travaux et les spécifications des instruments ont été soumis au groupe consultatif pour l'observation de la terre. Des appels d'offres ont été lancés, relatifs à des études sur les altimètres radar, les spectromètres à images et les radars à synthèse d'ouverture, tandis que d'autres sont en cours d'élaboration.

Des groupes de conseillers scientifiques sont désormais en place, spécialisés dans le domaine de l'ATLID, destiné à détecter les nuages et les aérosols, et du 'sondeur de limbe', qui étudiera la composition chimique de la haute atmosphère.

Microgravité

Les constructeurs poursuivent leurs travaux sur les charges utiles de microgravité pour utilisateurs multiples. Ces installations, qui comprennent Anthrorack, l'installation de point critique et le module avancé de physique des fluides, feront partie de la charge utile allemande D2 de Spacelab, dont le lancement est prévu pour 1991. La phase B, l'étude de faisabilité du four à gradient, est en voie d'achèvement et le contractant a été invité à élaborer une offre quant à la phase de développement C/D. La phase C/D de l'expérience 'bulles, gouttes et particules' a débuté.

En ce qui concerne le laboratoire international de microgravité (IML-1) géré par la NASA, dans lequel le 'Biorack' de l'ESA effectuera son second vol, les expérimentateurs ont tenu une réunion générale à l'ESTEC début septembre pour examiner la situation des travaux et l'état d'avancement des expériences.

Une charge utile européenne passive de type Biorack, de taille modeste, sera embarquée sur le Biosatellite soviétique, dont le lancement devait avoir lieu fin septembre.

Les préparatifs progressent en vue des prochains tirs de fusées-sondes destinées à transporter des charges utiles de microgravité. Une campagne Texus est prévue pour le mois de novembre prochain, et un lancement Maser-2 en mars 1988.

A la suite des vols paraboliques effectués au début de l'année, axés principalement sur la combustion en état de microgravité, on prépare pour octobre une campagne de vols similaires essentiellement consacrés aux sciences de la vie.

Le troisième colloque européen consacré à la recherche sur les sciences de la vie dans l'espace, organisé par l'ESA et placé sous le patronage conjoint de l'Agence solaire et spatiale autrichienne (ASSA), a eu lieu à la mi-septembre.

En ce qui concerne la charge utile Eureca, développée par l'ESA, les essais du modèle d'identification du four à miroir automatique ont été couronnés de succès. Le modèle a ensuite été installé au centre d'assistance aux utilisateurs de la microgravité (MUSC) du DFVLR.

Eureca

Eureca-A
La conception et le développement d'Eureca-A se poursuivent conformément au nouveau calendrier, en vue du lancement prévu pour avril 1990. L'intégration de l'ensemble de transfert d'orbite et du circuit de régulation thermique au fréon dans la structure de vol se poursuit chez BPD. La plate-forme sera ensuite transférée chez MBB/ERNO, à Brême, pour la suite des travaux d'intégration.

La livraison à MBB/ERNO par l'ESA du deuxième logiciel des équipements de vérification générale a dû être repoussée d'août à décembre. Le logiciel actuel est toutefois compatible avec les essais d'interface en cours dans l'installation d'essais de charge utile.

Parmi les éléments critiques, on citera le système de régulation thermique, en raison des problèmes liés au calendrier de l'unité de régulation thermique, le soudage des radiateurs et la nécessité d'installer une dérivation des radiateurs, la puissance étant insuffisante pour assurer une régulation thermique par chaufferettes, et enfin le système de correction d'attitude et d'orbite, dont la revue critique de conception a été retardée.

La deuxième revue de sécurité de la charge utile effectuée par l'ESA et la NASA a donné en juillet des résultats concluants pour onze des quinze instruments.

Eureca-B
L'étude de l'extension de la phase B-2 d'Eureca-B se poursuit de façon satisfaisante dans le cadre de l'extension

Spacelab and IPS

Spacelab contract close-out of all tasks except the production test, and delivery to ESA of the Payload Interface Adaptor (PIA) flight unit hardware is due to be completed by the end of the year. The last Data Display Unit has been repaired and delivered back to Kennedy Space Centre (KSC). Disposal of residual Spacelab inventory items is proceeding, with useful hardware being loaned or transferred to various interested parties.

On IPS, progress has been made in closing open items from the formal Phase C/D qualification and acceptance. The investigation and repair of the star-tracker assembly that failed during the Spacelab-2 mission has been completed. This assembly is now ready to be integrated into the Phase C/D Optical Sensor Package that is expected to be delivered to KSC in December. This will conclude the Spacelab and IPS activities committed to be undertaken by ESA under the Memorandum of Understanding with NASA.

Space Station/ Columbus

The space segment Phase-B2 studies of the Columbus Preparatory Programme ended in June with a Baseline Review and results were presented to the Columbus Programme Board. The impact of major changes in the Hermes configuration on the Columbus elements has had to be investigated. For this purpose a Columbus/Hermes Coherence Task Force (CTF) was set up in March. The results of its first evaluations were: the recognition that the Polar Platform can no longer be serviced by Hermes and that some relocation of external subsystems to the inside of the Man-Tended Free Flyer (MTFF) is needed to maximise internal servicing by Hermes.

Continuation of the space segment studies, B2X (extension), was initiated in June at industry's own risk for the months of June/July, due to a delay in achieving full approval of the extension phase by Member States. One of the major tasks is to identify design changes to the MTFF in order to accommodate the CTF recommendations. The Polar Platform design concept has been subjected to new user demands for a higher payload capability (3100 kg instead of 2500 kg). Planning for completion of Phase B2X is currently under review and it is likely that this phase will have to be extended until March 1988.

In April NASA received presidential approval for the block-1 Space Station and issued Requests for Proposals to industry. Proposals arrived on 21 July and are under evaluation at present. Negotiations on the Memorandum Of Understanding between ESA and NASA continue, with emphasis on management requirements, decision-making processes and access and utilisation rules.

Operations activities have continued to be covered by the space segment Phase-B studies, e.g. element transportation to the launch site, launch checkout, initial activities, rendezvous of the MTFF with the Space Station and MTFF servicing by Hermes. Flight operations studies, led by ESOC, have centred on establishing a strawman concept for the operation of the future in-orbit-infrastructure Ariane-5, Hermes, Columbus and Data-Relay Satellite (DRS). Taking into consideration offers made by various national agencies actively to participate in future operations, a Central Design Authority (CDA) Working Group has been set up. This Working Group, with involvement of the projects and the interested national agencies, is briefed until early 1988 to establish a detailed operations concept defining roles and responsibilities of the various Control Centres involved and the technical content of the total ground infrastructure.

Following the final presentation of the Utilisation Studies, a detailed internal evaluation of the study results was made. Statements of work were prepared for the further continuation of these studies in parallel with, and in support of, the industrial Columbus Phase-B2X studies. Statements of work were also prepared for further utilisation-/payload-related studies in the areas of payload operations, payload automation requirements, telescience test bed activities, crew work station utilisation activities, payload rack interfaces, payload-to-payload EMC activities etc. An initial study of a Columbus Payload Information System was finished and preparations were made for a more detailed study of an overall Columbus User Information System. The Columbus User Documentation Working Group continued its activities towards the preparation of its final report. A joint study with NASA was initiated on the potential commonality between the NASA and ESA Polar Platforms of the platform-to-payload interface. Preparations are underway for a similar joint study covering the payload interfaces for the different pressurised modules of the International Space Station. The Model Payload and Reference Mission set was updated to be in line with the revised Columbus configuration of the study Phase-B2X.

Technology Demonstration Programme (TDP)

The In-Orbit Technology Demonstration Programme was approved on 15 January. Five Member States have subscribed to the Programme, namely Spain, Switzerland, Belgium, The Netherlands and Italy. The United Kingdom's subscription to the programme is not yet decided.

Work on all experiments, with the exception of the three UK experiments, has started. To minimise cost, two common support subsystems – the Payload Control Unit (on-board computer) and the Hitchhiker-G Simulator – for the whole programme have been identified.

For the experiments, two types of contract will be awarded, one for adaptation and another for integration. By the end of the year, the majority of experiment adaptation contracts will have been awarded, and most of the integration contracts will be placed during 1988.

Proposals for experiment adaptation have already been received from industry for the Attitude Sensor Package (which includes the Infrared Earth Sensor, Modular Star Sensor, and Yaw Earth Sensor), the Solid State Microaccelerometer, and the Gallium Arsenide Solar Array. Invitations to Tender (ITT) have been initiated for the Inflatable Space-Rigidised Antenna, the Heat-Pipe Radiator, the Dynamic Cooler and the Collapsible Tube Mast. Studies are in progress to define the In-Space Aluminium Coating and the Liquid *de la phase B2 de Columbus, à partir d'un descriptif des travaux élaboré à l'issu de négociations, de la liste des documents requis et du contrat.*

Spacelab et IPS

Pour Spacelab, la liquidation de tous les contrats, sauf en ce qui concerne les essais d'usine, et la livraison à l'Agence du matériel de vol de l'adaptateur d'interface de charge utile sont prévues pour le courant de 1987. Après réparation, la dernière unité d'affichage de données a été renvoyée au Centre spatial Kennedy. Les opérations de réforme des éléments restants du stock de Spacelab se poursuivent. Le matériel utilisable sera prête ou cédé aux diverses parties intéressées.

En ce qui concerne le système de pointage d'instruments (IPS), les points en suspens à l'issue de la qualification et de la recette officielles de phase C/D sont en passe d'être résolus. On a déterminé et corrigé les causes de la défaillance du suiveur stellaire survenue lors de la mission Spacelab 2. Cet ensemble est désormais prêt à être intégré dans le bloc capteur optique de phase C/D, qui doit être livré au Centre spatial Kennedy en décembre. Ainsi s'achèveront les activités incombant à l'ESA dans le cadre du protocole d'accord signé avec la NASA.

Station spatiale/Columbus

Dans le cadre du programme préparatoire Columbus, les études de la phase B2 du secteur spatial se sont conclues en juin par une revue de la base de référence, dont les résultats ont été soumis au conseil directeur Columbus. Il importait ensuite d'étudier les conséquences pour les éléments de Columbus que pouvaient avoir les profondes modifications apportées à la configuration d'Hermès. Une équipe spéciale chargée d'assurer la cohérence entre les deux programmes a été créée à cet effet en mars. Les premières évaluations auxquelles elle a procédé ont permis de conclure que la plate-forme en orbite méridienne ne pouvait plus être desservie par Hermès et que certains sous-systèmes externes devaient être réimplantés à l'intérieur du module autonome visitable pour optimiser la desserte interne par Hermès.

Les études de l'élément spatial BX2 (extension) ont été reprises en juin pour deux mois aux risques des constructeurs, les Etats membres ayant tardé à approuver la phase d'extension. L'une des principales tâches sera de déterminer quelles modifications doivent etre apportées à la conception du module autonome visitable pour prendre en compte les recommandations de l'équipe spéciale mentionnée plus haut. Pour répondre à de nouveaux impératifs d'exploitation, la conception de la plate-forme en orbite méridienne a dû être adaptée à une charge utile plus lourde (3100 kg au lieu de 2500 kg). On examine actuellement les plans d'achèvement de la phase B2X, qui sera vraisemblablement prolongée jusqu'en mars 1988.

En avril, la NASA a reçu l'autorisation présidentielle pour la réalisation de la première tranche de la Station spatiale et a diffusé des appels d'offres à l'industrie. Les soumissions reçues le 21 juillet sont actuellement à l'étude.

L'ESA et la NASA continuent à négocier les clauses du protocole d'accord, en mettant l'accent sur les exigences en matière de gestion, les processus décisionnels et la règlementation de l'accès et de l'utilisation.

Les activités opérationnelles restaient couvertes par les études de phase B du secteur spatial, notamment le transport sur le lieu de lancement, les vérifications avant le lancement, les travaux initiaux, le rendez-vous du module autonome visitable avec la Station spatiale et la desserte de ce module par Hermès, tandis que l'ESOC effectuait les études relatives aux opérations de vol. L'objectif essentiel était l'ébauche d'un concept d'exploitation de la future infrastructure orbitale constituée d'Ariane 5, d'Hermès, de Columbus et du satellite de relais de données. Un groupe de travail chargé de la coordination de la conception (CDA) a été créé, compte tenu des offres faites par diverses agences nationales en vue d'une participation active aux opérations futures. Ce groupe de travail, avec la participation des équipes de projet et des agences nationales intéressées, est chargé d'établir d'ici le début de 1988 un concept d'exploitation détaillé, définissant les rôles et responsabilités des divers centres de commande intéressés, ainsi que le contenu technique de l'ensemble de l'infrastructure au sol.

A la suite de leur présentation finale, les résultats des études relatives à l'exploitation ont fait l'objet d'une évaluation interne détaillée. Des descriptifs de travaux ont été élaborés en vue de la poursuite de ces études, parallèlement aux études industrielles de la phase B2X de Columbus et au bénéfice de celles-ci. Les autres descriptifs de travaux concernaient des études se rapportant à l'exploitation de la charge utile, à l'automatisation exigée pour la charge utile, aux activités expérimentales en matière de téléscience, à l'utilisation des postes de travail pour astronaute, aux interfaces des baies de la charge utile, à la compatibilité électromagnétique entre charges utiles, etc. L'achèvement de l'étude initiale d'un système informatique pour Columbus a été suivi de préparatifs en vue d'une étude plus détaillée d'un système informatique général pour les utilisateurs de Columbus. Le groupe de travail sur la documentation destinée aux utilisateurs de Columbus a poursuivi ses travaux en vue de l'établissement de son rapport final. Une étude a été amorcée conjointement avec la NASA, sur les possibilités de compatibilité des interfaces entre plate-forme et charge utile. On prépare une étude conjointe similaire, portant sur les interfaces entre la charge utile et les différents modules pressurisés de la Station spatiale internationale. La charge utile type et la mission de référence ont été adaptés à la nouvelle configuration de Columbus dans la phase B2X.

Programme de démonstration technologique

Le programme de démonstration technologique en orbite a été approuvé le 15 janvier. Cinq Etats membres s'y sont associés, l'Espagne, la Suisse, la Belgique, les Pays-Bas et l'Italie. Le Royaume-Uni n'a pas encore pris de décision quant à sa participation.

Tous les travaux ont commencé, à

Gauging Technology experiment and will be completed during the first quarter of 1988. ITTs will then be issued for the adaptation of these two experiments.

The use of several different carriers is planned. In particular, four 'Get-Away Special (GAS)' carriers have been booked on the Space Shuttle, together with accommodation for three Hitchhiker-G experiments. For the Inflatable Space-Rigidised Antenna experiment, use of the USSR MIR station is being investigated. A carrier for the Dynamic Cooler Experiment is still under investigation. The use of a small free flyer satellite to carry the GaAs Solar Array experiment is foreseen. Internal studies are being carried out to investigate the use of Ariane-IV to carry secondary payloads 'piggy-back'. The result of the work is very promising and will be pursued further with the Ariane Programme and Arianespace.

Possible international cooperation with NASA on three technology flight experiments is presently under investigation in the context of technology programme coordination with the NASA Office of Aeronautics and Space Technology (Plume Impingement, Atomic Oxygen, Solar Plasma Interaction).

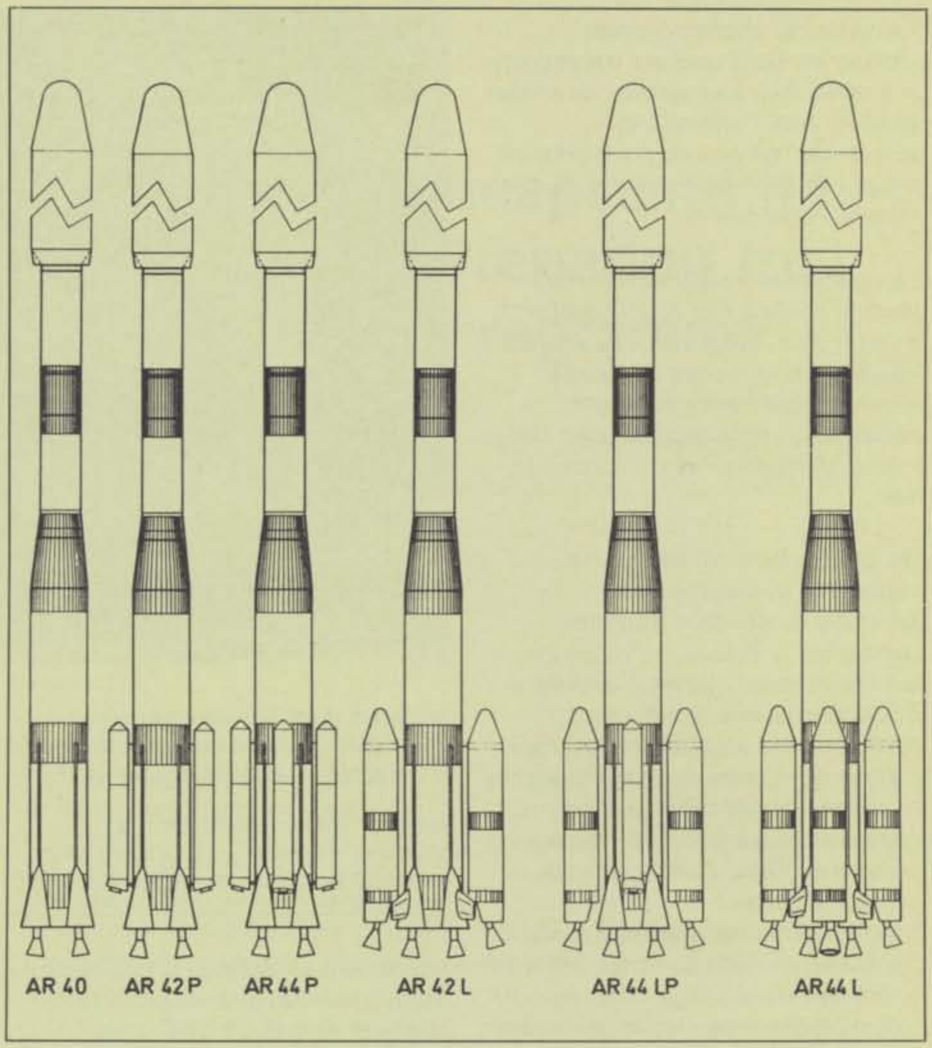
The content of the future TDP phases is currently being prepared for presentation to the IPC.

Space Telescope

NASA
The Space Telescope launch date is currently August 1989 although there is a small possibility of an earlier launch in March 1989.

Solar array
The Solar-array-V2 wing was successfully fit-checked to the Space Telescope. Plans are in preparation for returning the wings to Europe for reworking later in the year.

Faint Object Camera
The first phase of the in-air calibration of the Faint Object Camera (FOC) was successfully completed in July. The second phase is planned to start in October. The FOC will be reinstalled in the Space Telescope at the end of the year.



Ariane-4

Development and qualification
The pressure drop at the outlet of the first stage N_2O_4 pumps at the end of the flight is still being investigated. A likely scenario is now being checked.

A hot test of a Viking engine with a strengthened chamber throat was carried out at the beginning of August. Examination of the test measurements, together with a post-firing inspection of the hardware and, in particular, of the graphite throat, would seem to indicate that flight readiness has been demonstrated.

Additional tests on the flight control and guidance system will be over by mid-September.

Qualification of the cutting system for the SPELDA has still to be completed as far as the leak rate from the initiator is concerned (for any contamination of the upper section).

First Ariane-4 flight (401)
After confirmation of the inspection of the throat used for the long-duration test, the modified Viking engines will be integrated with the first stage so as to be ready for a flight scheduled for February 1988.

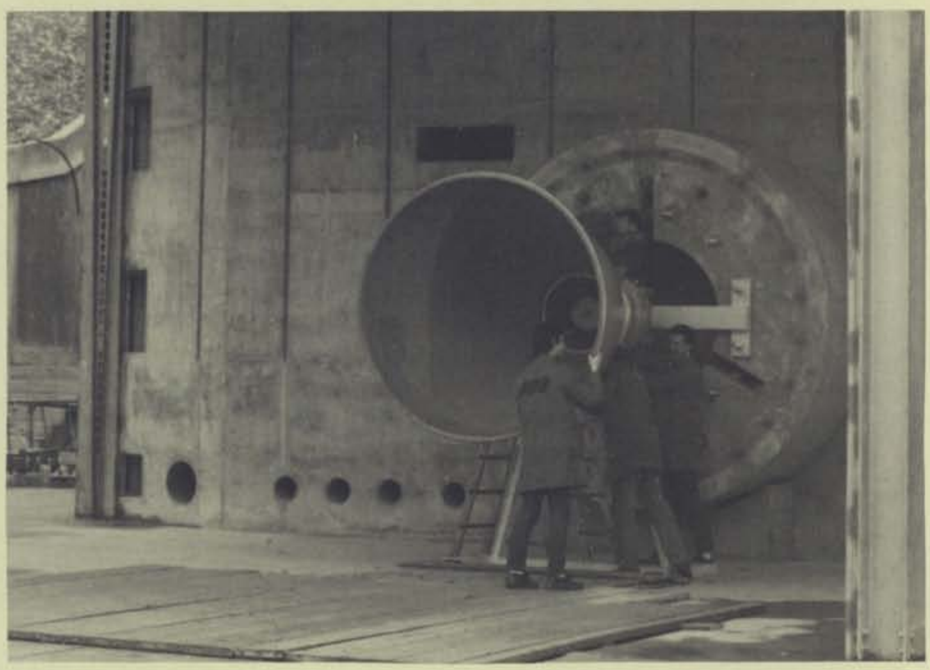
l'exception des trois expériences britanniques. Dans un souci d'économie, on a défini deux sous-système de soutien communs pour l'ensemble du programme, l'élément de commande de charge utile (ordinateur embarqué) et le simulateur Hitchhiker-G.

Les expériences feront l'objet de deux types de contrats, l'un pour l'adaptation et l'autre pour l'intégration. Les contrats adjugés dans le courant de l'année seront principalement des contrats d'adaptation, tandis que la plupart des contrats d'intégration seront conclus en 1988.

Des constructeurs ont déposé des propositions d'adaptation pour l'ensemble de détection d'attitude (comprenant le détecteur d'infrarouge terrestre, le viseur d'étoiles modulaire et le détecteur de lacet à référence terrestre), le microaccéléromètre à l'état solide et le générateur solaire à arséniure de gallium. Des invitations à soumissionner ont été lancées pour l'antenne gonflable à armature rigide, le radiateur à caloducs, le refroidisseur dynamique et le mât d'antenne repliable. Des études sont en cours pour définir les expériences d'aluminiage dans l'espace et de technologie de mesure des niveaux de liquide. Ils prendront fin au cours du premier trimestre 1988. Des invitations à soumissionner seront ensuite diffusées pour l'adaptation de ces deux expériences.

On prévoit d'utiliser plusieurs plates-formes différentes. La place a notamment été réservée sur la Navette pour quatre petites charges utiles embarquées, de même que pour trois charges utiles Hitchhiker-G. En ce qui concerne l'antenne gonflable à structure rigide, on envisage d'utiliser la station soviétique MIR. On recherche actuellement une plate-forme pour le refroidisseur dynamique. On prévoit de faire appel à un petit satellite autonome pour transporter le générateur solaire à arséniure de gallium. Des études internes sont en cours quant à l'utilisation d'Ariane-4 pour acheminer de petites charges utiles secondaires. Les résultats de ces travaux sont très prometteurs et les activités se poursuivront avec le programme Ariane et avec Arianespace.

Les possibilités de coopération avec la NASA pour trois expériences technologiques sont actuellement à l'étude dans le cadre de la coordination des programmes technologiques avec l'Office of Aeronautics and Space Technology de la NASA (effet d'impact des jets de propulseurs, oxygène atomique et interaction avec le plasma solaire).



Integration of the Ariane-4 combustion chamber model on the newly built test stand at Lampoldshausen (MBB, Germany)

Intégration de la maquette 'chambre propulsive' d'Ariane-4 sur le nouveau banc construit à Lampoldhausen (MBB, Allemagne)

L'élaboration des futures phases du programme de démonstration technologique est en cours, en vue de leur présentation au Comité de la politique industrielle.

Télescope spatial

Activités de la NASA
Le lancement du Télescope spatial est actuellement prévu pour août 1988, mais une date plus rapprochée n'est pas à exclure, peut-être en mars 1988.

Générateur solaire
L'aile V2 du générateur solaire a été remontée sur le télescope spatial, après vérifications. On prévoit de renvoyer les ailes en Europe dans le courant de l'annéee pour retouches.

Chambre pour objets faibles
La première phase de l'étalonnage de la chambre à la pression atmosphérique s'est achevée en juillet. La deuxième phase démarrera en octobre. La chambre sera remontée dans le Télescope spatial à la fin de l'année.

Ariane-4

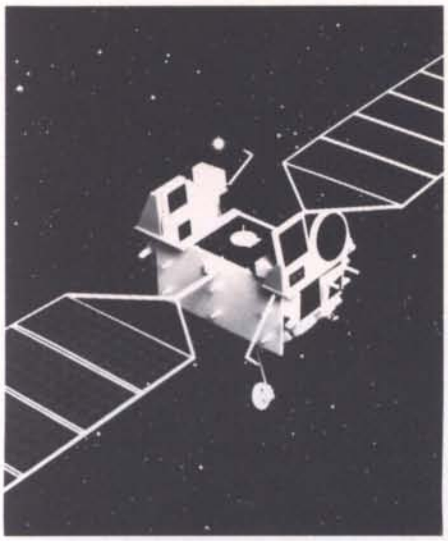
Développement et qualification
Sur le premier étage, les investigations se poursuivent toujours pour expliquer la chute de pression en sortie des pompes N_2O_4 en fin de vol. Un scénario probable est en cours de vérification.

Par ailleurs, un essai à feu d'un moteur Viking avec col de chambre renforcé, a été réalisé au début du mois d'août. L'examen des mesures réalisées pendant l'essai, ainsi que les premières expertises des matériels après tir, et notamment le démontage et examen du col graphite, permettent de penser que l'aptitude au vol est démontrée.

Les essais supplémentaires sur la chaîne de pilotage-guidage vont s'achever mi-septembre.

La qualification du système de découpe de la SPELDA reste encore à compléter vis-à-vis du taux de fuite de l'initiateur (pollution éventuelle de la partie haute).

Premier vol (401)
Après confirmation par l'expertise du col ayant servi à l'essai longue durée, les moteurs Viking modifiés seront intégrés au premier étage en vue d'être prêt pour un vol programmé en fevrier 1988.



The Eureca Concept and its Importance in Preparing for the Columbus Programme

R.D. Andresen & W. Nellessen, Columbus System and Projects Department, ESA Space Station and Platforms Directorate, ESTEC, Noordwijk, The Netherlands

In the late 1970s, ESA identified the need for a free-flying carrier system compatible with launch and retrieval by the US Space Shuttle. Early studies of such a system, now known as Eureca (EUropean REtrievable CArrier), were very much influenced by the thought that such a new system should be more economical to build and operate than the 'classical' nonrecoverable satellite system in a low Earth orbit. It was also realised that Eureca's size should meet European experimenters' needs for the 1988–1998 time frame, and that it should allow Europe to accumulate the technological and operational experience needed to develop and operate larger, autonomous European platform systems in the future, such as the Columbus Polar Platform.

Introduction

Eureca is being pursued within the European Columbus/Space-Station Programme as a co-orbiting platform. Two types of platforms are under development:
- Eureca-A designed for six-month-duration microgravity missions, now more than 2.5 years into the hardware development phase and planned to be launched at the beginning of 1991;
- Eureca-B, designed for one- to two-year-duration space-science missions, presently in the definition phase (Phase-B) and planned to be launched in 1993.

The overall Eureca concept

Eureca, shown in flight configuration in Figure 1, is a reusable platform to be launched and retrieved by the Shuttle. It will perform its missions in a free-flying mode. After retrieval and return to its integration centre, it will be refurbished and re-equipped for its next mission.

The Eureca configuration has been determined primarily by four goals:

(a) maximisation of available payload volume
(b) optimisation of the length-to-mass ratio to minimise the launch charges
(c) direct attachment in the Shuttle's cargo bay via a three-point attachment system
(d) mounting flexibility throughout the length of the Shuttle's cargo bay.

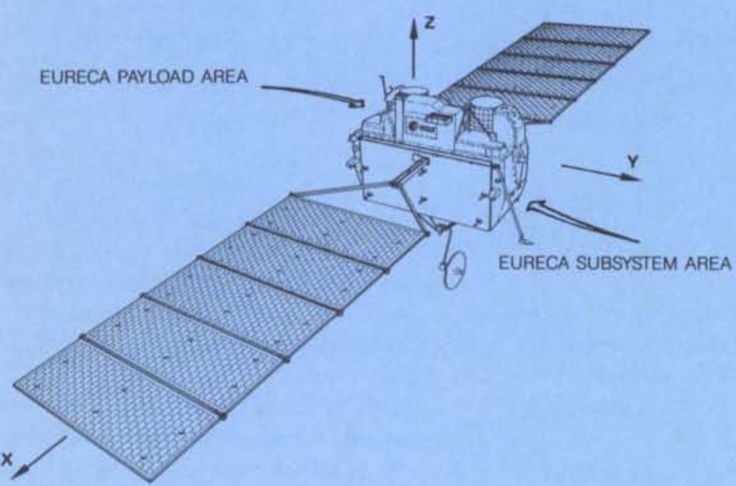
Eureca is designed for maximum user friendliness by providing standardised structural attachments as well as standardised power and data interfaces. The Data-Handling System (DHS) is decentralised, which allows the users to pre-process their data and simplifies instrument integration, thereby keeping the associated costs low for Eureca as well as for the users.

The DHS interfaces are compatible with industrial standards (IEEE 488), so that the users can employ commercially available checkout equipment, and they can reuse their software at the next higher integration level without reprogramming, again helping to reduce costs for experiment development, integration, and operations.

Eureca, being based on the 'ship and shoot' concept, is intended to be shipped as a fully integrated system, requiring only a minimum of Shuttle interface and safety checks at the launch site. In flight, the Shuttle will only control deployment and retrieval operations, while free-flight control will be conducted from ESOC via a single ground station. Outside ground contact times, the mission will be controlled by the onboard data-handling system, which is designed for fully autonomous operations for periods of up to 48 h.

An Inter-Orbit Communication (IOC) data-relay package will be flown on an experimental basis on Eureca's first flight. If successful, it will be used on subsequent flights to provide operational data-relay services via a geostationary satellite. This will significantly enhance real-time data coverage, with transmission rates of up to 2 Mbit/s.

Figure 1 — Eureca payload resources and operational scenario



	TYPE A	TYPE B
MASS	1000 KG	1000 KG
VOLUME	8.5 M^3	8.5 M^3
POWER (CONTINUOUS)	1000 W	800 W
THERMAL CONTROL	ACTIVE/PASSIVE	PASSIVE
CONTINUOUS ONBOARD PAYLOAD DATA ACQUISITION	1 KBIT/S	45 KBIT/S
ATTITUDE POINTING		
— DIRECTION	TO SUN	CELESTIAL
— ACCURACY	+/− 1°	+/− 1° ARCMIN
— STABILITY	+/− 0.5°	+/− 1 ARCMIN/H
— RECONSTITUTION	+/− 0.5°	+/− 5 ARCSEC
ORBIT ALTITUDE/ INCLINATION	~ 500 KM/28.5°	~ 500 KM/28.5°
MICROGRAVITY CONSTRAINT	$<10^{-5}$ G AT 1 HZ	NA
IN-ORBIT OPERATIONAL CAPABILITY	6 MONTHS	18 MONTHS

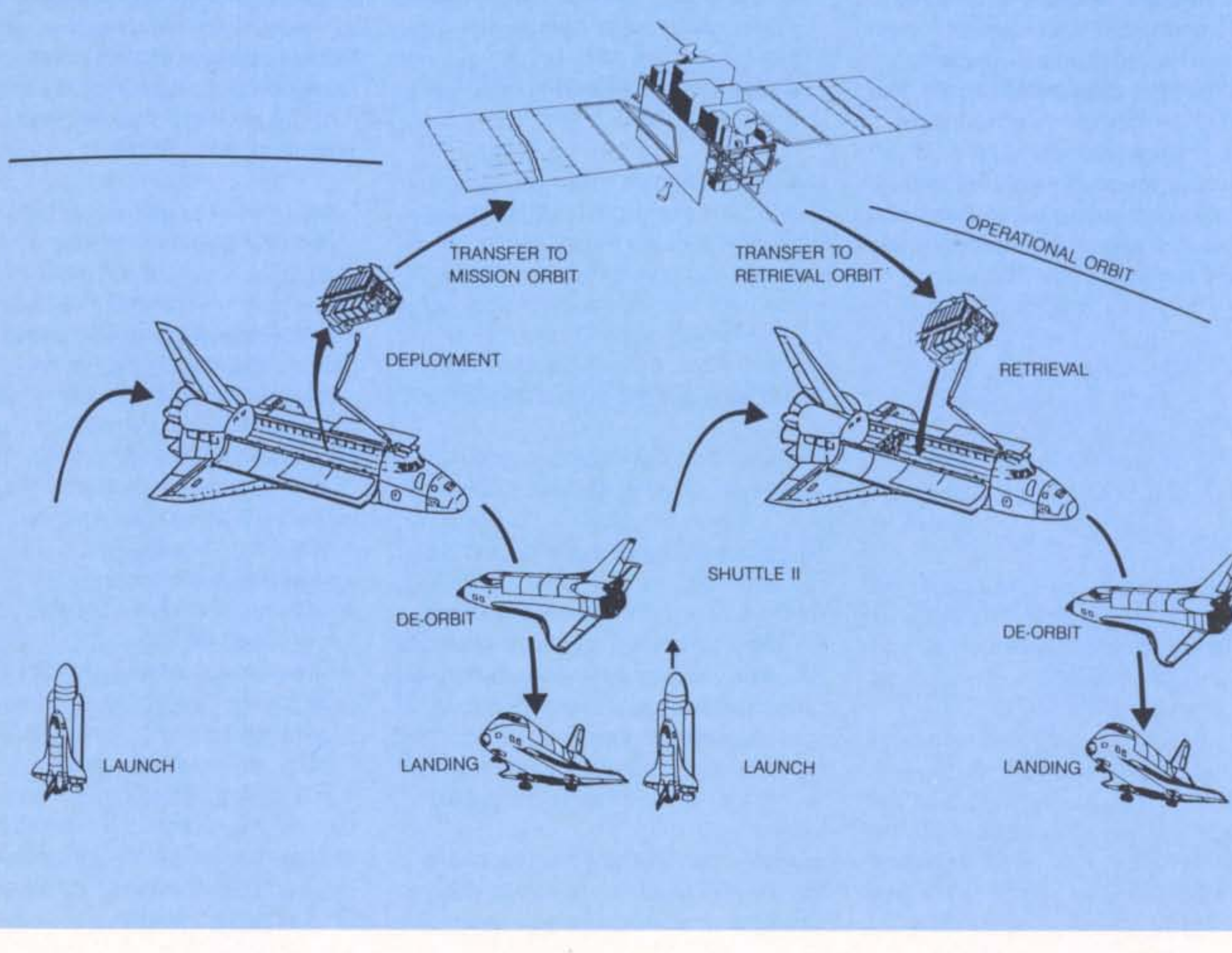
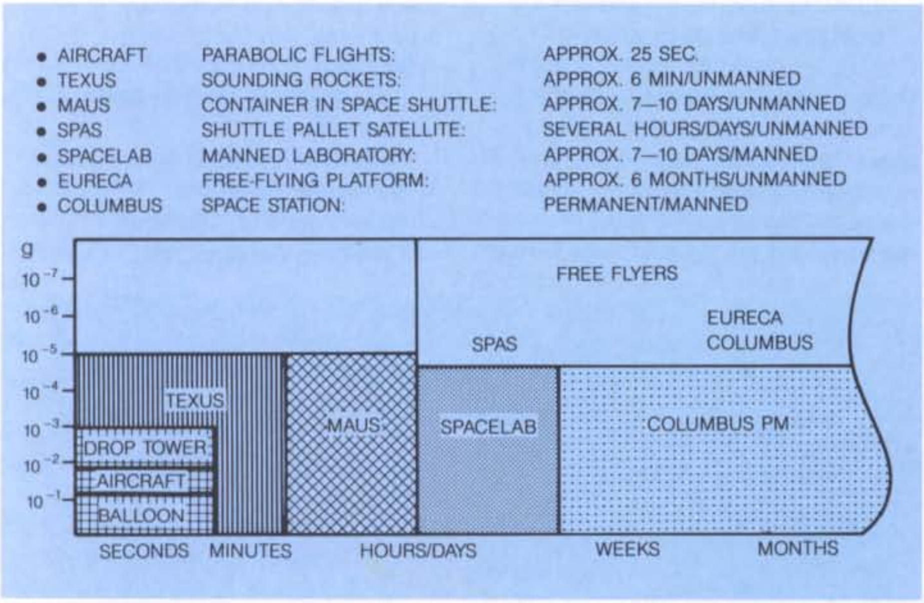


Figure 2 — Flight opportunities offering a microgravity environment

Figure 3 — Typical reusable microgravity research facilities for Eureca missions

On its first mission, Eureca-A will primarily serve the microgravity research community, requiring that carrier accelerations during the operating period stay below 10^{-5} g. This constraint has dictated use of a magneto-torquer attitude-control system, assisted by cold-gas jets, with torque levels below 0.3 Nm. It also determined the operational orbit of about 500 km altitude, to reduce decelerations due to residual aerodynamic drag.

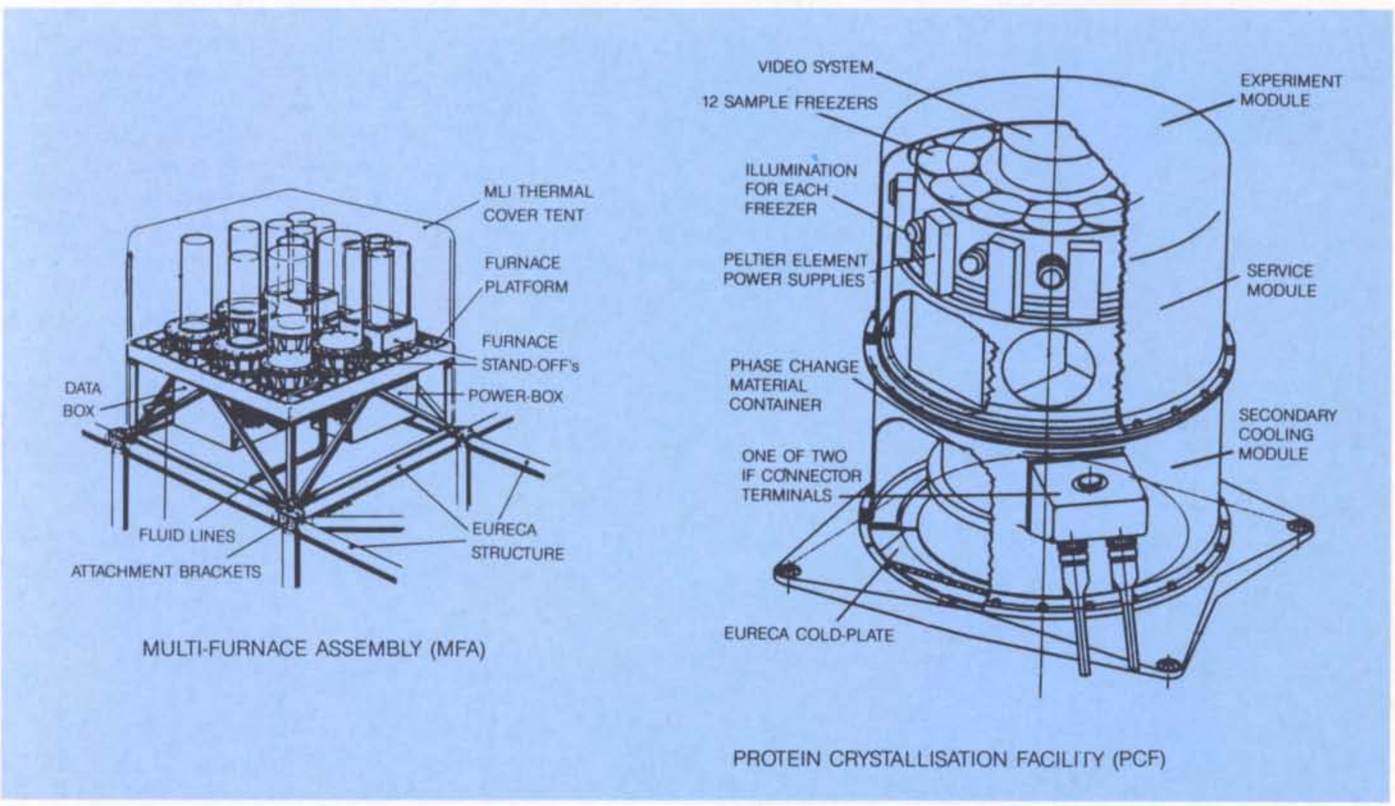


Based principally on the design of Eureca-A, Eureca-B will be particularly adapted to the mission needs of the classical space-science user community by providing improved pointing and data-acquisition capabilities.

Scientific research proposals for Eureca

The first mission of Eureca-A has been devoted to microgravity research (mainly material science) because of its unique ability to provide a low residual gravity environment of $< 10^{-5}$ g for long experiment durations, as illustrated in Figure 2.

ESA's first call for Eureca-A experiments resulted in 129 experiment proposals, 93 of which came from microgravity disciplines, and the remainder from space science, applications, and



technology-demonstration programmes.

To accommodate as many microgravity experiments as possible, ESA undertook the development of the following multi-user facilities to be flown as a 'core payload' on the first mission:
- an Automatic Mirror Furnace (AMF) Facility, to study semiconductor materials
- a Multi-Furnace Assembly (MFA), to study wettability, particle migration, sintering, and growth characteristics of materials
- a Solution-Growth Facility (SGF), to study crystal growth from fluids
- a Protein Crystallisation Facility (PCF), to study organic crystal growth
- an Exobiological Radiation Assembly (ERA), to study the exposure of biological materials to space.

These facilities will accommodate 37 experiments from eight ESA Member States. Together with two additional microgravity instruments — the High-Precision Thermostat (HPT) from Germany, and the Surface-Force Adhesion Facility (SFA) from Italy — they constitute about 80% of the payload mass for the first Eureca-A mission.

The remaining 20% will be filled by space-science and technology experiments, with the following instruments:
- Solar-Spectrum Measurement Assembly
- Solar-Variation Measurement Assembly
- Occultation Radiometer
- Wide-Angle X-ray Telescope
- Time-Band Capture Cell (to measure

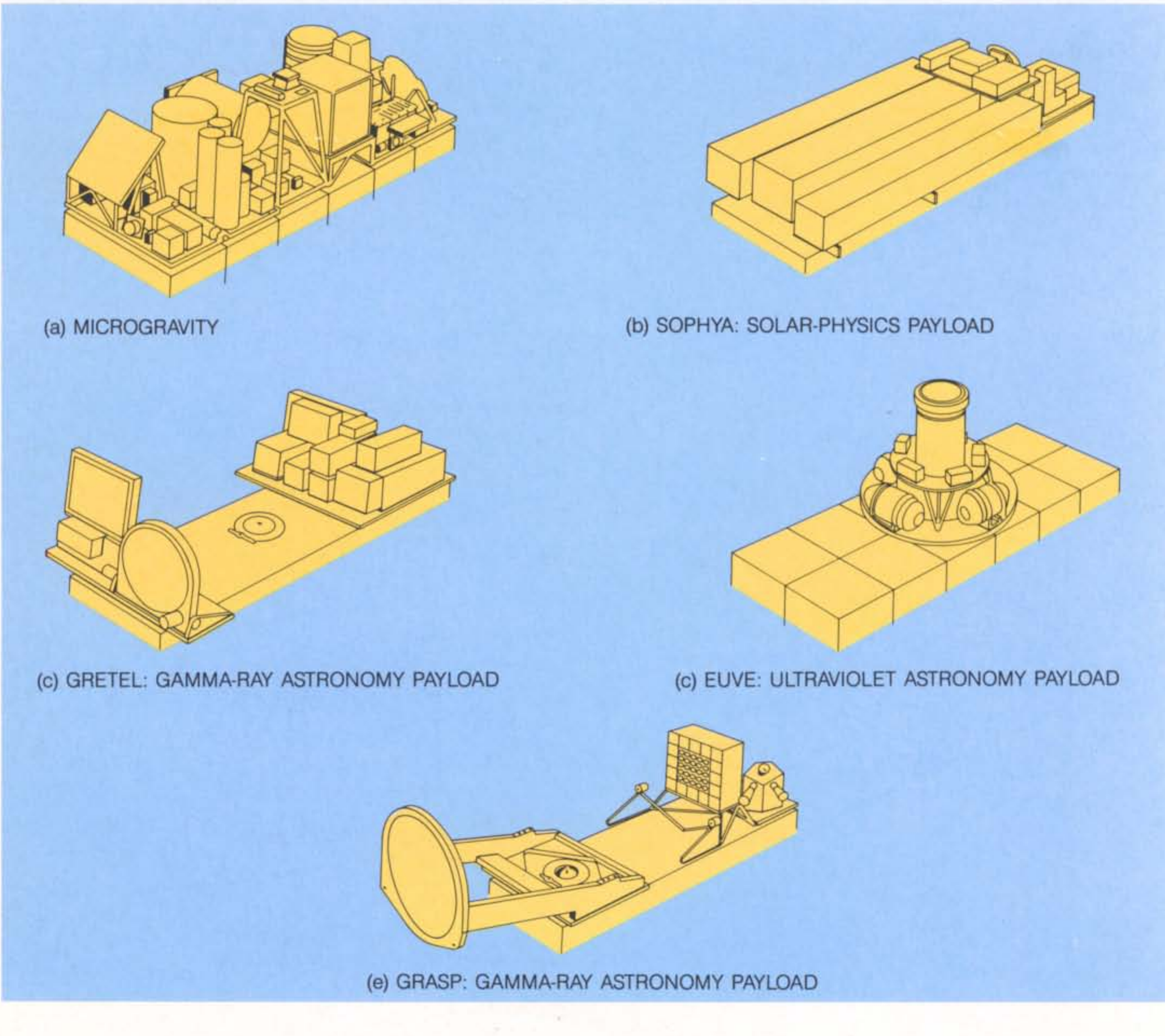


Figure 4 — Typical Eureca payload configurations

(a) MICROGRAVITY

(b) SOPHYA: SOLAR-PHYSICS PAYLOAD

(c) GRETEL: GAMMA-RAY ASTRONOMY PAYLOAD

(c) EUVE: ULTRAVIOLET ASTRONOMY PAYLOAD

(e) GRASP: GAMMA-RAY ASTRONOMY PAYLOAD

microparticles)
— Radio-Frequency Ionisation Thruster Assembly (RITA)
— Inter-Orbit Communication (IOC) Assembly
— Gallium-Arsenide Solar-Cell Assembly.

A total of 55 individual experiments will be conducted on the first mission.

Figure 3 shows two of the Eureca-A facilities, which can be considered typical of automated facilities that may be flown later on the Columbus Man-Tended Free Flyer.

ESA initiated a number of payload-accommodation studies in 1984 for missions in the fields of astronomy, solar physics, and Earth observation. As a result of these activities, the ESA Science Directorate included the utilisation of an adapted Eureca as a planning element in its 'Horizon 2000 Programme'. In addition, it released various announcements of mission opportunity to the European and the American space-science user communities. In response, a large number of proposals were received in the following disciplines:

— Astronomy: 73 (41 from the US)
— Solar Physics: 41 (8 from the US)
— Earth Observation: 48
— Technology Demonstration: 20.

As a consequence, ESA conducted detailed accommodation studies (carried out by MBB/ERNO, the Eureca prime contractor) on several science payloads, as listed below (closing month/year in brackets):

Sophya	(12/85):	Solar-Physics Instruments
Gretel	(12/85):	Gamma-Ray Telescopes
EUVE	(10/86):	Extreme Ultraviolet Explorer
Grasp	(06/87):	Gamma-Ray Astronomy with Spectroscopy and Pointing

The available configuration results are shown in Figure 4.

In addition, the following Eureca-B payload-accommodation and mission studies are presently in progress:
— Cosmic Structure Probe (Cosp)
— Probing the Rotation and Interior of Stars (Prisma)
— Environment Monitor (Dustwatch)
— Imaging Fourier Transform Spectroscopy (IFTS).

Although it is too premature for any significant conclusion, it seems feasible to execute three of the four mission proposals on Eureca-B, if a slow-spinning mode for 'sky-survey' missions can be implemented.

Potential Eureca technology-demonstration mission

Aside from the fact that the development of the autonomously operating Eureca encompasses many of the design techniques and operations applicable to the large Columbus platforms, the Eureca system is also very well suited for demonstrating in flight such technologies as assembly, operation, and maintenance of systems in space, as they will be required for Columbus. To explore this potential in detail, ESA has performed, or planned, the mission application studies discussed in the next section.

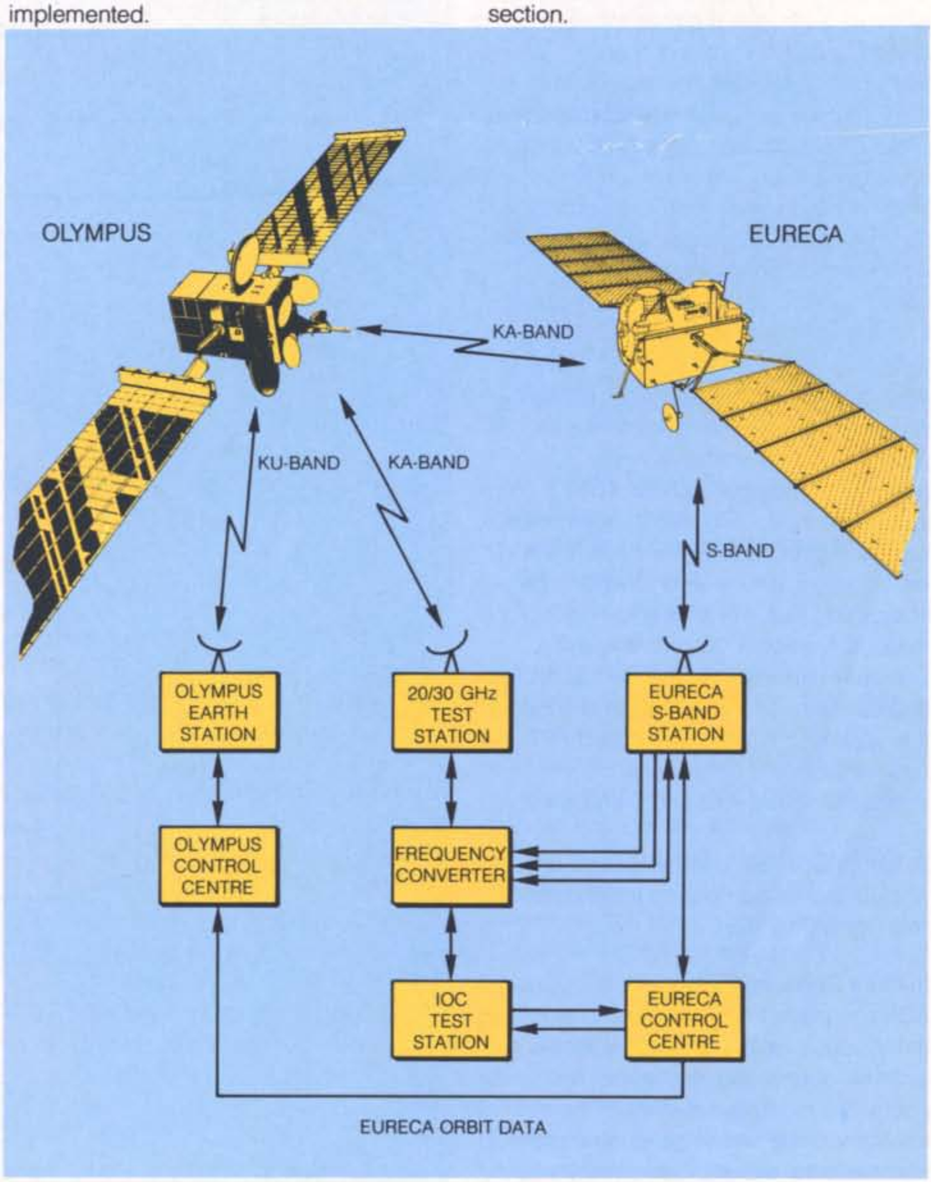


Figure 5 — Scenario for the Inter-Orbit Communication (IOC) demonstration

Figure 6a — Scenario for rendezvous and docking (RVD) demonstration mission

Figure 6b — Hermes RVD verification flight application of Eureca

Inter-Orbit Communications Demonstration

As already mentioned, an experimental package for inter-orbit communications will be flown on the first Eureca-A mission to demonstrate communications between the European Operations Control Centre and Eureca via the European Olympus satellite (Fig. 5).

Rendezvous and Docking Demonstration Missions

ESA has set up a dedicated development programme for automated Rendezvous and Docking (RVD), which is recognised as a key technique required for the assembly and servicing of future European space systems, e.g. Columbus. The programme covers definition of the preferred system and operations concept, development and design of long-, medium- and short-range navigation sensors, on-board processors, low-impact docking mechanisms, and utility connectors for data and electrical power transmissions, and fluid transfer.

A recently completed Aerospatiale study on in-flight verification, undertaken as part of this programme, strongly recommends use of two Eureca spacecraft to test RVD techniques under realistic flight conditions. Eureca-A would be the target vehicle and Eureca-B the chaser (Fig. 6a). For cost-economy reasons, Eureca-B deployment and Eureca-A retrieval would utilise the same Shuttle flight. A further cost advantage of this approach is that a dedicated RVD spacecraft would not have to be developed, designed, and launched.

A further potential role for Eureca is that of RVD test vehicle during initial Hermes trial flights (Fig. 6b).

In-Orbit Servicing

ESA has placed two contracts to study the in-space serviceability of reusable systems, addressing spacecraft operations in close proximity to the service vehicle, exchange of equipment and payloads either by man-intervention (EVA) or by remote manipulation, and spacecraft refuelling.

Figure 7 illustrates the Columbus servicing features proposed for demonstration using Eureca.

Towards a user-friendly Eureca Utilisation Programme

A study has been conducted to investigate the 'user-friendliness' of the Spacelab system by questioning the investigators of the FSLP and D1

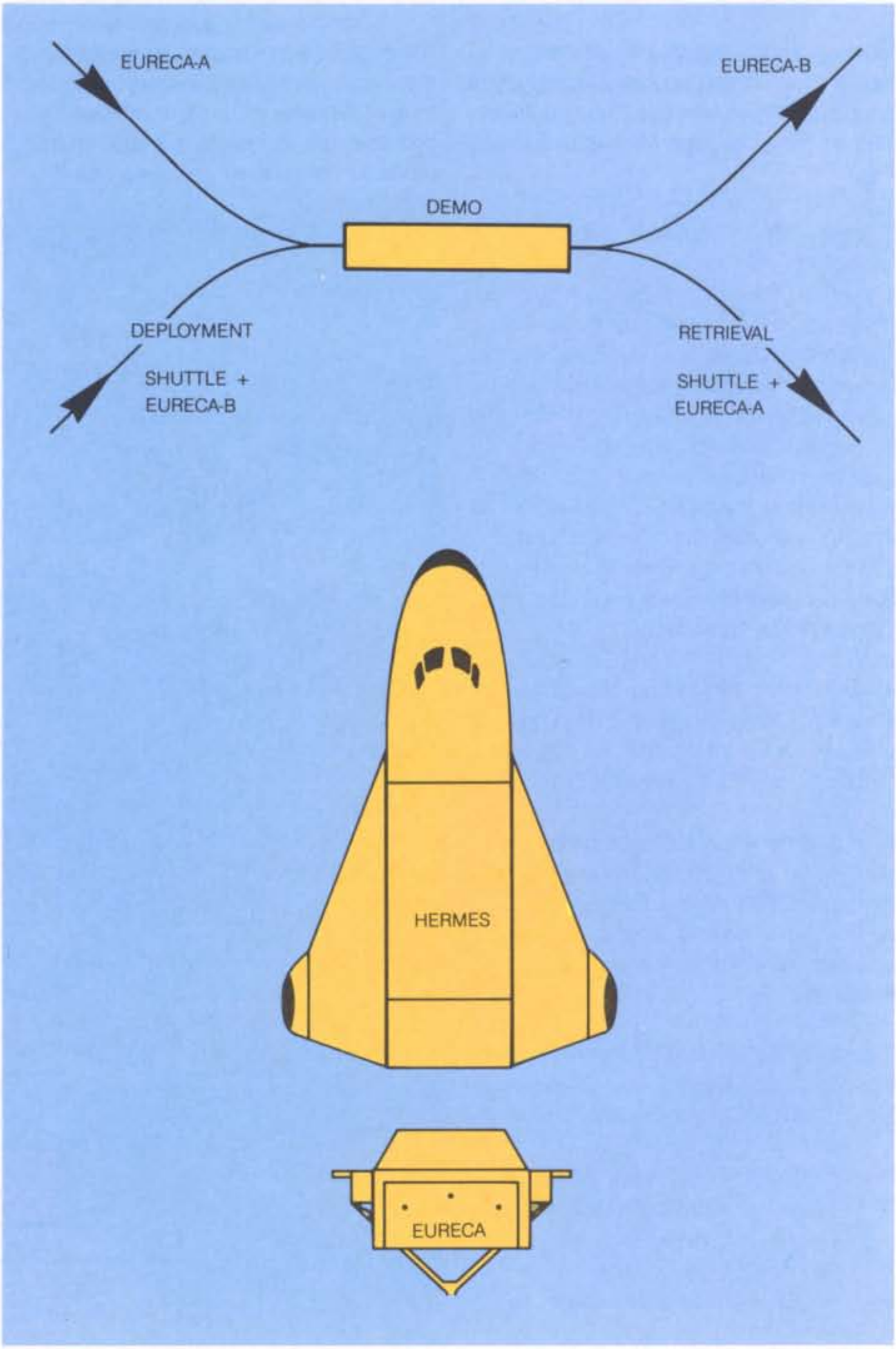
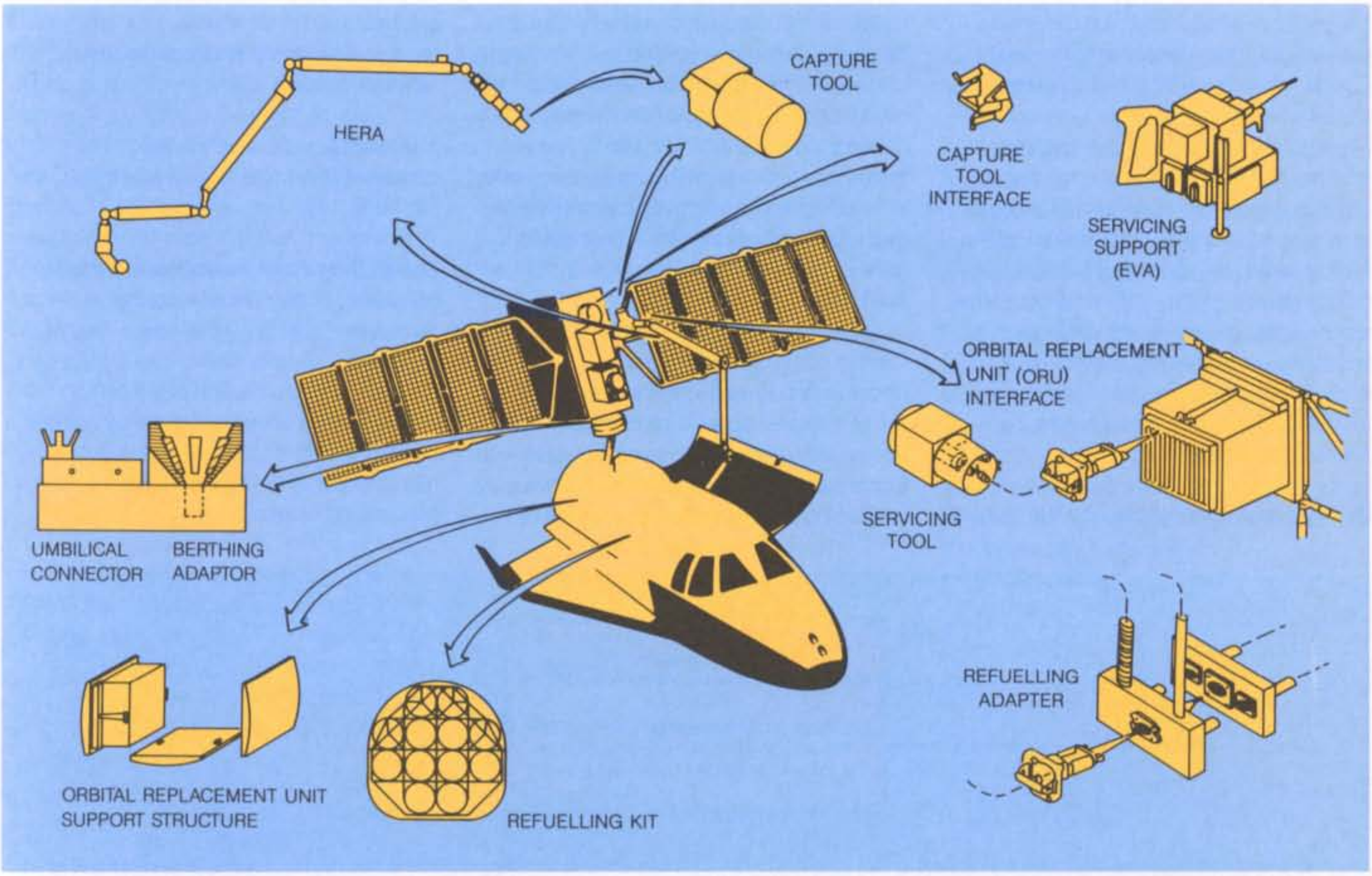


Figure 7 — Hermes/Eureca servicing interfaces



missions. The main conclusion was that the Principal Investigators (PIs) are less concerned about technical advances than about easier and simpler access to the system.

This approach need not be costly or difficult to adopt, and special design procedures are not really necessary. The user needs simple interfaces in all respects, including the human contacts, and an effective interface organisation to guide and assist him.

For Space-Station utilisation, therefore, a user-interface organisation is needed that aims to help the user through all phases and which

- measures its success by the success of the user
- has a staff that understands the user disciplines, and
- can call upon experts (e.g. safety) for assistance.

Such an organisation should become active early enough to understand and influence operations.

In the preparation phase, the user needs:
- clear and adequate descriptions of the system capabilities and constraints
- simple, Earth-like engineering interfaces
- skilled assistance in resolving system-generated problems for his equipment
- a minimum of bureaucracy
- a minimum of large meetings and long journeys
- avoidance of changing ground rules or increasingly stringent requirements as Space-Station development proceeds.

A good user interface organisation will have at least two kinds of tools to meet these needs:
- user handbooks and supporting documentation
- a problem-solving team.

User documentation should not only provide performance and interface data, but also include reliable information on:
- preferred methods of interfacing
- safety procedures (including definition of all nonacceptable materials)
- how to comply with requirements for verification
- ground and flight operations, in sufficient detail for instruments to be designed effectively.

The Eureca Programme has taken all of the above requests/desires into account in terms of both user-friendly documentation, end-to-end data communication and payload operation.

Figure 8 — Eureca payload documentation tree

A significant effort has been invested in achieving a user-friendly environment for Eureca missions. It is a fact that the typical user is not necessarily a skilled investigator, familiar with the paperwork required by space agencies to manage complex multinational industrial projects. In fact, a substantial gap resulted in the past between the documentation standards set for the industrial consortia responsible for the carrier development, and the documentation provided by relatively small investigator teams with limited budgets and more hardware-oriented personnel.

This gap was exacerbated by the normal praxis of industry, which usually tends to define system requirements by referring to documents of general validity and not ones specific to the current project. As a consequence, 'untrained' users were expected to devote substantial resources to reading and understanding reference documents of which only minor parts were of relevance for their own instruments.

On the contrary, the Eureca documentation approach is based on a set of payload-specific documents dedicated to (modular) familiarisation with Eureca payload management, with the interfacing carrier systems, and with the external interfaces imposed by firm mission-assurance and operational requirements.

The complete Eureca payload documentation tree is presented in Figure 8.

The Eureca data-management system, consisting of the Data-Handling Subsystem (DHS) — the space segment — and the Overall Check-Out Equipment (OCOE) and the Operations Control Centre (OCC) with the Data Disposition System (DDS) — the ground segment — has also been set up with user-friendliness in mind.

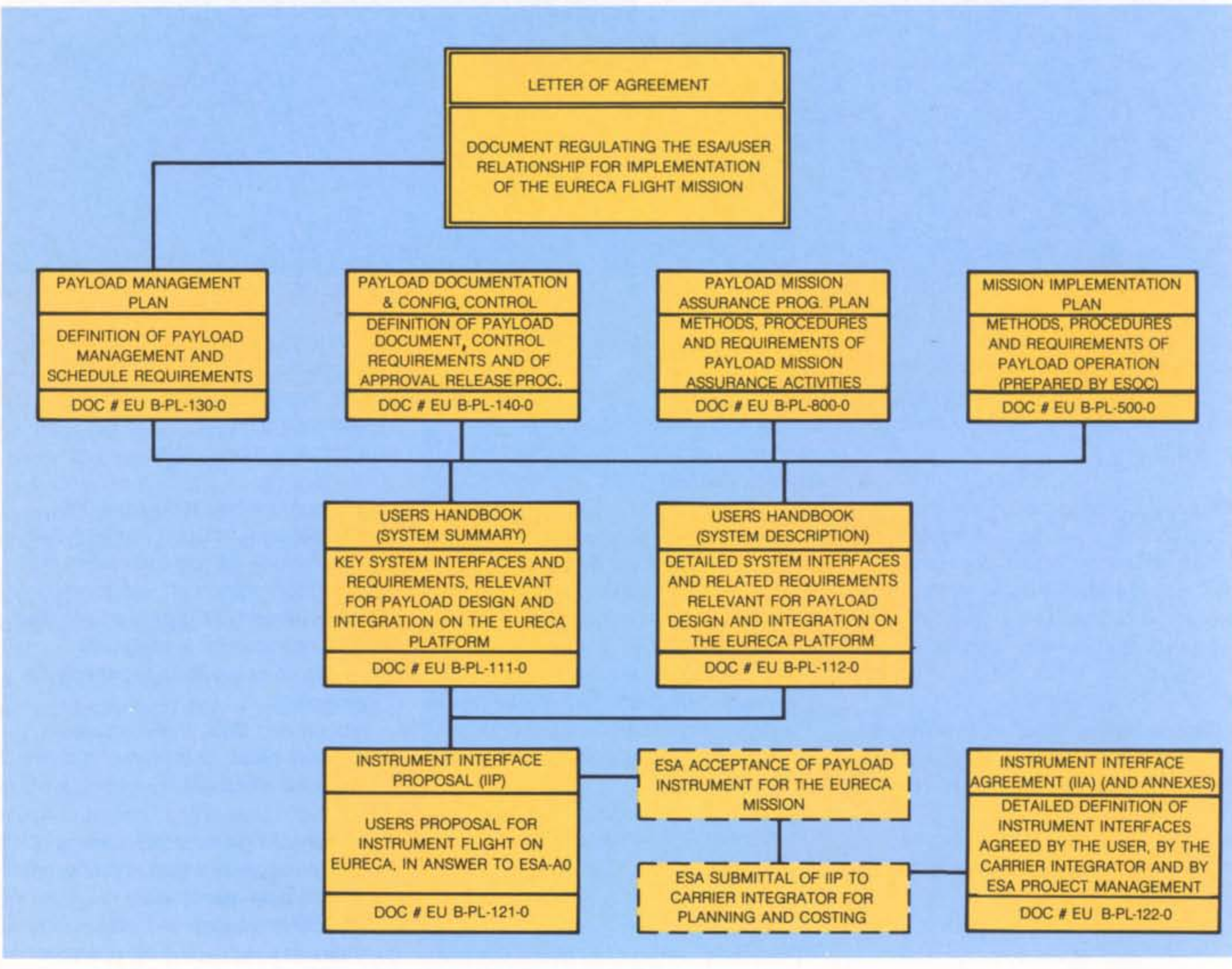


Figure 9 — Eureca-A in-flight and ground-segment configuration

During ground operations (assembly, integration, test, and verification) it achieves end-to-end data transfer from an instrument and/or subsystem to the instrument/subsystem-specific Individual Test Equipment (ITE). In this two-way data communication, the entire data-handling equipment between the two end points is transparent: the data arrives in exactly the same format and with the same content as it was sent.

During orbital operations (nominal mission phase), it relays the information from the subsystem/instrument via the DHS, the Telemetry and Telecommand Subsystem (TTC), the ground station, the OCC, and finally the DDS, to the user's home establishment, and vice versa. Again, the links mentioned are entirely transparent to the messages conveyed.

The user, defining and supplying both hardware and software for the instrument, for the ITE, and for the instrument data evaluation system, can employ the same software for stand-alone testing of the instrument, for the system integration and check-out phase, and for the instrument in-orbit operational phase, even though entirely different (but transparent) transmission links are being used for the two different phases.

The benefit of this end-to-end system is twofold:

(a) It reduces the hardware, software, and manpower efforts required of the user and minimises the time needed for system compatibility testing.

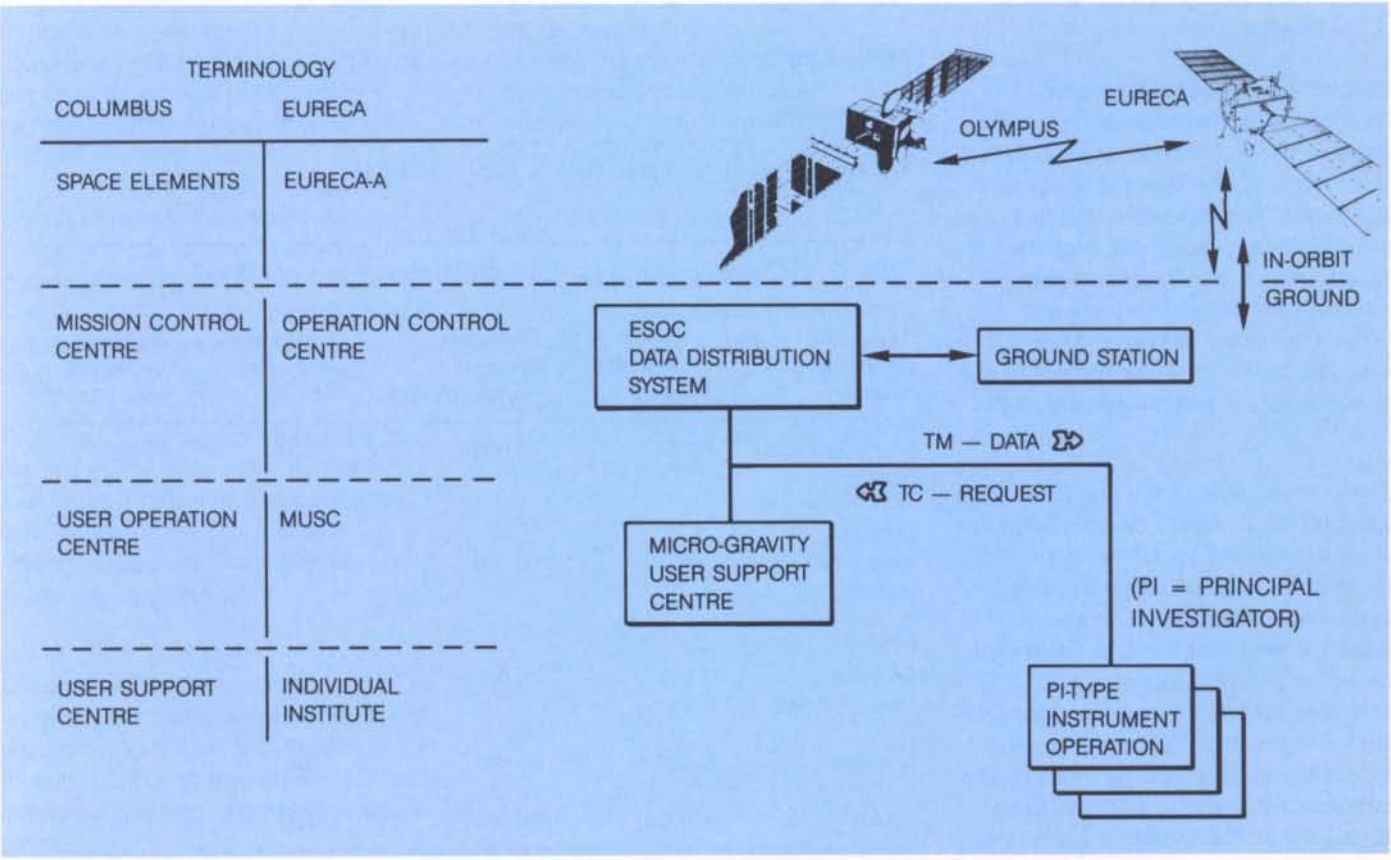
(b) The carrier/payload system is extremely flexible with respect to the interchange of instruments, e.g. refurbishment for new Eureca missions.

In effect, the Eureca payload can thus be 'plug-in/plug-out' by nature and requires only a minimum of integration and verification effort.

An important change from the 'classical' approach in Columbus payload operations will be the decentralisation of real-time operations as well as mission-preparation functions. Such a concept is already being implemented for the first Eureca mission via the creation of a Microgravity User Support Centre*, which is part of the German National Space Centre at DFVLR in Cologne.

The major tasks of the Microgravity User Support Centre are to support the user in the following three areas:

* A cooperative venture by the DFVLR Institute for Space Simulation, the DFVLR Institute for Aerospace Medicine, and the DFVLR Institute for Materials Research.



(a) Experiment preparation and qualification, by supporting experiment development tests, facility validation tests, sample qualification tests, experiment verification tests, and 1-g reference tests (where applicable).
(b) Experiment operation, by supporting experiment monitoring, command generation and experiment optimisation.
(c) Scientific experiment evaluation, by providing:
   — a microgravity information centre with a specialised microgravity library and access to literature databanks
   — a databank providing microgravity experiment data and technical data for experiment facilities
   — a scientific support programme with access to the knowhow and the scientific/technical infrastructure of the three participating DFVLR research institutes.

Cost/efficiency considerations
For future platforms to be commercially viable, a good economic return is critical. The Eureca system concept is inherently economical in its operation due to its retrievability and reusability. Moreover, the system offers a significant cost-saving potential with regard to launch and retrieval, provided two carriers are available, allowing the deployment of one to be combined with the retrieval of the other.

These advantages of the Eureca system can best be illustrated by comparing the development and operations costs with those of an expendable satellite-bus system of comparable performance. Table 1 summarises the cost predictions, based on presently available cost estimates, for the first and for subsequent Eureca flights into 500 km orbits with inclinations of 28.5° and 98° (polar). The overall launch mass is assumed to be 42 000 kg; for the satellite a launch mass

*Table 1 — Flight operations cost — Eureca versus satellite bus system**

Cost element	Eureca 28.5° orbit	Eureca Polar orbit	Satellite bus
System development			
to launch readiness	150	150	120
First flight			
Launch/retrieval	30	60	70
flight operations	30	30	30
Total: first flight	210	240	220
Subsequent flight			
Management/Eng/PA	5	5	5
Refurbishment	3	3	0
Spares	2	2	0
Rebuild	0	0	40
Payload integration	10	10	10
Launch/retrieval	30	60	70
Flight operations	30	30	30
Total: subsequent flight	80	110	155
Total: two flights	290	350	375
Total: three flights	370	460	530
Total: four flights	450	570	685
Total: five flights	530	680	840

* All figures in MAU, 1984 price basis. 1 AU = ±US$ 0.86.

Table 2 — Comparison of payload operations costs of retrievable systems

Retrievable system	Recoverable payload (kg)	Flight cost per kg of payload (AU/kg)	Experiment operations time (h)	Flight cost per kg per hour (AU/kg*h)
Sounding rocket (typical)	270	8 000	0.25	32 000
Chinese retrievable platform	150	50 000	100	500
STS Co-orbiting Platform (SPAS)	850	35 000	150	230
Spacelab	5 000	40 000	200	200
Eureca	1 000	80 000	4 320	**19**

of 3700 kg has been assumed, as it is usually inserted into orbit directly and does not require its own orbital transfer system. For the same reason, the development costs for the satellite are assumed to be lower than those for Eureca. The recurring costs for the satellite bus are assumed to be 35% of the first unit's development costs.

As Table 1 shows, a considerable cost saving can be realised with Eureca for 28.5° -inclination missions. For polar missions, the cross-over point is such that a two-flight programme already becomes more advantageous with Eureca. With further flights added, the retrievability of Eureca really comes to bear, resulting in savings amounting to 310 MAU* for the case of a five-flight, 28.5° -orbit programme, as shown in the lower part of the table.

Not taken into account is the fact that the satellite can stay longer in orbit and therefore can yield a higher data return. On the other hand, Eureca payloads can be retrieved, a feature that is not only of economic advantage, but for many payloads, particularly microgravity missions, essential.

Table 2 compares the cost efficiency of Eureca with that of other retrievable systems. Clearly Eureca is by far the most economical system, primarily due to its long mission-operation time.

The fullest advantage of Eureca will be realised by the user with a re-usable instrument. The five ESA microgravity core facilities of the first Eureca-A mission, for example, can offer low-cost experiment opportunities.

Conclusion

From the experience accumulated so far during the development of Eureca-A, and from the various studies discussed above, the following conclusions can be drawn:

- The Eureca design responds to the original programme objectives of developing a retrievable and re-usable carrier system, adaptable to various mission requirements, and offering a cost-effective utilisation programme compared with other systems.
- The Eureca system is attracting growing user interest.
- The Eureca system has good potential for serving as a test vehicle for demonstrating, in-flight, essential Columbus technologies, such as rendezvous and docking and in-orbit servicing.
- The user-friendly nature of the Eureca programme is demonstrated by:
  (a) user-friendly documentation aimed at making the system transparent and easy to access;
  (b) end-to-end data communication.
- The possibility of re-using experiment facilities on several flights minimises the cost to the Eureca user, attracting a large user community, potentially also to the benefit of the Columbus utilisation programme.
- The first Eureca-A mission will exploit decentralised real-time ground operations for the first time, with a User Support Centre working on-line in an interactive mode with ESA's Mission Control Centre.

In summary, therefore, it may be concluded that the Eureca system is not only a viable system in itself, but it can also be regarded as a major potential stimulant and contributor to the preparations for the Space Station and its Utilisation Programme.

Les normes de fonctionnement de l'ESA

G. Lafferranderie, Conseiller juridique, ESA, Paris

L'Agence spatiale européenne, personne juridique de droit international public, instituée par la volonté d'un certain nombre d'Etats pour conduire une mission spécifique, dotée de compétences et d'organes pour les mettre en oeuvre, vit sur la base d'un ensemble de règles. Le destinataire ou l'utilisateur de ces règles, comme l'observateur extérieur, peut s'étonner de leur foisonnement, parfois de leur enchevêtrement et éprouver quelque difficulté à retrouver le fil conducteur. Outre les règles posées par la Convention, les organes de l'Agence ont progressivement secrété un véritable droit interne. Entrer dans cet ensemble de règles fait songer au promeneur qui, au fur et à mesure qu'il avance, voit l'avenue principale se diversifer en multiples chemins. Cette avenue principale c'est bien sûr la Convention, colonne vertébrale assurant l'équilibre de l'ensemble.

Tout comme la Constitution d'un pays ne saurait apporter de réponses à toutes les situations possibles et a nécessité d'être complétée par des lois, décrets et règlements, les dispositions de base de la Convention se poursuivent à travers un tissu juridique qui vient irriguer et faire vivre l'Organisation. A son tour, l'Organisation secrète ses propres ramifications et règlements. Par ailleurs, elle entretient des relations internationales avec d'autres personnes juridiques. Quelles sont les diverses sources de toutes ces normes juridiques, les relations qu'elles entretiennent les unes par rapport aux autres, leur champ d'application?

Le droit 'initial' ou 'primaire' ou 'constitutionnel'

Par droit 'initial' on entend les règles qui fondent l'Organisation elle-même et qui ont été élaborées par les créateurs de cette nouvelle personne juridique. Comme toute Organisation internationale intergouvernementale, l'Agence est le fruit de la volonté d'Etats qui par traité, la **Convention**, lui ont donné à la fois vie et la personnalité juridique lui permettant de décider par elle-même sur un certain nombre de questions. La Convention et ses Annexes énoncent d'un côté l'équilibre des intérêts des Etats fondateurs, les règles du jeu, les droits et obligations de chacun, et de l'autre la mission de l'Agence et ses moyens d'action: ce qu'on appellera le droit initial ou primaire. A la Convention et ses Annexes, on peut ajouter **l'Acte final** (et les Résolutions qui y sont attachées) de la Conférence des Plénipotentiaires sur l'établissement de l'Agence (mai 1975).

Au cours de la période allant de la signature de la Convention de l'Agence à celle de son entrée en vigueur, il fallait également compter au titre de ce droit initial les Conventions du CERS/ESRO et du CECLES/ELDO.

En théorie, la Convention n'est pas immuable; mais comme elle énonce les régles fondamentales du jeu ayant conduit à l'institution d'une nouvelle personne juridique du droit international, la Convention, en pratique, ne peut être que difficilement amendée. Le texte introduit une distinction originale entre le corps (la Convention elle-même et l'Annexe I) et certaines Annexes (II à V), bien qu'au départ l'ensemble ait constitué un seul et même texte, avec la même valeur juridique et ayant fait l'objet de la même procédure de ratification.

Le Conseil peut recommander des amendements à la Convention et à son Annexe I. Pour entrer en vigueur, ces amendements doivent avoir reçu l'acceptation de tous les Etats membres conformément à leur procédure constitutionnelle propre. Il est intéressant de relever que la Convention a donné à l'un des organes de l'Organisation qu'elle institue, le Conseil, compétence pour amender lui-même, certes à l'unanimité, les autres Annexes et qui ne sont pas les moindres: dispositions financières, programmes facultatifs, internationalisation des programmes nationaux, politique industrielle. A ce jour, seul un article de l'Annexe II a fait l'objet d'une procédure d'amendement (la définition de l'unité de compte).

Le non respect de ces règles de base peut conduire à des sanctions, la sanction ultime étant l'exclusion de l'Etat en cause.

Le droit 'dérivé'

La Convention ne peut tout régler; elle fixe les principes de base. L'Organisation qu'elle crée reçoit le pouvoir d'édicter elle-même, pour l'accomplissement de sa mission, diverses normes de droit. Ces normes — le droit 'dérivé' — sont élaborées par les organes de l'Agence: le Conseil d'une part, le Directeur général d'autre part. On verra que ces normes ne sont pas toutes de nature identique.

Par ailleurs, l'Organisation est amenée à contracter avec d'autres personnes juridiques, soit les Etats membres eux-mêmes, soit les Etats non membres, d'autres Organisations internationales ou des organismes relevant de la juridiction d'Etats membres ou non-membres. Ces contacts peuvent conduire à l'élaboration d'autres normes juridiques mais qui, elles, seront le résultat de la volonté de l'Agence et de son partenaire.

Le droit dérivé 'unilatéral'

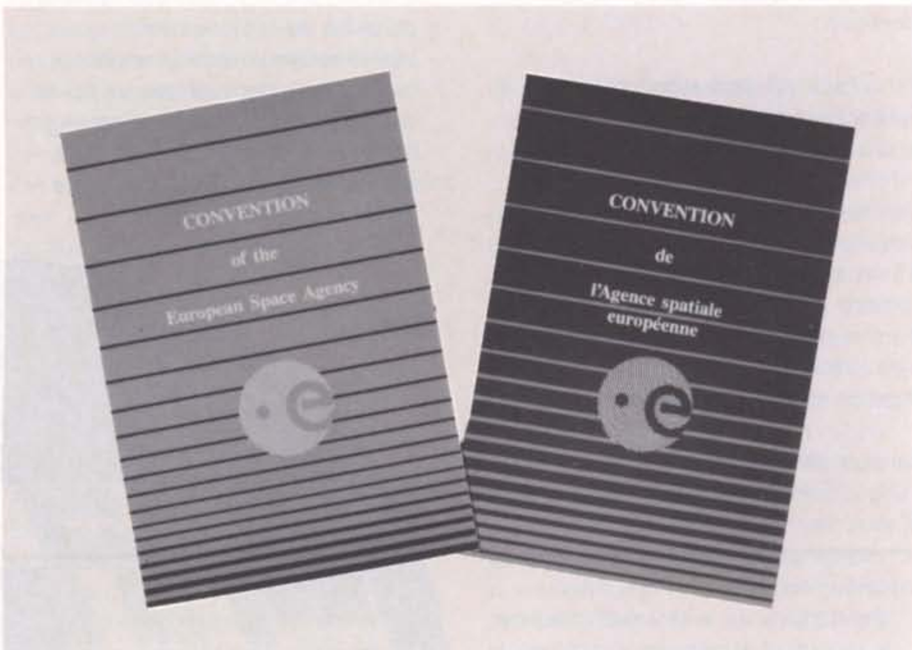
L'Organisation peut, selon la Convention et sous réserve de ses dispositions, adopter (et parfois la Convention l'y invite expressément):

- *des règlements:* le règlement financier, le règlement additionnel d'arbitrage, le règlement des contrats, le statut et le règlement du personnel, le règlement intérieur du Conseil et des organes subsidiaires, les règlements d'exécution des programmes facultatifs. Ces 'règlements', approuvés à la majorité des 2/3 par le Conseil, émanation des Etats parties à la Convention, ont force obligatoire et pour les Etats membres et pour l'Organisation elle-même. Sous ce vocable, on fera également figurer les dispositions de la Convention se référant à l'adoption de 'règles' (par exemple transfert de technologie, informations et données, politique industrielle). Les règlements partent d'une disposition de base figurant dans la Convention et viennent la détailler et la compléter. Il en va ainsi, par exemple, du règlement financier ou du règlement additionnel d'arbitrage. Il en va quelque peu différemment des règlements d'exécution des programmes facultatifs. Car s'ils viennent compléter et détailler la Convention et la Déclaration correspondante, ils peuvent légiférer dans des domaines non réglés par la Convention et, sous certaines réserves et limites, peuvent contenir des dispositions différentes de celles de la Convention;
- *des directives et recommandations* (art. XI.5.b.ii): par exemple les lignes directrices pour la mise en oeuvre de l'Annexe III de la Convention ou encore les lignes directrices sur le statut de membre associé, les conseils et aides pour l'harmonisation des programmes. Les directives n'ont pas de véritable force contraignante. Les Etats membres sont invités à les suivre sans que cela puisse faire l'objet de sanctions;
- *des 'décisions':* par exemple, approbation du niveau de ressources, admission de nouveaux Etats membres, adhésion, retrait, dénonciation, création d'organes subsidiaires, approbation du barème de contributions, approbation d'accords internationaux, amendements aux Annexes de la Convention autres que l'Annexe I. Ces 'décisions', adoptées soit à l'unanimité soit à la majorité simple ou des 2/3, peuvent s'inscrire formellement dans une **Résolution,** acte plus solennel qu'une simple mention dans le procès-verbal de la réunion. Les décisions majeures, marquantes, de la

vie de l'Organisation s'inscrivent dans une Résolution du Conseil. Parfois, dans ces décisions les Etats membres peuvent se donner des règles plus contraignantes que celles de la Convention elle-même (cf. la Résolution dite du 'FMI'). Elles sont alors une source importante des normes de fonctionnement de l'Agence quantitativement et qualitativement, du fait de leur caractère obligatoire pour les Etats membres (et les Etats non membres liés par un Accord de coopération ou de participation à un programme) et de leur mise en oeuvre immédiate.

Ces diverses normes s'appliquent à l'ensemble des Etats membres; il existe une autre source de normes qui n'auront d'effet que pour une catégorie particulière d'Etats, les Etats 'participants': il s'agit des **Déclarations** relatives aux programmes facultatifs auxquelles il faut faire une place à part. Stricto sensu, la Déclaration n'est pas élaborée par l'Organisation et à ce titre elle ne saurait relever du droit dérivé. Toutefois, bien qu'elle trouve son fondement dans la Convention, elle est l'oeuvre des seuls Etats intéressés, c'est-à-dire des représentants de tous les Etats membres sauf ceux qui se seront déclarés formellement non intéressés à participer. Le Conseil n'a pas à approuver (ce qui serait porter un jugement sur des engagements d'Etats souverains); il ne fait qu'en prendre note. En revanche, une Déclaration ne peut exister que si le Conseil a, au préalable, accepté que le programme correspondant soit exécuté par l'Agence. En outre, le Conseil, dans le cadre de sa responsabilité globale, aura à approuver le règlement d'exécution élaboré par les Etats participants. Cette séparation n'est toutefois pas totale puisque la Convention donne compétence au Conseil pour approuver les budgets annuels des programmes facultatifs (seuls les Etats participants prenant part au vote — compétence que le Conseil en règle générale délègue à un organe subsidiaire qu'il crée, le Conseil directeur du programme facultatif). La Convention reflète la conception d'un Conseil organe suprême, source de tout pouvoir, chargé de veiller à la bonne marche de l'Organisation.

Ces diverses normes produisent des effets sur les Etats membres, peuvent contenir des directives à l'attention de l'Agence (l'Exécutif); certaines ne s'appliqueront qu'à l'intérieur de l'Agence elle-même (ainsi le statut et règlement du personnel).



Le droit dérivé 'concerté'
On vise ici les divers Accords internationaux (quelle que soit la terminologie: Accord, Convention, Arrangement, Mémorandum d'Accord, et la forme utilisée: accord solennel, échanges de lettres, ...) conclus par l'Agence avec des Etats membres, non membres ou des Organisations internationales.

Les Accords sont approuvés par le Conseil, à l'unanimité des Etats membres lorsqu'il s'agit d'Accords avec les Etats non membres, à la majorité simple dans le cas d'Accords avec les Etats membres; ils engagent chacun des Etats membres et l'Organisation qui est leur émanation. Le Conseil autorise le Directeur général (représentant légal de l'Agence) et autre organe institué par la Convention à les signer.

Ces Accords peuvent porter sur les domaines les plus divers, dans le cadre et aux fins de la mission de l'Agence. Ils sont conclus avec les Etats membres, non membres, les Organisations internationales et les organismes relevant de leur juridiction (art. XIV).

Il peut s'agir d'Accords de siège avec les Gouvernements hôtes des établissements/installations de l'Agence, d'Accords de coopération générale, ou de participation à des programmes ponctuels, d'Accords d'association...

On a examiné jusqu'ici le droit 'dérivé' produit par l'un des deux organes, le Conseil. L'autre organe, le Directeur général, est également source de normes de droit.

Le Directeur général édicte les Instructions administratives (en matière financière, de règlement du personnel) elles-mêmes fondées sur des règlements adoptées par le Conseil, négocie et signe les contrats (avec les membres du personnel de l'Organisation, avec les firmes industrielles). Une partie de ces contrats reflètera des normes supérieures édictées par le Conseil.

Le Directeur général est habilité à prendre toutes mesures nécessaires à la gestion de l'Agence. L'exercice de cette compétence s'exerce dans le cadre des textes de droit initial ou dérivé et selon les directives complémentaires reçues du Conseil. Dans ses relations avec les membres du personnel, il agit par délégation du Conseil.

Les autres sources de droit

Les sources identifiées ci-dessus sont spécifiques à l'Agence. Celle-ci, une fois mise en place, va se trouver confrontée, comme les autres personnes de droit international public, avec d'autres normes, d'autres personnes juridiques. Parmi ces autres normes dont elle aura à tenir compte, on mentionnera bien évidemment le droit international général (la Convention de Vienne sur le droit des Traités de 1969, la Deuxième Convention de Vienne sur le droit des Traités de 1986, bien que l'Agence n'y soit pas partie). On fera une place à part au droit de l'espace: le Traité sur l'Espace de 1967, l'Accord sur l'assistance et le retour de 1968 et surtout la Convention sur la responsabilité pour dommages spatiaux de 1973 et la Convention sur l'immatriculation des objets spatiaux, Conventions applicables à l'Agence par sa déclaration formelle d'acceptation.

Le droit interne des Etats membres peut trouver application à l'égard de certaines activités de l'Agence (assurance, location, acquisition de biens, procédure judiciaire en cas de levée d'immunité, lois de police).

Le droit interne d'Etats non membres: par exemple, un 'Presidential Executive Order' du Président des Etats-Unis fait bénéficier l'Agence des dispositions de la Loi sur les Privilèges et Immunités des Organisations internationales auxquelles les Etats-Unis sont parties. L'activité de l'Agence à travers son Bureau de Washington est régie par le droit des Etats-Unis (location par exemple).

Parmi d'autres sources de normes de droit, on citera encore:

— les décisions rendues par la Commission de Recours de l'Agence, décisions qui peuvent annuler une décision du Directeur général à l'encontre d'un membre du personnel;
— les sentences susceptibles d'être rendues par des tribunaux d'arbitrage (en application de dispositions contenues dans les Accords internationaux ou les contrats industriels).

Le contrôle de l'application

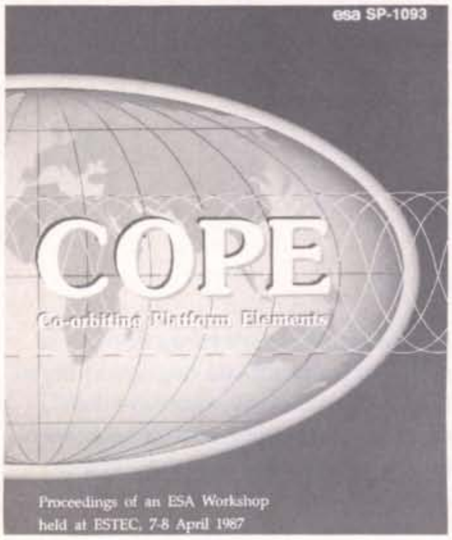
Que se passe-t-il en cas de conflit entre ces diverses normes, conflit entre une norme de droit initial et une norme de droit dérivé ou entre deux normes de droit dérivé?

Aucun système de contrôle de la constitutionnalité n'existe (que ce soit Chambre constitutionnelle ou Cour Suprême) qui pourrait être saisi par un Etat membre ou le Directeur général. Le système repose sur le concept d'un Conseil, organe suprême, constitué de représentants des Etats parties à la Convention, dépositaire de leur volonté. Le seul moyen légal institué par la Convention est l'arbitrage (art. XVII et règlement additionnel). Tout différend entre deux ou plusieurs Etats membres ou entre un ou plusieurs Etats membres et l'Agence au sujet de l'interprétation ou de l'application de la Convention est soumis en ultime ressort à l'arbitrage par un tribunal constitué à cet effet par les parties au différend. Le Conseil est investi d'une mission de conciliation et de bons offices.

Dans cette phase d'interrogation sur la portée et le sens d'une disposition de la Convention ou d'une norme de droit dérivé, le Conseiller juridique peut jouer un rôle en délivrant des notes et avis juridiques. Finalement, la recherche du consensus et, le cas échéant, un vote permettent d'éviter la création d'un différend au sens juridique du terme.

Par contre, les membres du personnel disposent de toute une procédure élaborée pour régler les différends qu'ils peuvent avoir avec le Directeur général si une décision de ce dernier leur fait grief. Dans certains cas, cette décision n'est d'ailleurs que la traduction d'une autre décision prise par le Conseil. La Commission de Recours par ce biais, sans se transformer en Cour Suprême, peut porter une appréciation sur la décision prise par le Conseil (par exemple le recours introduit contre le prélèvement sur les salaires).

Après ce tableau, il resterait à étudier l'évolution de ces normes, leur aspect dynamique. Certaines dispositions de droit initial sont restées pratiquement lettre morte, d'autres ont suivi une orientation qui n'était pas celle envisagée par leurs auteurs. Au-delà de ces sources écrites se constitue également une pratique, faut-il parler de coutume et de jurisprudence? Cette souplesse d'adaptation est certes un signe de vitalité, encore faut-il s'assurer qu'elle évolue dans les limites de la volonté initiale des créateurs de l'Organisation.



The Use of the Space Station for Earth Observation — The COPE Symposium

C.J. Readings, Earth-Observation and Microgravity Directorate, ESA, Paris

Although expendable satellites with quite limited payloads are currently used to observe the Earth and its atmosphere from space, the advent of the Space-Station era introduces new possibilities, including retrievable and serviceable platforms capable of carrying large payloads. This will have a large impact on the Earth-observation community as, for the first time, it will become possible to plan missions that are truly multi-disciplinary, with a single platform meeting the needs of scientists with quite disparate interests, such as agriculturists and atmospheric chemists. This may be contrasted with the current situation where individual satellites tend to be tied to specific disciplines.

Over the past two years, in anticipation of the radical changes in the modus operandi that will accompany the advent of the Space-Station era, ESA's Earth Observation and Microgravity Directorate has organised a series of Workshops designed to:

(a) brief potential users on which facilities are likely to become feasible in the last decade of the twentieth century and beyond;
(b) give potential users the opportunity to indicate which of these facilities should be exploited for Earth observation.

This approach follows the current practice by which ESA solicits the views of its users, but assumes an added significance in the current situation where the scenario is about to change radically.

To put the findings of the latest Workshop in the series, 'COPE' (Co-Orbiting Platform Elements), held at ESTEC in April 1987 into context it is necessary to outline first the facilities planned for inclusion on the Space Station, and then to summarise the findings of previous Workshops in this series which were concerned with the use of the Polar Platform for Earth observation.

Facilities to be provided by the Space Station

As currently envisaged, the Space Station consists of four main elements:

- the Space Station itself, which includes various Pressurised Modules/Laboratories as well as various manoeuvring vehicles
- a Man-Tended Free Flyer
- Polar Platforms
- Co-orbiting (Eureca) Platforms.

ESA is planning to contribute a Polar Platform, a Co-orbiting Platform, a Pressurised Module and the Man-Tended Free Flyer. An appreciation of the form that these various facilities will take is provided by Figures 1—4, which illustrate the basic concepts.

The Shuttle (or Hermes), plus launch vehicles such as Ariane-5, will play a central role both in the construction/deployment of the various elements and in their servicing. This is well illustrated by Figure 5, which shows the operational sequence for a Eureca platform. All elements except the Polar Platforms will be in low-inclination orbits (i.e. lying within the band 30°N to 30°S) at quite low altitudes (around 500 km). The Polar Platforms will fly in orbits with inclinations of about 97°, at altitudes of about 800 km.

The use of Polar Platforms for Earth observation

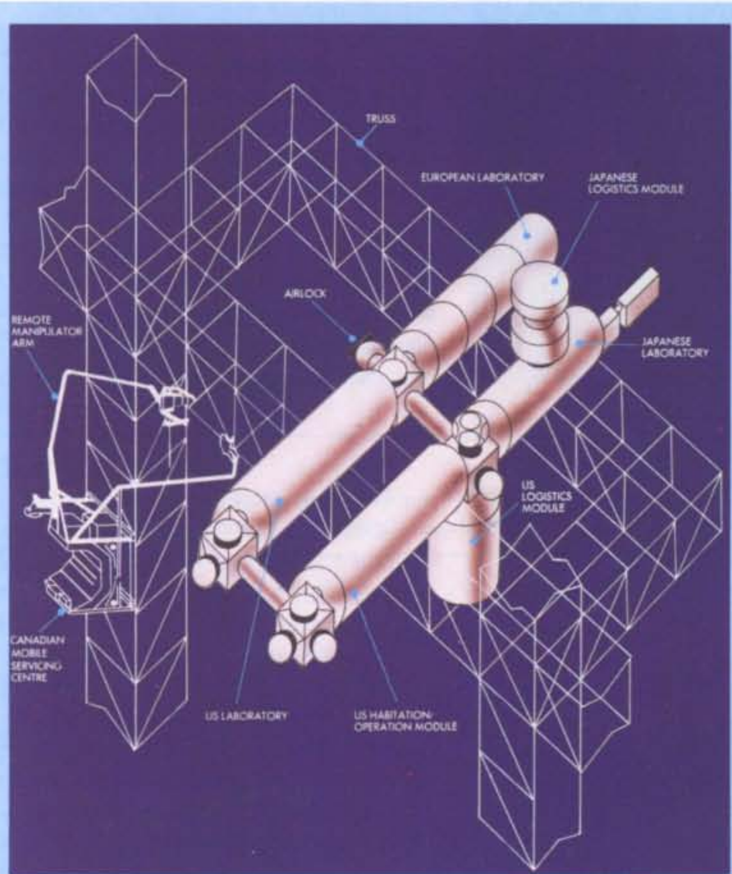
Over the past decade or so the use of polar-orbiting satellites to monitor the weather has become well-established, and without doubt a priority as far as Earth observation is concerned is to maintain and improve this service. This goal, coupled with the global coverage provided by polar orbiters, means that the element of the Space Station of prime interest to the Earth-observation community is the Polar Platform. Thus, prior to the COPE Workshop, only the

Figure 1 — Possible Space-Station core arrangement

Figure 2 — A Polar Platform

Figure 3 — Eureca

Figure 4 — The Man-Tended Free Flyer (MTFF)

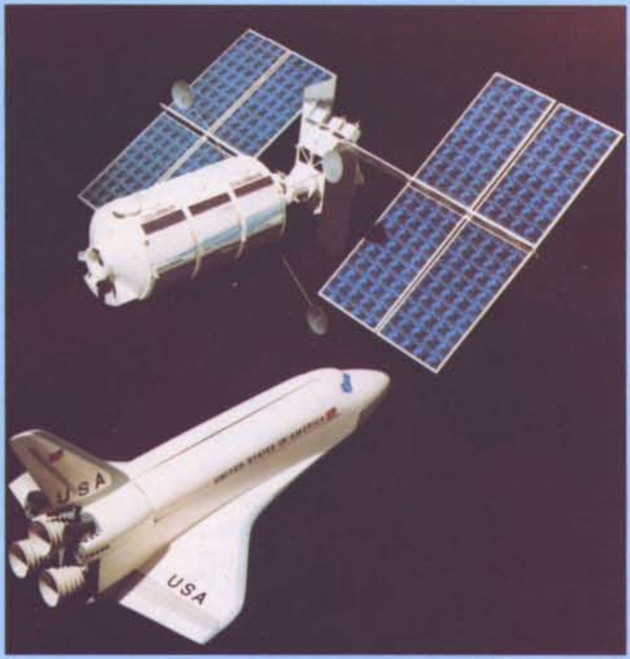


1

2

3

4



exploitation of this element had really been considered in detail by these users.

Current plans for Polar Platforms envisage at least two being put into orbit, with ESA providing one and NASA the other. Both would be Sun-synchronous, with the ESA Platform crossing the equator at about 10.00 h local time (the 'morning' platform) and the NASA Platform crossing it at about 14.00 h local time (the 'afternoon' platform). It is intended that each Platform will carry a mix of instruments designed to meet both operational and research needs, as well as the requirements of different groups of scientists (i.e. atmosphere, ocean/ice, land and solid Earth), so that each will be multi-disciplinary in the true sense of the word.

ESA determined the requirements of the various scientific communities by organising a series of Workshops at which scientists were encouraged to indicate the instruments they would like to see flown on the Polar Platforms. The

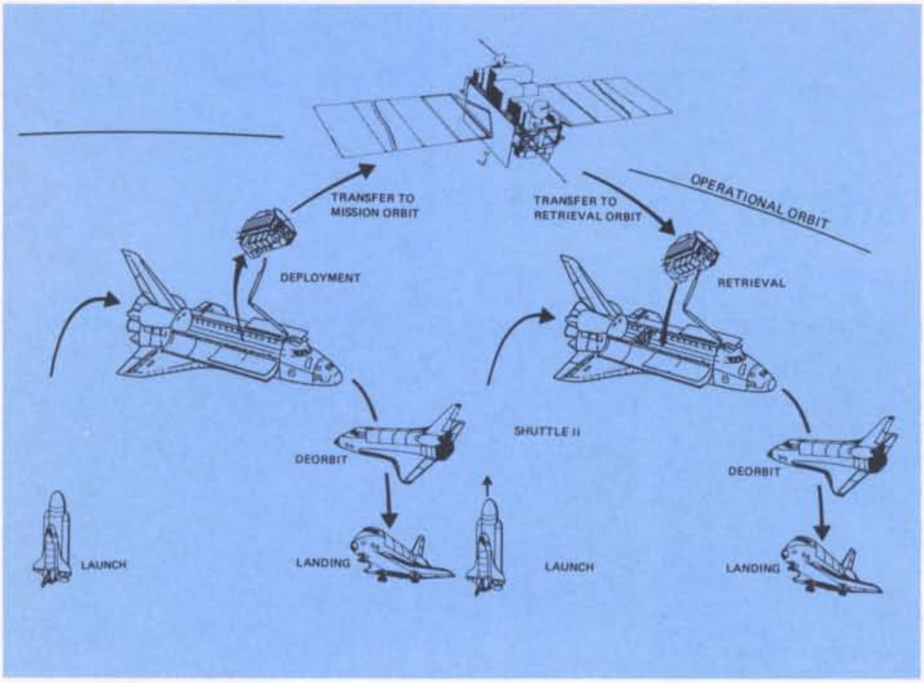


Figure 5 — Eureca flight scenario

Agency has also liaised closely with its space partners in the United States and Japan in producing 'strawman lists' of instruments designed to meet as many of the user requirements as possible.

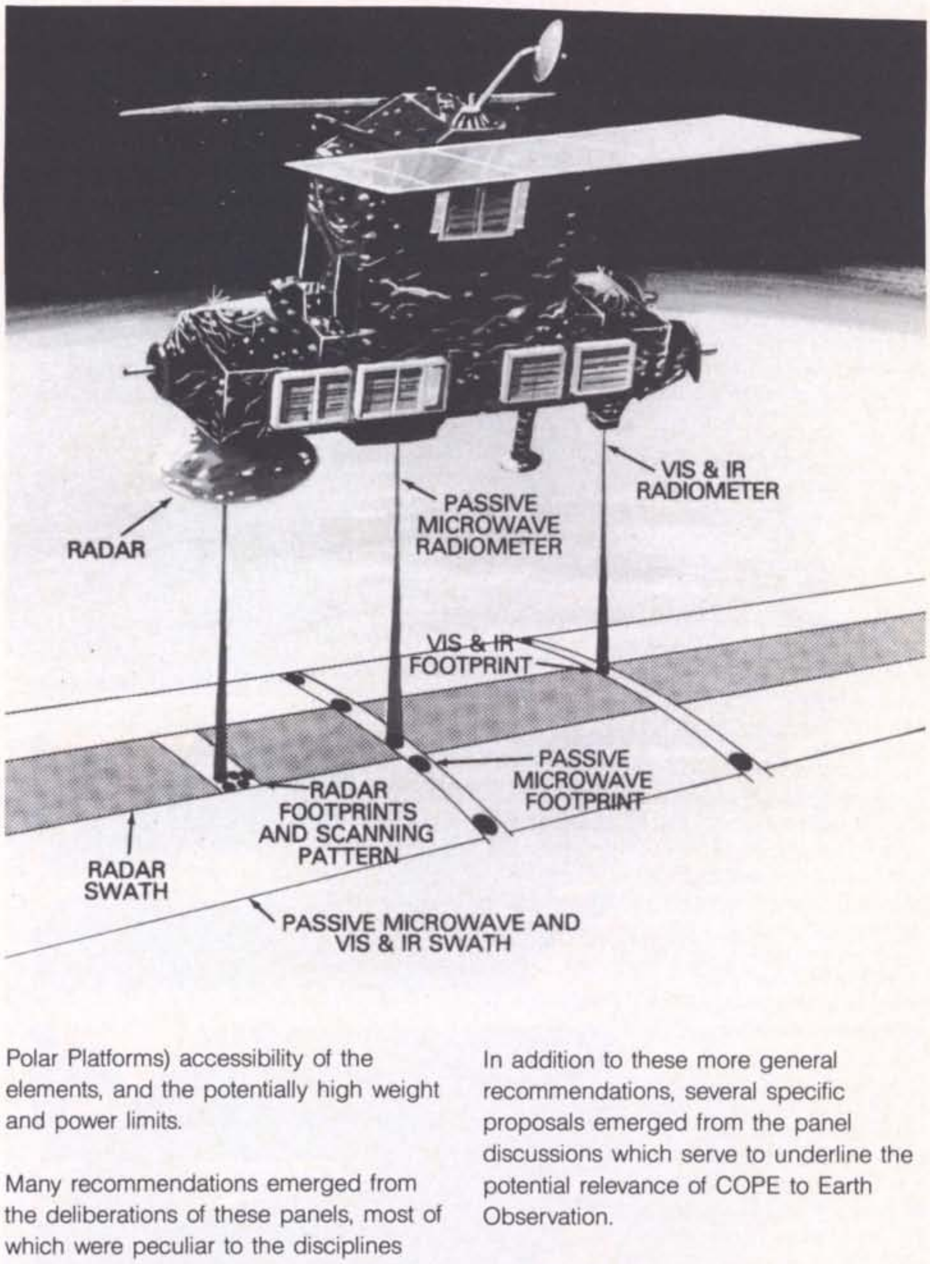
A typical list is reproduced in Table 1, illustrating the multi-disciplinary nature of the proposals and their international dimension, as well as the types of instrument being considered. Full details

*Table 1 — Some of the instruments being considered for the Polar Platforms**

	Disciplines addressed			
	Atmosphere	Ocean/Ice	Land	Solid Earth
Research Instruments				
Optical-Passive				
Ocean Colour	X	X	O	
Moderate-Resolution Imaging Spectrometer	X	O	X	
High-Resolution Imaging Spectrometer	O	O	X	
Intermediate Thermal Infra-Red Radiometer		X	X	
Visible and Near-Infrared Radiometer	X	X	X	
Optical-Active				
Backscatter Lidar	X			
Doppler Wind Sounder	X			
Laser Ranging System				X
Microwave-Passive				
Advanced Microwave Sounding Radiometer	X	X	X	
Microwave-Active				
Scatterometer	X	X		
Altimeter	O	X	X	O
Synthetic Aperture Radar		X	X	
Operational Instruments				
Optical				
Advanced Very High Resolution Radiometer (AVHRR)	X	X	X	
High-Resolution Infra-Red Sounder (HIRS)	X			
Global Ozone Monitoring Radiometer (GOMR)	X			
Earth Radiation Budget Instrument (ERBI) Non-Scanner	X	O	O	
Earth Radiation Budget Instrument (ERBI) Scanner	X	O	O	
Microwave				
Advanced Microwave Sounding Unit (AMSU)	X			
Other				
Data Collection & Location System	O	O	O	O
Space Environment Monitor (SEM)	X			
Direct Broadcast	O	O	O	O

* This list is only indicative and not exhaustive. Other possibilities include Limb Scanners and the Along-Track Scanning Radiometer
X = Major contribution O = Minor contribution

Figure 6 — Concept for a possible Rainfall-Measuring Satellite



are to be found in the 'ESPOIR' Report*. The other document the reader might find it useful to consult is the 'POPE' Report**. Both reports summarise the views of Earth-observation scientists on the uses to which the Polar Platforms should be put; both also refer to servicing, considering later additions to platforms as well as initial payloads. Plans are not completely finalised yet, but there is broad agreement on the types of instruments that should be flown.

The COPE Workshop

It was against the above background that it was decided to organise the COPE Workshop. It had become clear that the time had come to broaden the debate on how the Earth-observation community should exploit the facilities provided by the Space Station so that it included not only the Polar Platforms, but also the other elements. As the first step in this process about thirty leading scientists were invited to a two-day Workshop at ESTEC, in the Netherlands, in April 1987 to give their views.

The Workshop followed the format established at previous workshops in this series with the first part of the meeting being devoted to briefings on the facilities available, the usages already planned, etc. During the second part, the Group divided itself into Panels covering the four prime disciplines of Earth-observation, namely 'Atmosphere', 'Ocean', 'Land' and 'Solid Earth'.

In considering the use of the COPE (i.e. all elements of the Space Station except the Polar Platforms) the Panels sought to capitalise on the opportunities afforded by the characteristics of the various elements for Earth observation, notably the low-inclination and non-Sun-synchronous nature of the orbits, their relatively low altitude, the relative (to the Polar Platforms) accessibility of the elements, and the potentially high weight and power limits.

Many recommendations emerged from the deliberations of these panels, most of which were peculiar to the disciplines involved, but two were common to all, namely:

(a) that as far as the Earth-observation community as a whole was concerned, the Polar Platforms are the priority, given the need for global coverage and long-term continuity;
(b) there should be a space—time sampling study to determine the optimum mix of Polar Platforms and COPE elements to meet the needs of Earth observation.

In addition to these more general recommendations, several specific proposals emerged from the panel discussions which serve to underline the potential relevance of COPE to Earth Observation.

Atmosphere Panel
(Chairman: Dr J.E. Harries)

The tropical atmosphere, and the underlying ocean, is the heat engine that drives the whole of the atmosphere. Our understanding of the processes that occur and our ability to monitor them is, however, woefully inadequate so the panel sought to exploit COPE to remedy the situation. In so doing, it took full account of the improvements that should ensue with the advent of the Polar Platforms, but highlighted three areas of

* ESPOIR, ESA SP-266, Proc. ESA Workshop, Avignon (F) 16—18 June 1986.
** Report of the POPE Working Group (1986).

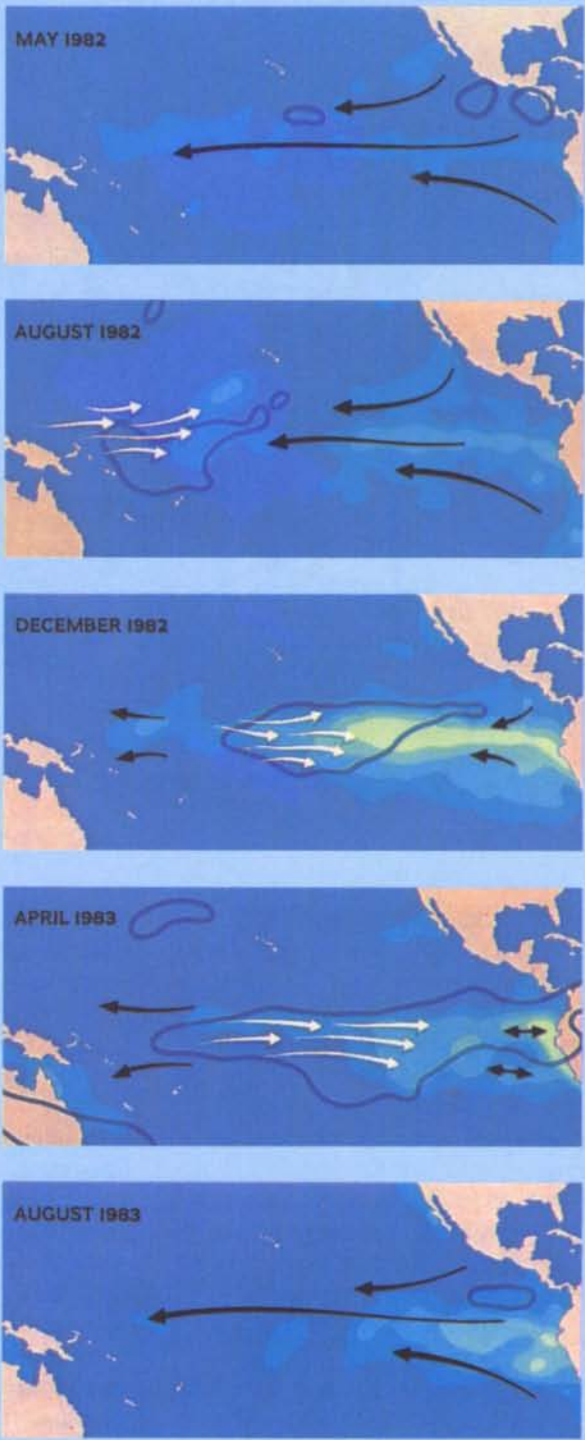
Figure 7 — Mechanics of a Disaster — The El Niño

Normal weather sees a high-pressure system parked over the eastern Pacific, prompting trade winds to blow 'downhill' towards a wet low-pressure system over Indonesia and inducing a westward-setting current. Warm water piles up in the Western Pacific. Cool subsurface water returns in an undercurrent; the warm-water layer remains shallow off South America.

Every few years the pattern breaks down, disastrously so in 1982/83. The low moves eastward, and the high weakens. The trade winds falter and are replaced by east-blowing winds, causing the surface current to reverse and warm water to surge towards South America in a phenomenon known as a Kelvin Wave.

Since this generally stable weather machine spans a quarter of the globe, its collapse has far-reaching effects. The cause remains unknown, although El Nino and the monsoon system may be so intricately linked that changes in one affect the behaviour of the other.

El Nino's footprint on the ocean shows up as a rapid warming of the sea surface that culminated in December 1982 in a tongue of warm water stretching 8000 miles along the Equator (shades of blue, from dark to light, identify temperatures 1°, 2°, 3°, and more than 4°C above normal). Dark blue perimeters enclose areas of heavy rain. Black arrows show wind direction and speed; white arrows indicate the variation from normal. (Courtesy of National Geographic)



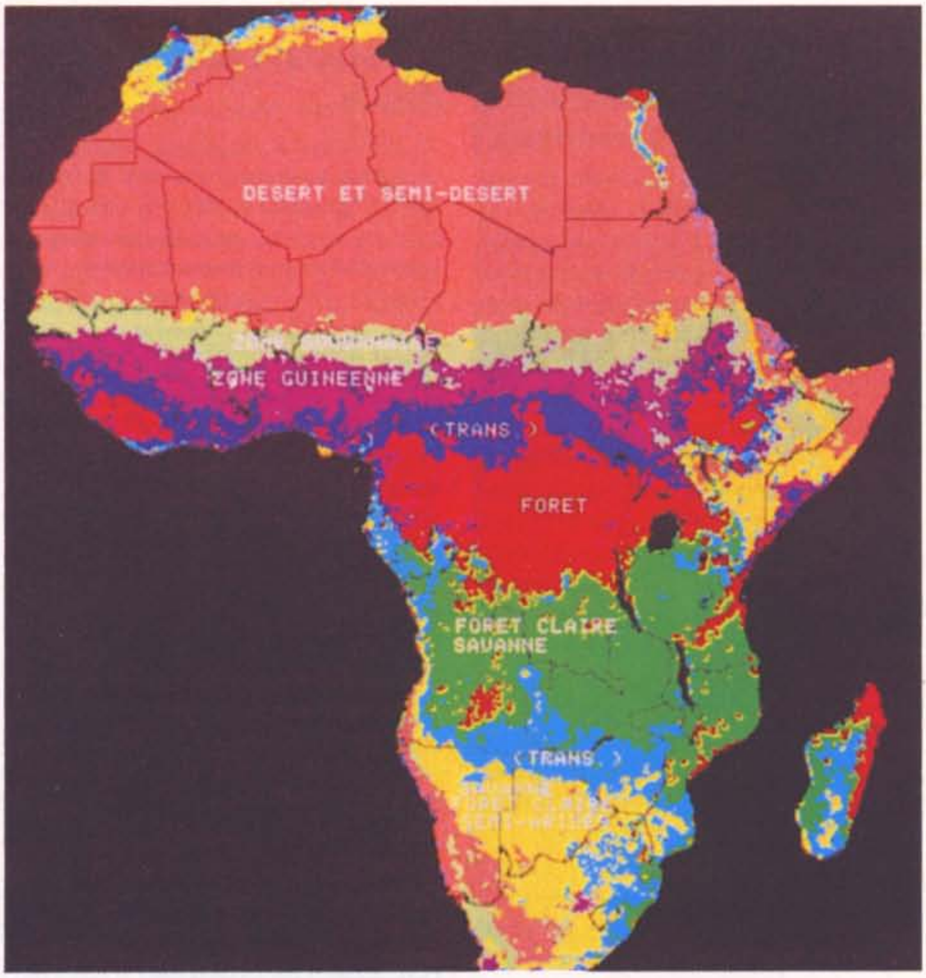
major deficiency; namely wind, precipitation and chemistry. The first two have much in common as in both cases the technology is not established, the instruments are likely to be very expensive, and currently data coverage is almost non-existent despite the importance of these variables. The Panel therefore saw COPE as a logical facility to exploit in attempting to ameliorate the situation.

The third area, chemistry, was also a logical candidate for COPE mainly because of the nondiurnal nature of the coverage it provides. This is vital if the photochemical processes that occur in the regions covered by COPE, the most chemically active part of the globe, are to be studied properly. As far as instrument performances are concerned, the relatively low altitudes could facilitate the provision of data, as instrument specifications could be relaxed somewhat (relative to those needed to make the same measurements from Polar Platforms).

Ocean Panel (Chairman: Dr M. Lefebvre)
Given the close links between oceanography and meteorology, it was not surprising to find that there were significant similarities between the report of this Panel and the previous one. This Panel also stressed the particular importance of this region of the globe, fully accepting the need to improve observations of wind and precipitation and therefore supporting the recommendation of the Atmosphere Panel that the provision on COPE of instruments capable of remedying these deficiencies be considered.

In addition, the Panel highlighted the importance of sea-surface temperature and the basic role of the Tropical Oceans Global Atmosphere (TOGA) Experiment to oceanographic studies in this area, recommending that the field plans for TOGA should be re-appraised, seeking to exploit the potential of COPE. Like TOGA, this re-evaluation should include

Figure 8 — Vegetable indices for Africa



studies of the monsoon as well as oceanography. The low altitude could lead to significant improvements in the quality of the data gathered, though the Panel were of the general opinion that the bulk of the requirements could be met by the Polar Platforms.

Land Panel
(Chairman: Dr A. Sieber)
This Panel also underlined the importance of this part of the globe, though for different reasons, being primarily concerned with land usage, crop monitoring etc. COPE covers the areas where the greatest rates of change in land usage are occurring (viz. the clearance of the tropical rain forests) as well as those of very high vulnerability in terms of food supply. Also included are the outlets of the main sources of sediment and countries with poor topographic maps and little knowledge of their natural resources.

The Panel identified two parameters that were especially important for the tropical belt, namely the water content of the soil and the state of the vegetation. These could be studied from space using new techniques which exploited the characteristics of COPE. However, generally the Panel took the view that most requirements could be adequately covered by instruments flown on Polar Platforms.

Solid-Earth Panel
(Chairman: Prof. P. Paquet)
The region to be overflown by COPE includes some of the most volcanically and seismically active areas of the globe, as well as the bands of latitude that encompass the bulk of the anomalies in the Earth's magnetic field. Thus, although the Panel would prefer coverage of the entire globe, COPE could definitely be used with advantage to advance our understanding in two areas, namely geokinematics and geomagnetism, in a way not possible with the Polar Platforms, the orbits of which are to be at too high an altitude.

Working on this basis and drawing on the recommendations of the SESAME Report*, which summarises the findings of a Workshop organised to consider the needs of the European Solid-Earth community, the Panel drew up a list of instruments which, if installed on COPE, should lead to a significant advance in our knowledge in two important areas. Typical candidates for studies of geokinematics are high-precision microwave ranging systems and, ultimately, spaceborne laser ranging systems.

These are of course no more than outlines of the findings of the four panels and the interested reader is encouraged to consult the COPE Workshop Report**, which provides full details of the discussion as well as much relevant background material.

* SESAME, ESA SP-1080, Proc. ESA Workshop, Ising am Chiemsee, 4—6 March 1986.

** COPE, ESA SP-1093, Proc. ESA Workshop, ESTEC, 7—9 April 1987.

Conclusion
The COPE Workshop represents but one stage in the process by which ESA assesses the needs of the Earth-observation community, with the overall aim of obtaining a general consensus as to how the facilities of the Space Station as a whole should be exploited. However, it represents a very significant step as COPE has widened the scope of the debate by highlighting the importance of the tropical belt and the fact that to a certain extent the use of the COPE provides the means to significantly increase our knowledge and hence our understanding of this area.

Acknowledgement
It would be inappropriate to end an article of this nature without fully acknowledging the debt the author owes to both the scientists who participated so enthusiastically in the COPE Workshop and the staff in ESA's Earth-Observation Directorate who provided such wholehearted support.

In Brief

ESA Council Meeting at Ministerial Level in The Hague

An ESA Council Meeting at Ministerial Level is to take place in The Hague, on 9 and 10 November 1987. At the last meeting of the Council held at Ministerial Level, in Rome in January 1985, the Ministers of the Agency's Member States agreed on a general framework of objectives and programmes for future European space activities. Based on the Rome decisions, the Agency has subsequently elaborated a European Long-Term Space Plan until the year 2000. This plan will be submitted for decision to the Ministers of the 13 ESA Member States, plus Finland (Associate Member) and Canada (which cooperates in several ESA programmes), in The Hague.

A detailed account of the outcome of the Meeting will appear in the next issue of the Bulletin (no. 53, February 1988).

'CODE': A Co-operative Olympus Data Experiment*

The Agency has proposed an information dissemination and exchange system that will operate through the 30/20 GHz repeaters of the Olympus-1 satellite, scheduled for launch in 1989. The system is primarily modelled around the requirements of Universities and Technical Laboratories.

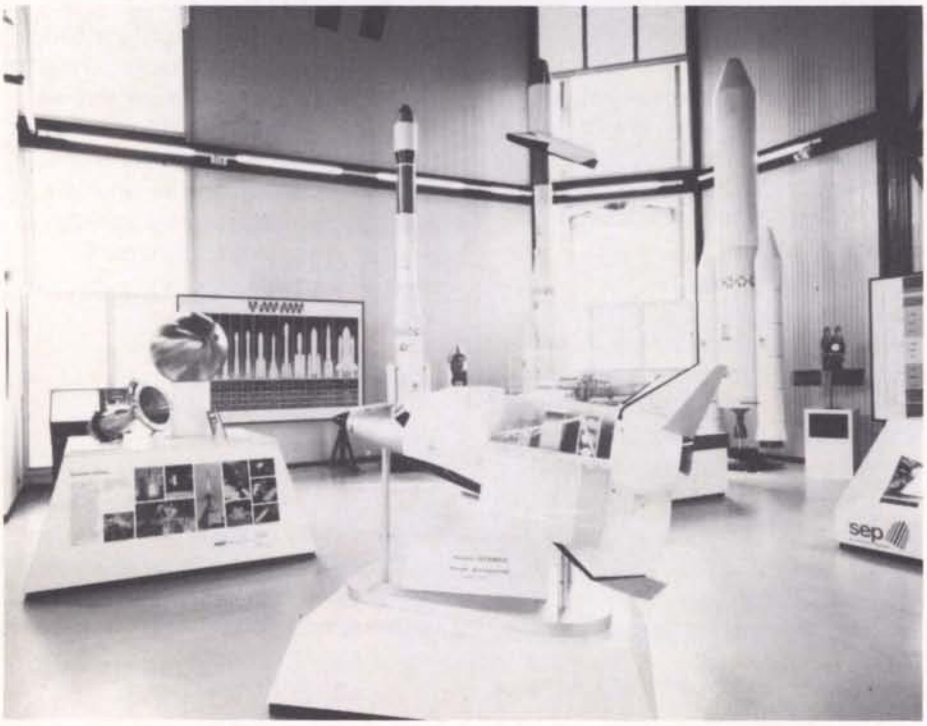
It will permit personal computers associated with small earth terminals at the user locations to be connected, via satellite, to a central earth station where databases containing information on scientific and technical subjects of mutual interest are located. The users will be able to update the central databases themselves from their terminals in accordance with simple procedures.

Distribution of information from the central earth station to all or specified

Le Centre Européen d'Exposition Spatiale (CEES) de Kourou

Le Centre Spatial Guyanais (CSG) accueille une bonne dizaine de milliers de visiteurs par an. Parmi ceux-ci on compte de nombreux officiels venant du monde entier lors des lancements Ariane, sans parler des touristes étrangers ou des habitants de la Guyane, dont une majorité de jeunes. Or l'accroissement des activités opérationnelles et les contraintes de sécurité et de sauvegarde limitent de plus en plus l'accès des visiteurs aux installations sensibles du Centre — zones d'intégration des satellites et de préparation des lanceurs — suscitant de cette façon une certaine frustration...

Vue de la salle Ariane, avec Hermès au premier plan



C'est ainsi qu'en août 1984, sous l'impulsion de M. Marius Le Fèvre, alors directeur du CSG, a été prise la décision de créer sur la Base de lancement une vitrine permanente des techniques spatiales européennes, des activités du CSG et du programme Ariane en particulier. Le Centre Européen d'Exposition Spatiale a été conçu et réalisé grâce à l'effort conjoint de l'Agence spatiale européenne, du CNES, de la société Arianespace et des industriels européens.

L'exposition, qui occupe une surface de plus de 500 m^2, a adopté comme base de présentation, le principe d'une information didactique, dynamique et attrayante à travers les nombreux moyens mis en oeuvre, tels que panneaux photographiques explicatifs, diaporamas et spectacles vidéo. Elle traite de l'espace au sens le plus large (organisation, sciences et techniques) à travers les domaines suivants, répartis sur groups of users will be possible. Users will also be able to communicate with each other via the central facility for joint authorship of papers and exchange of experiment results, etc.

The central earth station facility will be one of the Agency's TDS-6 30/20 GHz earth stations, located in the United Kingdom. The small earth stations and the associated computers will be specified and procured by the users themselves, based on their own requirements. CODE will simply specify the minimum requirements for system interfacing. It is felt that many users will be able to design and build the stations themselves and co-operation between users in the provision of key technology items may be possible.

The small stations will have antenna diameters of about 1 m and will employ solid-state amplifiers for transmission to the satellite. The data rate from the central station to the user stations will be 2 Mbit/s. The data rate in the reverse direction will be 9.6 kbit/s.

The design of the system is being handled by a steering group of key universities and scientific establishments. It is planned to produce technical details at the physical level by October 1987, protocol and software information being released progressively thereafter. Expressions of interest in participating have already been received from many establishments, both in Europe and North America. Prospects are therefore good for a flourishing and widely dispersed user community.

*Further information can be obtained from C.D. Hughes, in the Agency's Communications Satellites Department at ESTEC.

cinq salles:

- **Le CSG:** ses missions, ses moyens et son organisation, ses relations avec la région Guyane;
- **L'Espace Utile:** les grands domaines d'application de l'espace, des télécommunications à la microgravité, en passant par l'observation de la Terre;
- **L'Espace scientifique:** la découverte et l'explication de l'Univers avec les grandes missions d'exploration du système solaire;
- **La famille Ariane** de I à V: sa technologie et ses industriels; perspective de la station Columbus et de l'avion spatial Hermes des années 1995–2000;
- **L'ambiance d'un lancement Ariane** en faisant revivre en dix minutes à travers 5 écrans, les 29 heures d'une chronologie de préparation des moyens du CSG, du décollage du lanceur et de l'injection en orbite des satellites.

Depuis son ouverture, le CEES connaît un succès grandissant. Les visiteurs — officiels comme écoliers — admirent et s'instruisent. Ils trouvent dans ce Centre ce que ses promoteurs avaient voulu au départ: un outil de dialogue permanent et attrayant entre le public et l'espace, un des pôles d'attraction de la Guyane.

Organisational Change in the Directorate of Space Transportation Systems

Following the adoption of the Ariane-5 Programme and the definition of the role of the Agency in the Hermes Programme, it has become necessary to adapt the organisational structure of the Directorate of Space Transportation Systems (D/STS) based on:

- Extended tasks in the framework of the Ariane-5 Programme
- Extended tasks in the framework of the Hermes Programme.

The changes involve: the establishment of dedicated project-control teams within the Ariane and Hermes Programme Departments; incorporation of future launcher and technology studies in the Ariane Programme Department; establishment, within the Directorate at Headquarters, of a Hermes Utilisation Office and a Hermes Department representative; establishment of a Coordination Office; introduction of coherence management units within the Ariane and Hermes Departments; and establishment of an STS Technology Programme Coordination Office at ESTEC, in Noordwijk.

'DICE': A Direct Inter-Establishment Communications Experiment*

In association with British Aerospace and the University of Graz in Austria, the Agency is planning a business-communication and video-conferencing experiment to link participating organisations on a multi-location, simultaneous-presence basis.

The experiment, called 'DICE', will initially link three British Aerospace establishments in the United Kingdom. The video terminals developed by the University of Graz will allow video conferences to be conducted in a normal office environment with the minimum of special arrangements. Up to four locations can be interconnected at one time and all participants will be able to see each other and talk to each other simultaneously without restriction, as would be the case in the type of informal meeting prevalent at all levels of decision making in industry and commerce. Participants will also be able to exchange digital data, hard copy and visual-display information, as would be the case at a single-location meeting.

Transmission between the sites will be via the 30/20 GHz transponders of the Agency's Olympus-1 satellite, to be launched in 1989. Three TDS-6 transportable earth stations, currently being built by Marconi Space Systems for the Agency, will be used to access the satellite. The video coding equipment will be of modified standard design, but specially developed interface equipment will be employed. In particular, techniques for limiting the degree of motion available in the video pictures, whilst maintaining high-quality sound and data during fading events, will be tested.

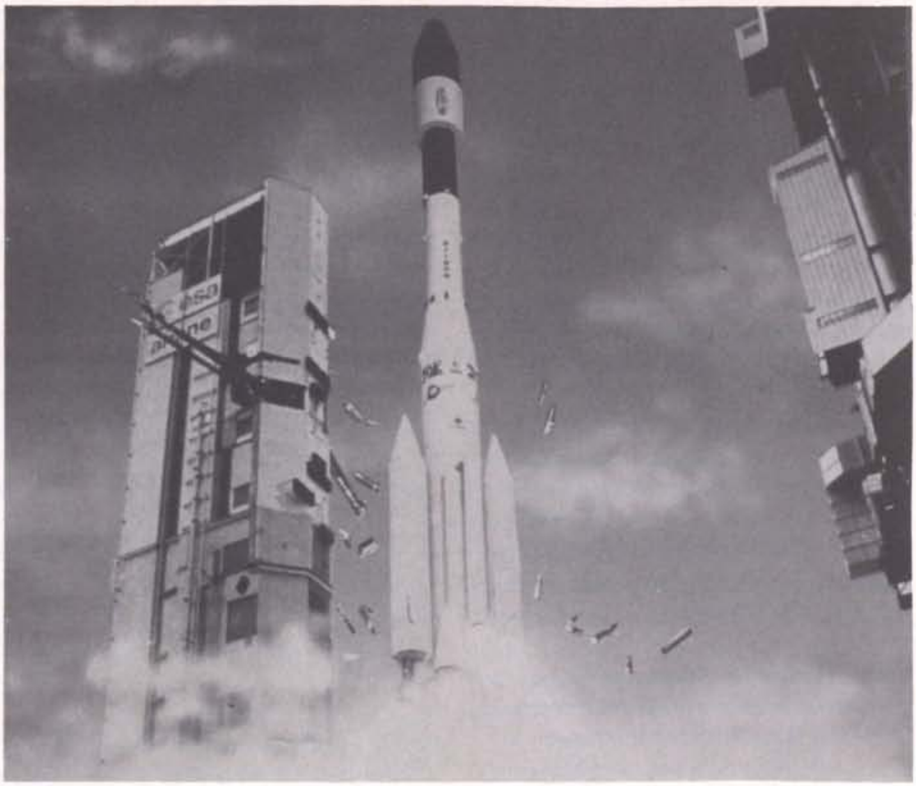
The DICE experiment will start shortly after the Olympus-1 launch, and will have an initial duration of 18 months, with the possibility of extension and modification, depending upon the results obtained.

Contract Awarded to Supply Payload Launch System for Ariane-4

A contract worth more than £20 million to supply Arianespace with twenty 'Spelda' payload-bay structures for ESA's Ariane-4 launcher has been awarded to British Aerospace Space and Communications Division.

The Spelda is an integrated payload-bay structure that will enable Ariane-4 to launch two or more spacecraft independently during the same mission. It is a large cylindrical structure 3.97 m in diameter, below a truncated conical section. One satellite will be carried on a mounting ring fitted to the top of the conical section, and the other will be enclosed within the cylindrical portion.

Ariane's nose fairing will be jettisoned early in the vehicle's flight, clearing the way for the upper satellite to be released into orbit. A pyrotechnic charge will then separate the upper and lower sections of the Spelda, before the upper section is propelled away by a pre-compressed spring system, leaving the second satellite free for release into transfer orbit.



The first flight model will be employed in 1988 on the maiden flight of Ariane-4 (flight V21), which will give Europe the ability to place the largest satellites now being built into geotransfer orbit.

Flight of the 'Arctic Tern'

Earlier this year, Calin Rosetti, a staff member in ESA's Directorate of Telecommunications, and Richard D. Norton, a US citizen, successfully flew a single-engined airplane around the world via the South and North Poles for the first time in aviation history. The flight also commemorated the 60th Anniversary of Charles Lindberg's North Atlantic crossing and the 50th Anniversary of Tschkalov's first flight from Europe to the USA (Moscow to Portland via the North Pole).

A number of technical and scientific experiments were attempted during the flight, one of which concerned satellite aeronautical communications. During the flight leg from Mould Bay in the Canadian NW Territories, to Europe, via the North Pole, radiotelephony contacts were established between the aircraft and ESA's ground station in Villafranca, Spain, by using the ESA-built Marecs Atlantic satellite which is operated by INMARSAT.

The first of these contacts was established from a position 86°N, 15°E and an altitude of 25 000 feet. The satellite was at that time below the horizon, at a negative elevation of about 3°, making this something of a first in satellite-based communication.

The mobile communications equipment used aboard the Arctic Tern was built at ESA's Space Research and Technology Centre (ESTEC) in Noordwijk (The Netherlands). INMARSAT kindly permitted the use of their Marecs satellite for this novel experiment.

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table and using the Order Form inside the back cover of this issue.

ESA Special Publications

ESA SP-270 // 472 PAGES
PROC EIGHTH ESA SYMPOSIUM ON EUROPEAN ROCKET AND BALLOON PROGRAMMES AND RELATED RESEARCH, SUNNE, SWEDEN, 17-23 MAY 1987 (AUGUST 1987)
GUYENNE T D & HUNT J J (EDS)

ESA SP-273 // 239 PAGES
PROC ESA WORKSHOP ON OPTICAL INTERFEROMETRY IN SPACE, GRANADA, SPAIN, 16–18 JUNE 1987 (AUGUST 1987)
LONGDON N & DAVID V (EDS)

ESA SP-275 // 224 PAGES
SMALL-SCALE PLASMA PROCESSES, PROC 21ST ESLAB SYMPOSIUM, BOLKSEJØ, NORWAY, 22–25 JUNE 1987 (AUGUST 1987)
BATTRICK B & ROLFE E J (EDS)

ESA SP-278 // 760 PAGES
THE DIVERSITY AND SIMILARITY OF COMETS, PROC INTERNATIONAL SYMPOSIUM, BRUSSELS, BELGIUM, 6–9 APRIL 1987 (OCTOBER 1987)
ROLFE E J & BATTRICK B (EDS)

ESA SP-1093 // 71 PAGES
COPE – CO-ORBITING PLATFORM ELEMENTS, PROC ESA WORKSHOP, ESTEC, NOORDWIJK, THE NETHERLANDS, 7–8 APRIL 1987 (SEPT 1987)
GUYENNE T D (ED)

ESA SP-1083 // 118 PAGES
REPORT BY THE ESA OCEAN COLOUR WORKING GROUP, VILLEFRANCHE-SUR-MER, 5–6 NOVEMBER 1986 (JULY 1987)
GUYENNE T D (ED)

ESA Brochures

ESA BR-32 // 42 PAGES
INTRODUCTION TO THE METEOSAT OPERATIONAL SYSTEM (SEPTEMBER 1987)
MASON B D (COMPILER) & GUYENNE T D (ED)

ESA Folders

ESA F-05
THE EUROPEAN SPACE AGENCY (4 LANGUAGES)
LONGDON N & DAVID V (EDS)

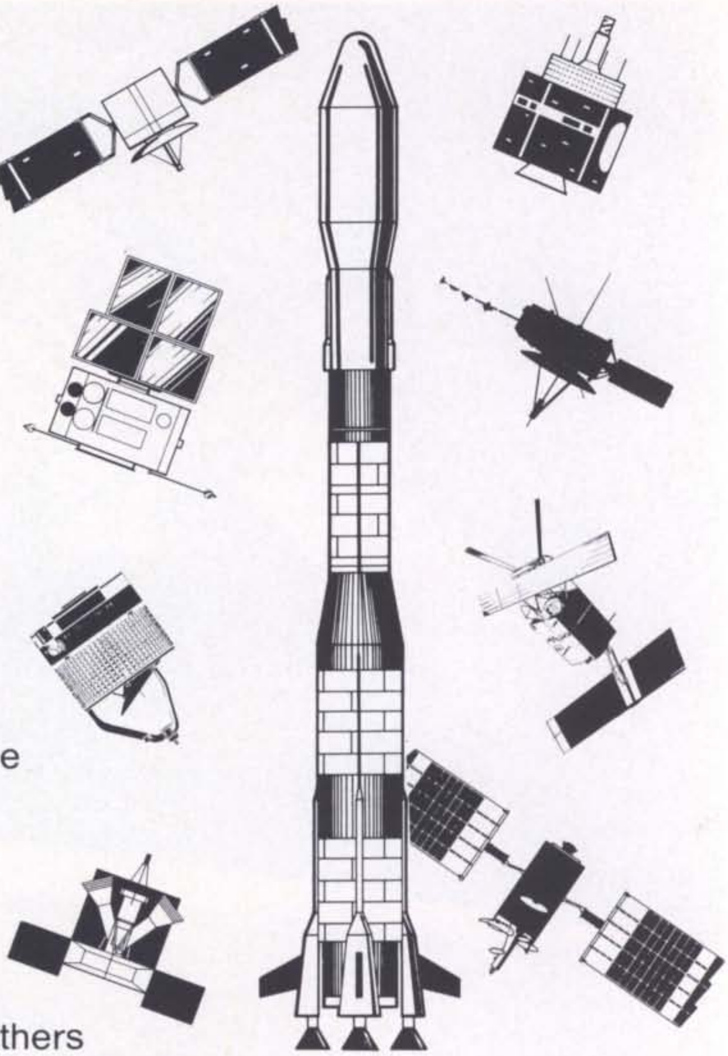
ESA F-08
A SPANISH WINDOW ON THE UNIVERSE (ENGLISH & SPANISH)
LONGDON N (ED)

ESA F-10
A PORTRAIT OF IMAGES – THE EARTHNET CONTRIBUTION
LONGDON N (ED)

ESA Scientific & Technical Reports

ESA STR-222 // 148 PAGES
THE APPROPRIATE USE OF CONTRACT TYPES IN DEVELOPMENT CONTRACTS (A SYSTEMS APPROACH WITH EMPHASIS ON THE EUROPEAN SPACE SECTOR) (OCTOBER 1987)
PEETERS W A

ESA STR-224 // 21 PAGES
METEOROLOGICAL INFORMATION EXTRACTION CENTRE (MIEC) PROCESSING (SEPTEMBER 1987)
BURKE W R (ED)



Publications Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Availability	Source
Periodicals				
ESA Bulletin	4	ESA's magazine	Free of charge	ESA Publications Division, ESTEC,
ESA Journal	4	ESA's learned journal	,,	2200 AG Noordwijk, The Netherlands
Earth Observation Quarterly (English or French)	4	Remote sensing newspaper	,,	,,
Columbus Logbook	4	Space Station/Columbus newspaper	,,	,,
News & Views	6	ESA Information Retrieval Service's newspaper	,,	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Volumes on specific Conference subjects	Prices below	ESA Publications Division, ESTEC,
Scientific/Technical Monographs	(SP-xxxx)	Specific/detailed information on graduate-level subjects	,,	2200 AG Noordwijk, The Netherlands
ESA Brochures	(BR-xxx)	Summary of less than 50 pages on a specific subject	,,	,,
ESA Folders	(F-xxx)	'Folders' giving short description of a subject for the space-interested layman	Free of charge	ESA Publications Division, ESTEC, 2200 AG Noordwijk, The Netherlands
Scientific & Technical Reports	(STR-xxx)	Graduate level — reflecting ESA's position on a given subject	Prices below	,,
Scientific & Technical Memoranda	(STM-xxx)	Graduate level — latest but not finalised thinking on a given subject	,,	,,
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of contracts	,,	,,
Other Publications				
Contractor Reports	(CR-xxx)	Study reports from contractors: CR(P) given unlimited distribution CR(X) confined to certain ESA Member States	Prices below ,, ,,	ESA Publications Division, ESTEC 2200 AG Noordwijk, The Netherlands ,,
Technical Translations	(TT-xxx)	Translations of national space-related documents — (Microfiche or photocopy only)	Prices from ESRIN	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy, or ESA/IRS Office, 8-10 Mario Nikis 75738 Paris 15, France
Public-relations material		General literature, posters photographs, films, etc.		ESA Public Relations Service 8-10 rue Mario-Nikis 75738 Paris 15, France

Charges for printed documents	E0	E1	E2	E3	E4
Number of pages in document:	1—50	51—100	101—200	201—400	401—600
Price (Dutch Guilders)	20	30	40	60	80

1. Cheques to be made payable to: ESA Publications Division
2. Prices subject to change without prior notice
3. Postal charges (non Member States only): Australia Dfl. 25; Canada Dfl. 20; Other Countries Dfl. 15.

Order Form for ESA Publications

RETURN TO: DISTRIBUTION OFFICE ATTN.: F. DE ZWAAN
ESA PUBLICATIONS DIVISION
ESTEC, POSTBUS 299
2200 AG NOORDWIJK
THE NETHERLANDS

No. of copies	ESA Reference	Title	Price per copy, Dfl.	Total Dfl.

Postal charges
(non Member States only: Australia Dfl. 25; Canada Dfl. 20; Other countries Dfl. 15):

Total Amount to be Invoiced: Dfl.

IF OUT OF PRINT **SUPPLY / DO NOT SUPPLY** **IN** **MICROFICHE / PHOTOCOPY**

MAILING AND INVOICING ADDRESS (Print carefully)

Name ....

Function ....

Organisation ....

Mailing Address ....

....

Town & Postal Code ....

Country ....

Customer's Ref. .... Signature ....

Date ....

ADDITIONAL INFORMATION

1. Publications are available in printed form (as long as stocks last), in microfiche and as photocopies.
2. Publications in the ESA TT series are not available in printed form.

ADVERTISE YOUR SPACE-RELATED PRODUCTS/SERVICES IN

esa bulletin

Under the terms of its Convention, ESA has an obligation to 'facilitate the exchange of scientific and technical information pertaining to the fields of space research and technology and their space applications.'

The Bulletin is the Agency's quarterly magazine that helps to fulfil this obligation, carrying information on ESA, its activities and its programmes, on-going and future.

The ten or so articles that go to make up each issue (approximately 100 pages) are drafted by professional scientists and technologists. They are original and significant contributions on space technology, space science, space missions and space systems management and operations. The goal is to bring the results of ESA's space research and development activities to the notice of professionals concerned with the exploration and exploitation of space, many of whom are senior politicians and those responsible for government contracts.

Every Bulletin also carries some 16 pages of 'progress information' that comprehensively describe the last three months' developments in all the major European space programmes (telecommunications, meteorology, earth observation, and scientific satellites, the Spacelab/Space Shuttle programme and the Ariane launch-vehicle programme). Newsworthy events, conferences, symposia and exhibitions associated with the European space programme are also featured in every issue.

The Readership

Through the nature of its content and the role that the Agency plays in shaping Europe's space research and development activities, the Bulletin has come to have a fast-growing (currently 10500 copies per issue) but *select* distribution among 'decision makers' in space matters not only in Europe but around the World. The Bulletin is now distributed in more than 100 countries. It is read by managers and senior staff in space-oriented organisations – both national and international – in ministries, in industry, and in research institutes. It forms a fundamental part of the continual dialogue between ESA and its national counterparts and between ESA and the industrial firms to whom the contracts and subcontracts are awarded that account for the major part of the Agency's $950 million per year budget (contract awards on a geographical-return basis linked directly to the financial contributions of the individual ESA Member States).

Advertising Potential

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

CIRCULATION

Algeria
Andorra
Argentina
Australia
Austria
Belgium
Brazil
Bulgaria
Burma
Burundi
Canada
Chile
China
Colombia
Congo
Cyprus
Czechoslovakia
Denmark
Ecuador
Egypt
El Salvador
Ethiopia
Falkland Islands
Finland
France
French Guiana
German Democratic Republic
Germany
Ghana
Greece
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Ivory Coast
Jamaica
Japan
Jordan
Kenya
Korea
Kuwait
Lebanon
Lesotho
Liberia
Lichtenstein
Libya
Luxembourg
Madagascar
Malaysia
Malta
Mexico
Mongolia
Morocco
Mozambique
Netherlands
New Guinea
New Zealand
Nicaragua
Niger
Nigeria
Norway
Pakistan
Papua New Guinea
Peru
Philippines
Poland
Portugal
Puerto Rico
Quatar
Romania
Rwanda
Saudi Arabia
Senegal
Sierra Leone
Singapore
South Africa
Soviet Union
Spain
Sri Lanka
Sudan
Surinam
Sweden
Switzerland
Syria
Taiwan
Thailand
Trinidad
Tunisia
Turkey
Uganda
Uruguay
United Kingdom
Upper Volta
U S A
Venezuela
Yugoslavia
Zaire
Zimbabwe

RATES IN SWISS FRANCS

	1×	4×	8×
1/1 page B/W	1.500.–	1.250.–	1.050.–
1/2 page B/W	850.–	750.–	650.–

Extra charge for 4 colour processing: Swiss Fr. 1.200.–

Advertising representative

LA PRESSE TECHNIQUE S.A.

3a, rue du Vieux-Billard – P.O. Box 108
CH-1211 GENEVE 4 (Switzerland)
Tel. (022) 21 92 26 - Tlx 428 456 ptsa ch

european space agency
agence spatiale européenne

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