

esa bulletin

number 35

august 1983





European Space Agency

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

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

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

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

The Directorate of the Agency consists of the Director General, the Director of Scientific Programmes, the Director of Applications Programmes, the Director of Space Transportation Systems, the Technical Director, the Director of ESOC, 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: Prof. H. Cunen (France).

Director General: Mr. E. Quistgaard.

Agence spatiale européenne

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

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

- (a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
- (b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
- (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 satellites 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, du Directeur des Programmes scientifiques, du Directeur des Programmes d'Applications, du Directeur des Systèmes de Transport spatial, du Directeur technique, du Directeur de l'ESOC 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: Prof. H. Cunen (France).

Directeur général: M. E. Quistgaard.

esa bulletin

no. 35 august 1983

contents/sommaire



Front cover: ECS-1 (left), Exosat (right) and the Ariane L6 launch.

Back cover: Exosat images of the supernova remnant CAS-A as seen by the Channel-Multiplier Array (CMA) detectors of the Low-Energy Telescopes and the Position-Sensitive Detector (PSD).

Editorial/Circulation Office

ESA Scientific and Technical Publications Branch
c/o ESTEC, Noordwijk, The Netherlands

Publication Manager
Bruce Battrick

Editors
Bruce Battrick, Duc Guyenne

Editorial Assistants
Erica Rolfe, Jim Hunt

Layout
Carel Haakman

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

The ESA Bulletin is published by the European Space Agency. Individual articles may be reprinted provided that the credit line reads 'Reprinted from the ESA Bulletin' plus date of issue. Signed articles reprinted must bear the author's name. Advertisements are accepted in good faith: the Agency accepts no responsibility for their content or claims.

Copyright © 1983 by the European Space Agency.
Printed in The Netherlands
ISSN 0376-4265

**european space agency
agence spatiale européenne**

8-10, rue Mario-Nikis
75738 Paris 15, France

The Ariane L6 Dual Launch: An Unqualified Success

R. Orye

8

First European Communications Satellite ECS-1 on Station

12

Switch-on of Exosat's Scientific Payload

B.G. Taylor

14

The Exosat Launch Operations

G. Altmann, G. Scoon & C.B. von Stieglitz

18

L'apport du programme Météosat opérationnel sur le plan juridique

G. Lafferranderie

23

The Meteorological Product: Cloud Analysis

R.R. Warner

30

Experiment Data Communications (48 Mbit/s) between Spacelab, the Space Shuttle and the Ground

R. Selg & G.A. Weijers

34

Human Physiology Research under Microgravity Conditions and the Proposed 'Anthrorack' Facility

H. Oser & J. Ives

40

Programmes under Development and Operations

Programmes en cours de réalisation et d'exploitation

51

The New IRS Personal-Time-Series (PTS) Service

S. D'Elia

65

Le principe de 'juste retour industriel'

J. Bouillet

70

A European Heat-Pipe Experiment on the Second Flight of Space-Shuttle 'Challenger'

C.J. Savage

76

High-Accuracy Orbit Determination for Spacecraft in Low Earth Orbits

J.M. Dow

82

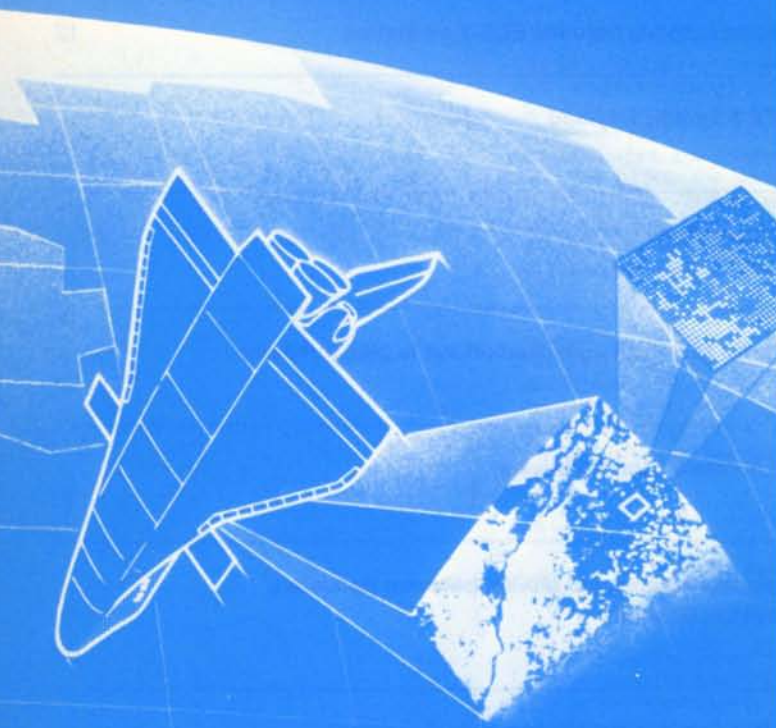
In Brief

90

Publications

96

Dornier Remote Sensing



Study on 2nd Generation
SAR-Experiment with 2 Frequencies.



Microwave Remote Sensing Experiment
for FSLP



Computer-based Meteorological
Satellite Ground Station

DORNIER's continuous engagement led to a broad variety of remote sensing projects carried out in national, european, and international programmes.

DORNIER's present capabilities and experience are the basis for further remote sensing tasks.

DORNIER – The reliable partner for:

- Design and Development of Overall Systems
- Design and Development of Airborne and Spaceborne Instruments
- Technology Development
- Ground Systems

Programs. Products. Perspectives.

 **DORNIER**

Dornier System GmbH, Dept. VRK, P.O.Box 1360, D-7990 Friedrichshafen 1,
Federal Republic of Germany, Tel. 07545/81, Telex: 0734209-0

Crouzet, the space challenger



Crouzet's answer to the challenge of space. Power conditioning, on board data handling, space mechanics, microelectronics, instrumentation, Crouzet's expertise and technological advance are geared to the satellites, launchers, and orbital station programmes of tomorrow.



The "systems" approach.

CHARGE SENSITIVE PREAMPLIFIERS

PRODUCT SUMMARY

FEATURING

- Thin film hybrid technology
- Small size (TO-8, DIP)
- Low power (5-18 milliwatts)
- Low noise
- Single supply voltage
- 168 hours of burn-in time
- MIL-STD-883/B
- One year warranty

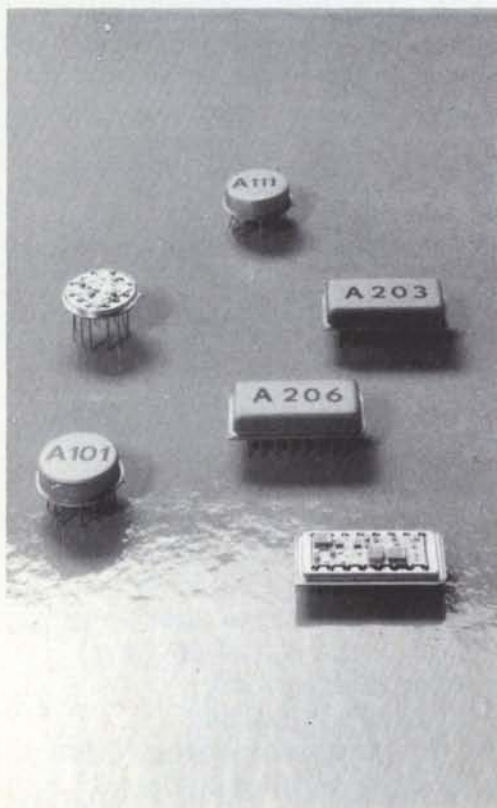
APPLICATIONS

- Aerospace
- Portable instrumentation
- Mass spectrometers
- Particle detection
- Imaging
- Research experiments
- Medical and nuclear electronics
- Electro-optical systems

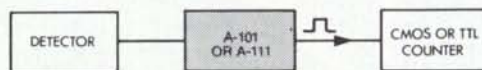


ULTRA LOW NOISE < 280 electrons r.m.s.!

Model A-225 Charge Sensitive Preamplifier and Shaping Amplifier is an FET input preamp designed for high resolution systems employing solid state detectors, proportional counters etc. It represents the state of the art in our industry!

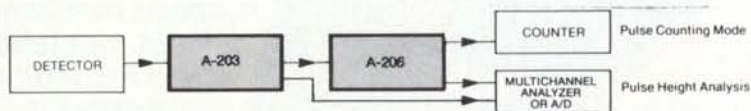


Models A-101 and A-111 are Charge Sensitive Preamplifier-Discriminators developed especially for instrumentation employing photomultiplier tubes, channel electron multipliers (CEM), microchannel plates (MCP), channel electron multiplier arrays (CEMA) and other charge producing detectors in the pulse counting mode.

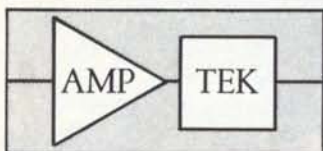


TYPICAL PARTICLE COUNTING SYSTEM

Models A-203 and A-206 are a Charge Sensitive Preamplifier/Shaping Amplifier and a matching Voltage Amplifier/Low Level Discriminator developed especially for instrumentation employing solid state detectors, proportional counters, photomultipliers or any charge producing detectors in the pulse height analysis or pulse counting mode of operation.



THE A-203/A-206 COMPLETE SYSTEM



AMPTEK INC.

6 DE ANGELO DRIVE, BEDFORD, MASS. 01730 U.S.A. (617) 275-2242

SOUTH AFRICA: GEORGE F. SPURDLE ASSOCIATES, Rivonia: 011-706 4587 **SOUTH AUSTRALIA 5014:** TEKNIS PTY. LTD., P.O. Alberton, Adelaide 2686122; **AUSTRIA:** AVIATICA Vienna 654.318; **BELGIUM:** LANDRE INTECHMIJ N.V., Antwerp 03/231.78.10; **BRAZIL:** TEKNIS LTDA. Sao Paulo 2820915; **DENMARK:** TEKNIS DANMARK, Værløse 481172; **ENGLAND:** TEKNIS LTD., Surrey 8685432; **FRANCE:** TEKNIS S.A.R.L.: Cedex 955.77.71; **WEST GERMANY:** TEKNIS GmbH. Munich 797457; **INDIA:** SARA-TEKNIS Division of BAKUBHAI AMABALAL PVT. LTD., Bombay 260419; **ISRAEL:** GIVEON AGENCIES LTD., Tel-Aviv 266122; **ITALY:** C.I.E.R., Roma 856814; **JAPAN:** K.K. EWIG SHOKAI, Tokyo 4647321; **HOLLAND:** HOLLINDA N.V., The Hague 512801; **HONG KONG:** S & T ENTERPRISES LTD., Watson's Estate, North Point 784921; **NORWAY:** TEKNIS A/S, Oslo 555191; **POLAND:** Overseas Marketing Corp. Ltd., Warsaw 279693; **SPAIN:** COMELTASA, MADRID 2549831; **SWEDEN:** LES-KONSULT AB, Bromma 985295; **TAIWAN:** TAUBE & CO., LTD., Taipei 331-0665;



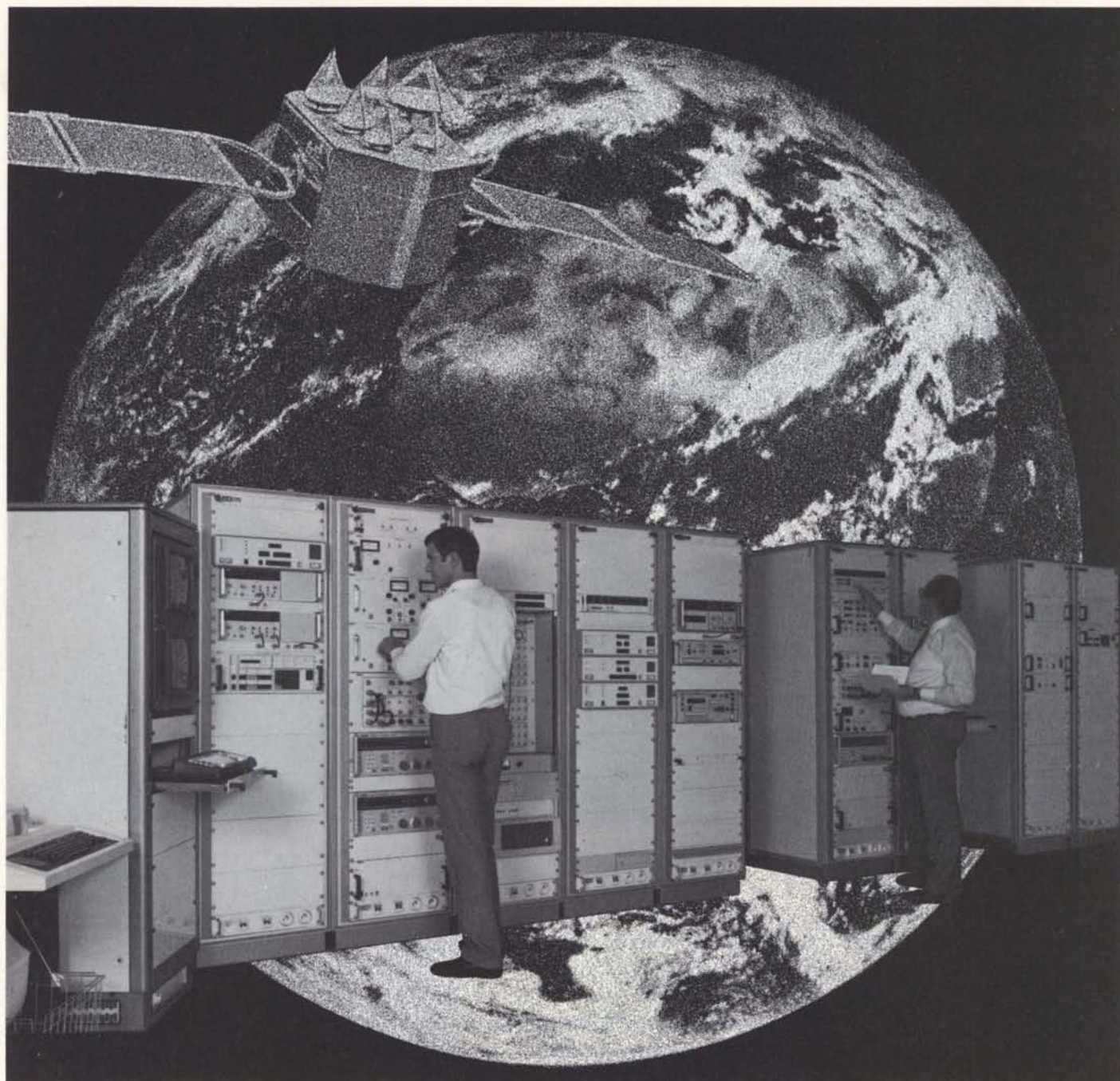
Born with 20 years experience.

A company — Saab Space — is born from the Saab-Scania Aerospace Division, specializing in spaceborne technology since the 60's. The development trend has gone from exclusive one-of-a-kind telemetry and telecommand systems (TTC) to larger subsystems and low-cost satellite systems as the VIKING — Sweden's first satellite. ■ Our first TTC system was developed for the ESRO TD-1A scientific satellite and Saab Space on-board computer system (OBC) was first used on the ARIANE rocket launcher. ■ Our experience in the field of TTC and OBC led to our development of general systems for on-board data handling (OBDH). A multipurpose system has been developed to be used in a number of current and future space missions. ■ We are experienced suppliers of sounding rocket equipment (payloads, booms etc). The maiden flight of our Guidance System — Saab SSC S19 — for instance, was described as a "milestone in sounding rocket technology". ■ With the scientific VIKING project a further technological step is being taken. The VIKING is a satellite concept, based on a low-cost profile. ■ Our next satellite project — the TELE-X — is an experimental communication satellite for transmission of data, video and television. Our undertaking comprises joint systems responsibility, delivery of structure, TTC, AOCS computers and other equipment. ■ Today Saab Space has well proven competence both as a supplier of equipment and as a major partner in the development of complete space systems. **SAAB SPACE**

20 years of experience forms a platform to rely on.

You will find our TTC, OBC and OBDH systems in various satellite projects: TD-1A, INTERCOSMOS 16, OTS, MARECS, SIRIO-2, ECS, TV-SAT, TDF-1, EXOSAT, SPOT, VIKING, TELE-X and onboard the ARIANE European heavy rocket launcher.

Saab Space AB, Box 13045, S-402 51 Göteborg, Sweden. Phone Int. + 46 31 37 00 00, Telex 21652 saabra s
 Saab Space AB, S-581 88 Linköping, Sweden. Phone Int. + 46 13 18 44 00, Telex 50040 saablg s



We provide the feet on the ground for the eyes in the sky.

In order to inform authorised users, highly sensitive receiving and demodulation equipment is needed.

We have such equipment. Our current product range includes: tracking and telemetry receivers, MSS and RBV channel receivers and demodulators, and high-resolution TM and HRV data QPSK/UQPSK demodulators with their attendant RF conversion equipment from 2 and 8 GHz.

For SPOT we supplied CNES with the world's most advanced multimission orbit control network, including angular tracking, range and range-rate, housekeeping telemetry acquisition, and spacecraft command systems.

The network comprises three S-band TT&C stations (Toulouse, Pretoria and Kourou) each capable of unattended operation thanks to a comprehensive, automated remote control and supervisory system.

Will be provided by the latest generation spacecraft:

LANDSAT-4 (USA) and SPOT-1 (France).

Bell Telephone Manufacturing Company S.A.

Defence and Aerospace Systems Group

Francis Wellesplein 1

B-2018 Antwerpen - Belgium

Tel. nat.: (03) 237 17 17

int.: 323/237 17 17

Telex: 72128 BELLA B

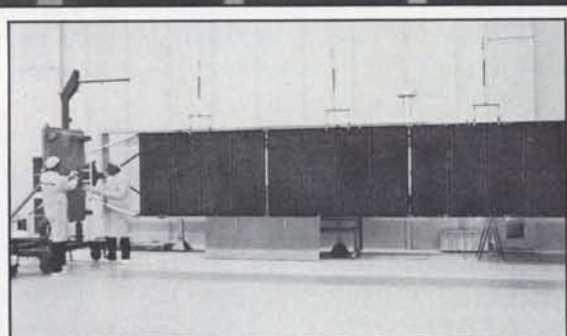
Bell Telephone Manufacturing Company

A Belgian Company associated with ITT

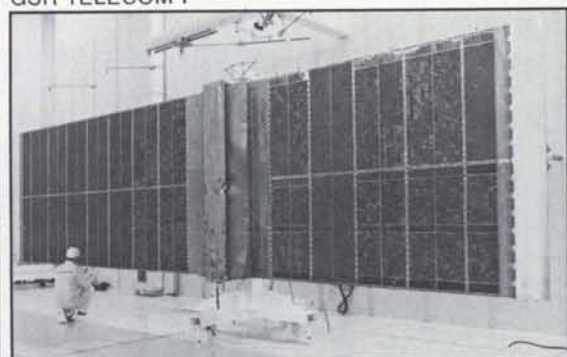
ITT

SOLAR ARRAYS

aerospatiale IS MORE



GSR TELECOM I



GS SPOT

GSR

Aerospatiale's GSR (Générateur Solaire Rigide) solar array is designed for a wide power range (up to 10 kW) and has been selected for such varied missions as point-to-point telecommunications (Telecom 1 and Arabsat) and direct TV broadcasting (TDF-1, TV-SAT, and Tele-X). A light-weight carbon fiber frame supports modules of solar cells bonded to a Kapton and carbon cloth substrate.

Power/mass ratio =
25 to 30 W/kg, end-of-life

ILSA

For the French earth observation satellite, SPOT, Aerospatiale designed a flexible, fold-up array, ILSA, (Improved Light-weight Solar Array). Solar cells are bonded to a composite Kapton foil/fiberglass cloth substrate. The array deploys from its stowage box by means of a motorized pantograph device. ILSA is suitable for missions requiring 4 to 10 kW and even higher.

Power/mass ratio =
30 to 40 W/kg, end-of-life

Both of these arrays can be partially deployed in transfer orbit providing up to 1 kW.



aerospatiale

Division Systèmes Balistiques et Spatiaux
Direction des Programmes Civils
B.P. 96 - 78133 Les Mureaux cedex - France

Figure 1 — The first European Communications Satellite (ECS-1), mounted on the Sylva (containing Amsat) prior to launch. In the background the Ariane fairing.

The Ariane L6 Dual Launch: an Unqualified Success

R. Orye, Directorate of Space Transportation Systems, ESA, Paris

ESA's ECS-1 spacecraft and the Amsat P 3/b radio-amateur satellite were launched successfully by Ariane (L6) on 16 June at 11 h 59 m 00 s (H_0 : ignition of first-stage engines; lift-off at $H_0 + 3.8$ s). The launcher stages and its various systems performed perfectly.

The ECS-1 spacecraft was separated from the launcher at $H_0 + 954.4$ s and the Amsat spacecraft at $H_0 + 1072.4$ s. Separation conditions (attitude and spin rate) were as planned for ECS-1, though a perturbation, the origin of which has not yet been determined, occurred after the separation of Amsat.

Propulsion from the launcher's three stages was nominal; in particular no Pogo occurred during second-stage flight and the third-stage powered flight was very quiet. Stagings and fairing jettison also went smoothly.

The geosynchronous transfer orbit achieved was very close to the nominal orbit:

Perigee	198.7 km (for 200 km required)
Apogee	35 790 km (for 35 870 km required)
Inclination	8.605° (for 8.602° required)

The launch campaign

The L6 customer spacecraft, ECS-1 and Amsat, arrived in Cayenne (French Guiana) on 14 April, and their preparation for launch started on 15 April. Spacecraft integration and test activities in the S1 building were completed on 26 April for Amsat, and on 11 May for ECS-1.

Final preparation for launch of both spacecraft was carried out in the S3 building, where ECS-1 was fuelled with hydrazine and its apogee boost motor (Mage-2) fitted and where the Amsat propellants to be used with a Symphonie type engine were loaded. The spacecraft were then mounted on the Ariane dual-launch system (Sylva), with ECS-1 in the upper and Amsat in the lower position. The accompanying photographs show the final stages of integration.

The launch-vehicle campaign started on 19 April. After the countdown rehearsal on 2 June, the ECS-1/Amsat/Sylva composite was mated with the launcher on 7 June; the final launch countdown started on 15 June at 03.09 h local time (06 h.09 GMT).

The Sylva

The L6 flight allowed the first fully representative use of the Ariane dual-launch system Sylva (Système de Lancement Double Ariane). The system functioned as planned.

The Sylva is an important element of the Ariane operational phase, since it allows the simultaneous launching of two spacecraft of mass up to 1200 kg into geosynchronous transfer orbit. Spacecraft of this size will constitute a major share of the world satellite market in the years to come, and the Sylva therefore increases Ariane's competitive position in this important sector of the launch market.

Post-L5 activities

The successful L6 launch represents the

culmination of a very significant effort initiated immediately after the L5 failure, as reported in the progress pages of ESA Bulletin No. 34. A Failure Enquiry Board was set up by ESA and CNES to establish the possible causes of the L5 third-stage malfunction and to recommend remedial action. The malfunction was rapidly traced to the either a breakdown in the turbopump gearing between the LH2 shaft and the LOX shaft, or a malfunctioning of the turbopump lubrication system.

Measures have been taken to avoid the recurrence of this malfunction: for the gearing, by a tightening of the gear tolerances; and for the lubrication, by using a modified system on the Ariane third-stage engine. Considerable additional test time was accumulated with the turbopump (11 000 s) and with the third-stage engine (1 300 s) prior to the L6 launch to validate the modifications.

In parallel with this, all other launch elements were reviewed in depth to identify potential weak points. This exercise led to additional studies and tests, and to a strengthening of the test and acceptance procedures; it did not result in vehicle design changes.

The Ariane L7 launch

The next Ariane launch has been earmarked for Unit 7 of the Intelsat-V series, with lift-off scheduled for 15 September. The launch campaign starts on 8 July for the spacecraft, and on 4 August for the launcher.

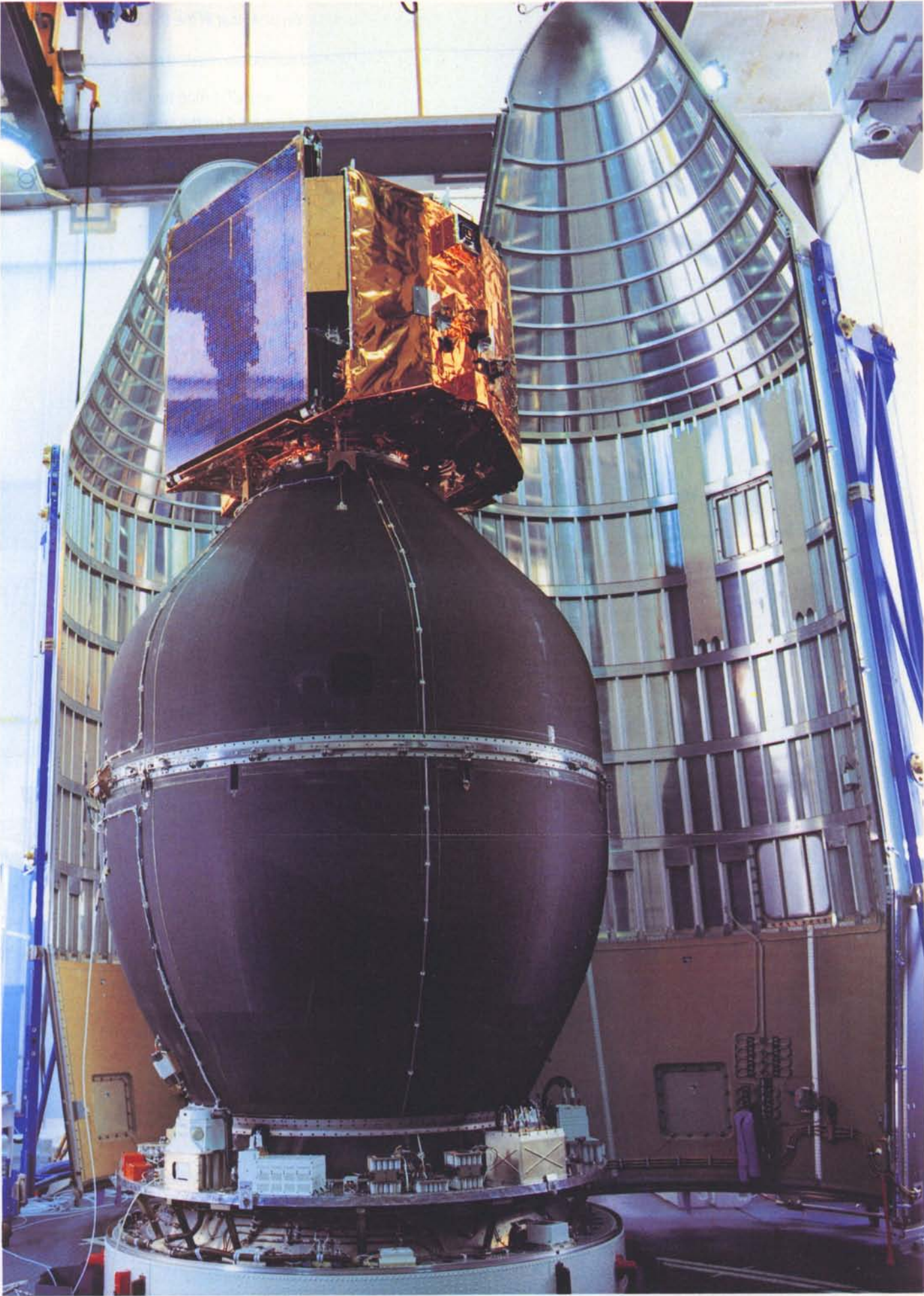




Figure 2 — Installation of Amsat in the Sylva

Figure 3 — Payload composite readied for transport to the launch tower

Figure 4 — Raising of payload up the launch tower

Figure 5 — Mating of payload and launcher third stage

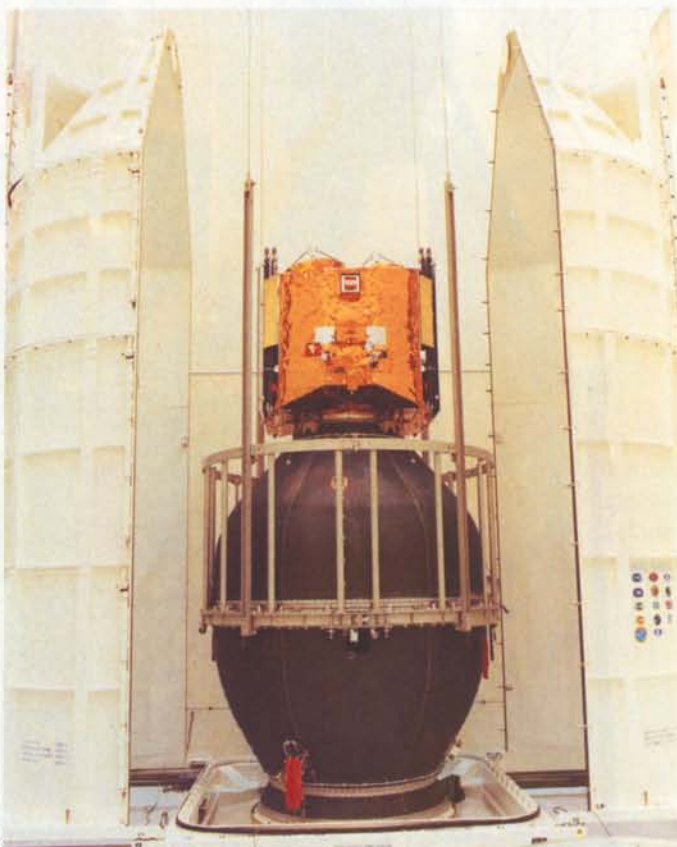
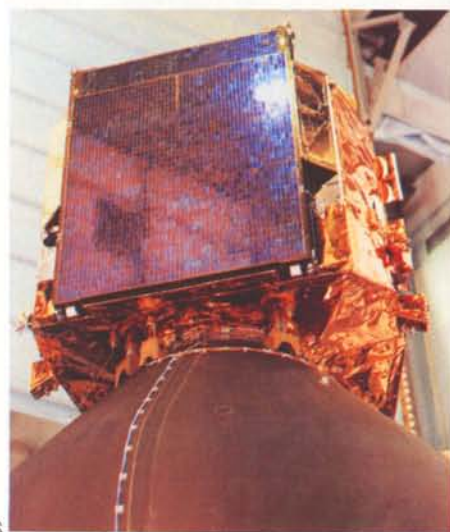


Figure 6 — ECS-1 on the Sylida

Figure 7 — Fairing closure

Figure 8 — Control Room at the Guiana Space Centre

Figure 9 — Lift-off



6



7



8



9

First European Communications Satellite ECS-1 on Station

The Agency's operational communications satellite ECS-1 was successfully launched from ESA's Kourou launch site by Ariane L6 on 16 June. All phases were as planned and the variations allowed for in computed flight paths, impulses, and pointing directions were all well within specification (see previous article by R. Orye).

ECS separation from the third stage was reported by Ascension Island tracking station, and Malindi ground station confirmed good PCM signal lock at 12.21 h. From this point onwards, the Operations Control Centre at ESOC, Darmstadt acquired full telemetry and command capability; the operations team at ESOC conducted all succeeding phases, with support as necessary from co-located ESTEC and contractor engineers.

Following separation, the spacecraft was spun up to 58 rpm; this stabilised pointing during transfer orbit, and permitted attitude-reorientation manoeuvres prior to apogee-motor firing (also in spinning mode) on the third orbit. The high precision of the launch trajectory meant that only slight trim manoeuvres were necessary during the transfer orbits leading up to apogee-motor firing (AMF).

As the timing of this impulse is critical, it is linked into an autonomous onboard timer trigger, which is initiated by ground command. The timer was set to ignite the apogee motor such that burn midpoint occurred at the apogee of the transfer orbit and AMF took place exactly as scheduled at 00.51.50 h on Saturday

18 June. The first indication of a correct AMF impulse was received from Kourou, which reported the expected 50 Hz Doppler shift in its received signal frequency. Later ranging signals and flight-dynamics computations confirmed a near-perfect impulse of 1516.23 m/s.

A series of configuration and attitude changes and orbit adjustments now took place with the objective of bringing the satellite on station with its antennas Earth pointing. The standard Flight Operations Plan time line was used to achieve the following sequence: between 02.21.50 h and 03.29.00 h the spin rate was reduced, first to 22.7 rpm (to calibrate thruster performance) and next to 9.7 rpm. The final despin and Sun acquisition took place between 06.30 h and 08.00 h resulting in the roll axes being aligned with the Sun and the arrays deployed.

To facilitate Earth acquisition at the next orthogonality of spacecraft-Sun and spacecraft-Earth geometry, a turnover manoeuvre was executed to place the -x axis Sun pointing. Roll rate was adjusted to +1.5 deg/s at the selected evening orthogonality and telemetry displayed the expected Earth crossings. Roll rate was reduced in two stages and the Earth acquired successfully at 20.09 h.

Spin-up of the two primary momentum wheels to 3600 rpm was followed by the sequence to erect the pitch axis parallel to the Earth's spin axis, which was completed by 22.16 h. The spacecraft was successfully configured for normal-mode operation shortly afterwards.

With ECS-1 then correctly oriented, the slow drift of about 2° per day from 30° W to the on-station position of 10° E began. The unexpectedly low usage of hydrazine fuel at this stage enabled a decision to be taken to speed up this drift phase slightly, to allow ECS-1 to reach its final position by 7 July.

Following a manoeuvre on 6 July designed to slow down the satellite's drift rate, ESOC carried out the final operation to position ECS-1 exactly on station at 11.58 h (GMT) on 7 July.

On 8 July, the new ECS control centre, set up at the ESA Tracking Station at Redu (Belgium) took over control of the satellite. Commissioning tests, started whilst ECS-1 was drifting in geosynchronous orbit, indicate that the spacecraft's subsystems are functioning correctly.

On 10 July, the communications payload was switched on for the first time. The 12 repeaters were checked one by one and found to work satisfactorily. During the coming weeks, the payload will undergo a series of acceptance tests, carried out jointly by ESA, Interim EUTELSAT, and the MESH consortium which developed the spacecraft. The outcome of these tests and the latest status of the satellite will be reported in the next ESA Bulletin (No. 36).

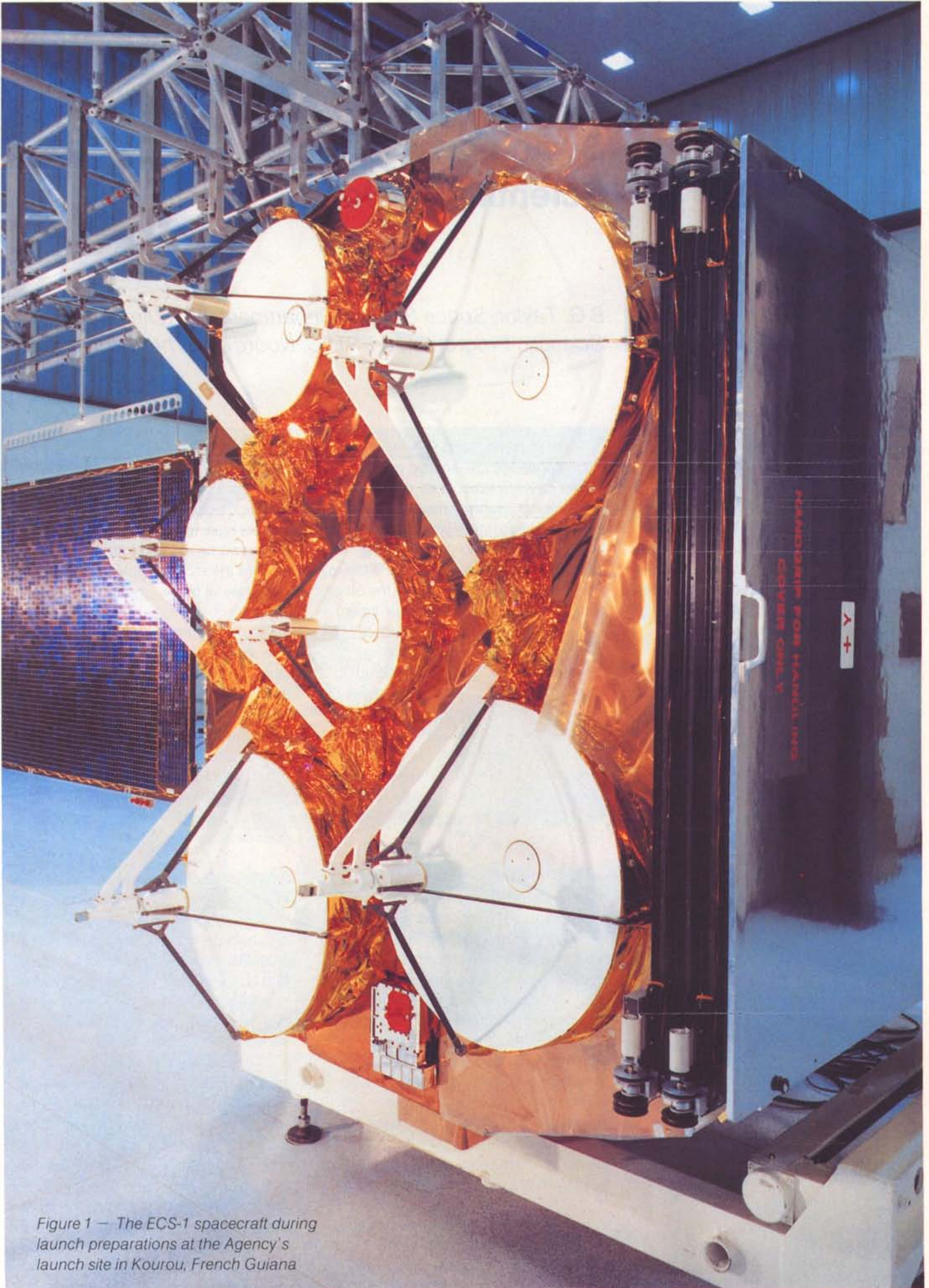


Figure 1 — The ECS-1 spacecraft during launch preparations at the Agency's launch site in Kourou, French Guiana



Switch-on of Exosat's Scientific Payload

B.G. Taylor, Space Science Department, ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

Switch-on and early operation of the Exosat payload has demonstrated that, with the exception of one detector, technical performance is as expected from ground test and calibration. The non-X-ray background in the detectors is, however, much lower than predicted before launch, so that Exosat will have a higher sensitivity to cosmic X-ray sources than anticipated.

Exosat's scientific payload consists of four instruments: two low-energy, grazing-incidence X-ray telescopes, a large-area proportional counter array (in Exosat called the 'medium-energy experiment'), and a gas-scintillation proportional counter. The telescopes cover the energy range from 0.04 to 2 keV, while the other two instruments cover the range from 1.5 to 50 keV. A total of 21 independently controllable detectors make up the instruments. The instruments, including detectors, electronics units, gas-supply systems (not forgetting 13 mechanisms), etc. are integrated onto the spacecraft as 19 separate boxes (Figs. 1&2). A detailed description of these scientific instruments and the Exosat mission can be found on page 20 of ESA Bulletin No. 31 (August 1982).

In the period between launch and 4 June, the low-voltage sections of the instruments were activated, the position-sensitive proportional counters of the telescopes pressurised, and the six clamped mechanisms released by firing the associated pyrotechnic devices. When it was confirmed, through the 'in-flight test' sequences, that the payload was functioning correctly, the sequence of switching-on the high-voltage sections was begun, starting with the gas scintillator on 5 June, and working one by one through the medium-energy experiment detectors, and ending with the telescope detectors on 11 June.

A major surprise, and a very pleasant one, from the initial switch-on was that the 'background' in the detectors of the medium-energy experiment and gas

scintillator was a factor 3 to 10 lower than pre-launch predictions. This lower background, caused mainly by cosmic radiation against which the X-rays of interest have to be observed, means that Exosat will be markedly more sensitive and will therefore be able to 'see' further and observe fainter objects.

A less pleasant surprise was that, after operating correctly for a short period, one detector in one of the telescopes started to behave anomalously and after a few further checks has remained switch-off. Extensive analysis has been undertaken and possibly some investigative work on spare detectors on the ground will be instigated. Meanwhile that telescope is being operated with the microchannel plate detector only.

Switch-on of all experiments in parallel was delayed on 15 July when it was recognised that a solar flare, producing high background counting rates, was in progress. It was decided to wait until the flare had subsided, in case any possible anomalous behaviour of the detectors would be masked by the high background.

From 18 June when final switch-on was accomplished, a series of in-orbit calibration and performance-verification observations was started. The first observation, that of Cygnus X-1, the most famous black-hole candidate (Fig. 3), demonstrated that the angular resolution performance of the telescopes on a point-like source was in accordance with measurements performed in X-ray beam tests on the ground, namely about

Figure 1 — Integration of the two X-ray imaging telescopes in the clean room at the launch range. The two tube-like structures contain the X-ray optics (left) and the focal-plane detector assemblies (right)



Figure 2 — 'Front' view of Exosat showing the circular entrance apertures to the telescopes (left), the four quadrants of the medium-energy instrument (centre) and the gas-scintillator location (upper right). The apertures of the medium-energy and gas-scintillator instruments are covered with ultra-thin, aluminised-mylar thermal-control foils.

15 arcsec for the microchannel plate detectors and 1 arcmin or so for the position-sensitive proportional counter. The performance of the telescopes in observing an extended object, the supernova remnant CAS-A, was also demonstrated (see back cover of this issue).

The spectrum of CAS-A obtained by the gas scintillator is shown in Figure 4.

An example of measurements obtained by one of the medium-energy experiment detectors on the pulsar 4 U 1145-61 is shown in Figure 5.

By the end of July, the performance of all instruments will have been fully assessed with observations, inter alia, of binary systems, pulsars, white dwarfs and supernovae in our galaxy, nearby galaxies like the Andromeda nebula and the more distant clusters of galaxies like Virgo and Coma. All these objects have been studied to a greater or lesser degree by earlier missions in X-ray astronomy and so may be regarded as 'standard candles'.

It is expected that Exosat will be ready to commence its investigative observation programme at the beginning of August. Facilities at the Operations Centre at ESOC will enable the satellite to be used as an observatory, just like, for example, a ground-based optical telescope, though in this case the telescope will be in its highly eccentric orbit going out 190 000 km into interplanetary space. Furthermore, operations are conducted round the clock for the 80 h of the 91 h orbital period when Exosat is outside the radiation belts. Its instruments will study the X-ray emission from all types of objects in the cosmos, ranging from stars near to the Sun to the colossally powerful quasars out to the edge of the observable universe.

It is certainly too early to comment on the success of the mission which will probably last for up to four years but, the low-

Figure 3 — The image of the black-hole candidate Cygnus X-1 as detected by the channel-multiplier array of telescope number 2 and displayed on the colour-graphics facility at the Observatory

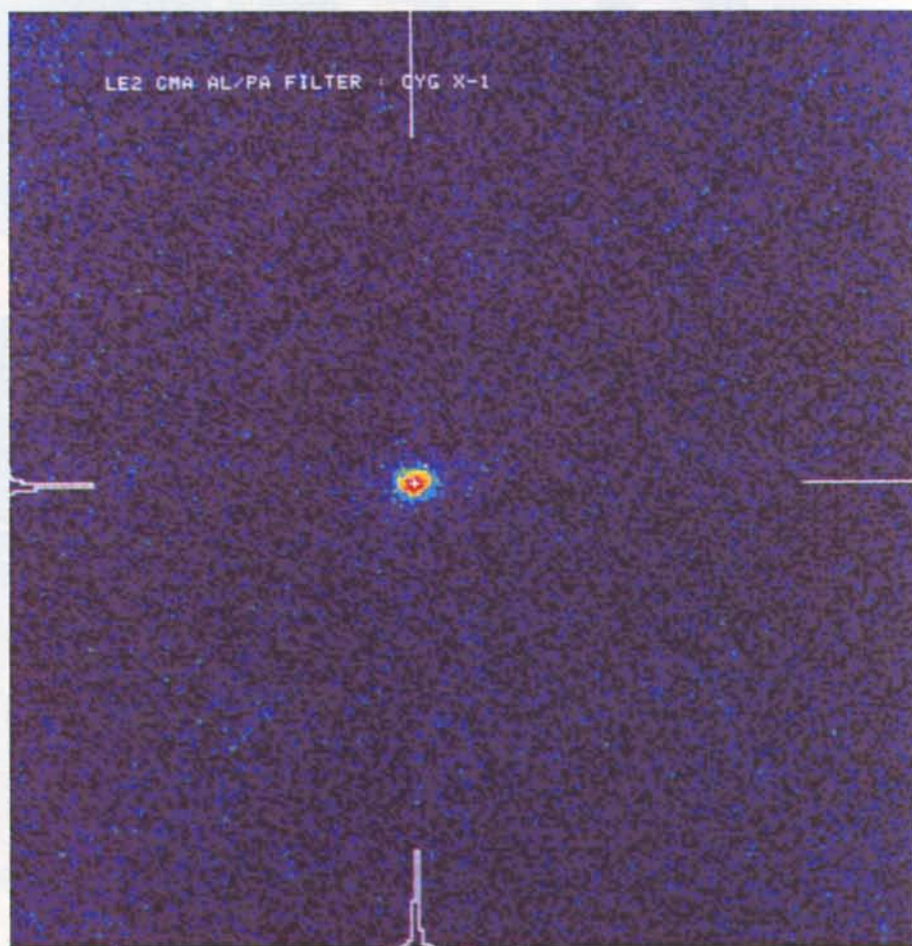
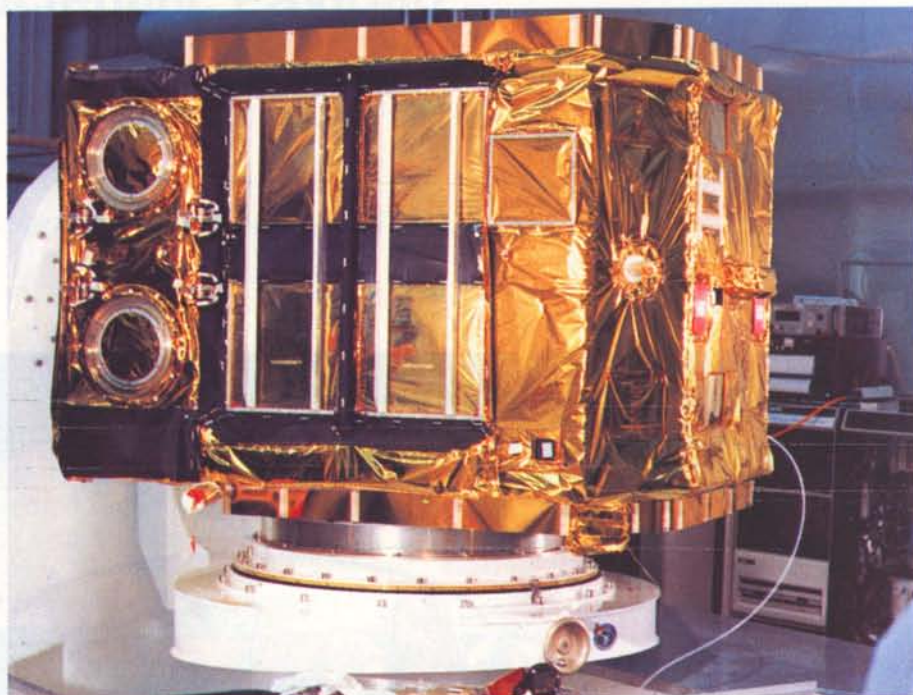


Figure 4 — The X-ray spectrum of the supernova remnant CAS-A, as detected by the gas-scintillator experiment, exhibiting the strong emission line attributed to highly ionised iron around channel 90 and a complex of line-like features around channels 40-60

Figure 5a — The counting rate of the medium-energy experiment observing 4 U 1145-61 for a period of about 7 h, indicating extended low-level periods punctuated by flaring phenomena

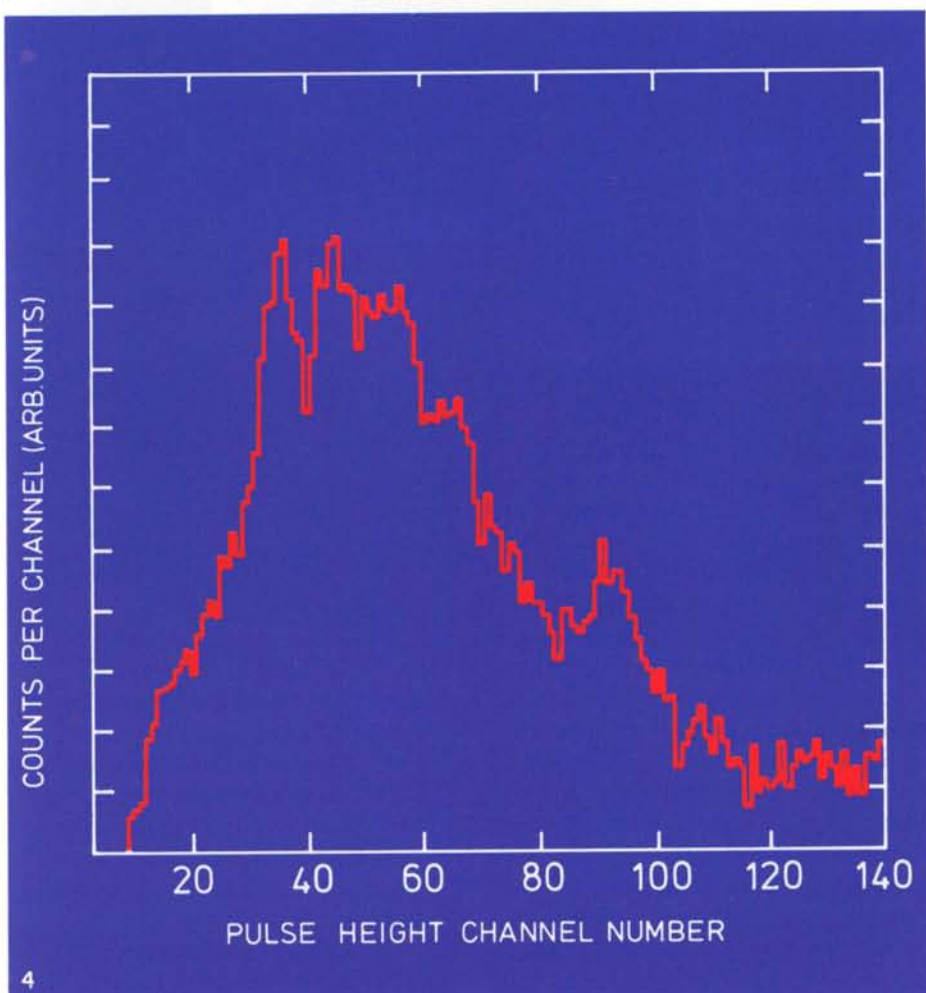
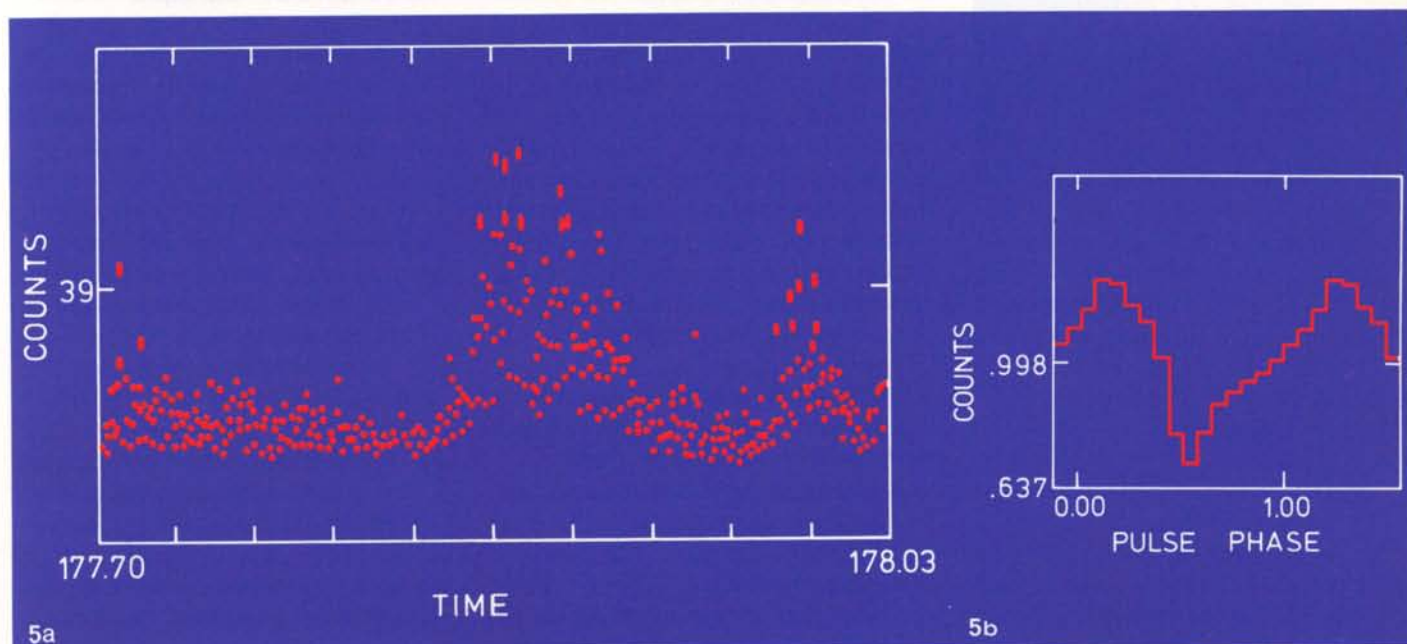


Figure 5b — Analysis of the counting rate indicating the pulsar nature of the source (pulsar period about 290 s)

energy detector problem apart, so far so good. It would thus be fitting to mention, and thank, those who have done so much towards bringing the Exosat payload this far, including the research groups at Leicester and Garching/Tübingen (medium-energy experiment); Leiden, Utrecht and MSSL, London (low-energy telescopes); and SSD, Milan/Palermo and MSSL (gas scintillator); the instrument contractors CIT Alcatel, Jobin Yvon and Fichou for the optics; Matra, Sira, Snias and Laben for the focal-plane assemblies; BAe, LND and GEOC for the medium-energy detectors; Laben and Matra again for the experiment electronics assemblies; and Laben, AEG and Electrofusion Corp. for the gas scintillator; the Exosat payload team within the High-Energy Astrophysics Division of SSD, and the Observatory Team formerly also located therein and now located at ESOC in Darmstadt.





The Exosat Launch Operations

G. Altmann, G. Scoon & C.B. von Stieglitz, Exosat Project Division, ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

The European X-ray Observatory Satellite, Exosat, was successfully launched on a Delta-3914 vehicle from Western Test Range (Vandenberg) California, at 15.18 h GMT on 26 May. The launch and early orbit events took place exactly as scheduled, and the satellite's signal was acquired at the ESA Ground Station in Villafranca (Spain), 1 h 10 minutes after lift-off. The signal was immediately rerouted to the Agency's Space Operations Centre (ESOC) in Darmstadt (Germany), which then assumed control of the satellite.

It was originally planned to launch Exosat on Ariane L6, but the L6 launch-schedule delay incurred as a result of the L5 mishap prompted the ESA Council to decide to switch it to a Delta launch. The main reasons for this choice were their desire to redress the Ariane launch schedule for subsequent customers, and to avoid the risk of deterioration in certain Exosat payload elements that would have been incurred if the spacecraft had had to remain in storage for a longer period.

The Exosat Flight Model (FM) qualification/acceptance phase had been completed by the end of September 1982 and the satellite stored pending the conclusions of the Flight-Readiness Review Board and the availability of the launch vehicle.

The Flight-Readiness Review (FRR) Part-1 was successfully concluded on 19 October 1982, and the Board confirmed the satisfactory qualification/acceptance status of the FM and its flight readiness, but recommended that certain subsidiary investigations be performed during the proposed storage/reactivation periods in order to close-out satisfactorily any remaining nonconformances or anomalies.

The decision to change launch vehicle was preceded by exploratory studies on the feasibility of this change. These studies were carried out in January/February 1983, and a consequence of the final decision to change to a Delta for a launch on 26 May was that Exosat's conversion for the new launch vehicle and launch range had to be performed

within the extremely short span of eight weeks.

Conversion phase

The most significant aspects of the conversion were related to:

- Launch-operations documentation, especially the conversion, submission, review and approval of:
 - Safety Documents (Missile System Ground Safety Approval Package)
 - Launch Operations Manual
 - Hazardous-Operations Manual
 - Gantry Operations Manual (including countdown)
 - Satellite operations procedures (where relevant)
 - Support Instrumentation Requirements Document.
- Verification of interface compatibility, which was performed by a combination of analyses, inspections and tests. Particular attention was paid to the access to the satellite under fairing, i.e. location of access doors, the fairing environment, including the nitrogen (N_2) flushing umbilical for experiment flushing, and mechanical/electrical compatibility with the launch vehicle. A satellite/launcher payload-attach-fitting fit check was performed at ESTEC in February, while verifications of other launch-range interfaces were being performed in parallel at Western Test Range (WTR). Exosat-specific modifications to the launcher's third stage were also performed during this conversion period.



Photo: USAF/NASA

- Structural coupled analysis of major load cases confirmed adequacy of structure design and FM environmental tests.

Extraordinary efforts were made by the ESA/MBB Exosat Combined Operations team, our NASA/McDonnell Douglas counterparts, and the ESTEC Support Divisions to complete the conversion and prelaunch preparation. As a result, these milestones were completed on schedule prior to Easter. At a Coordination Meeting at WTR on 7–11 March, the main operations documents were reviewed and approved, and final interface details were settled.

The Flight-Readiness Review Part-2 was conducted on 22 March, the satellite was declared to be ready for flight, and the Board authorised the shipment of the FM and associated Ground Support Equipment (GSE) to WTR for the start of launch operations on 6 April.

Launch-operations phase

The majority of the Exosat GSE and operations' documentation had been shipped to Amsterdam's Schiphol airport before Easter awaiting embarkation, the FM remaining in its container at ESTEC

until the transport day, for safety and environmental reasons. On 5 April the FM and GSE were embarked, accompanied by three team couriers, on to a Flying Tigers Boeing-747 cargo aircraft for a direct flight to Vandenberg Air Force Base, touching down at 1010 h PST on 6 April. The flight was uneventful and by midnight on the same day the cargo had been completely discharged and the flight satellite and equipment transported to the Spacecraft Preparations Building (Bldg-836) and stored.

The preparatory activities for the campaign and the setting up of satellite and ground-support equipment were performed by reduced elements of the combined operations team, who were available at the launch range from 6 April. This reduced team proceeded with the parallel activities of unpacking, setting up, and commissioning the GSE and the initial inspection of flight hardware after transport.

The installation and commissioning of both the single Overall Checkout Equipment (OCOE) station and the Special Checkout Equipment (SCOE) was completed within seven working days of arrival, in readiness for satellite system

Figure 1 — Unloading of Boeing-747 at Vandenberg, California

Figure 2 — Preparation for integration of second Low-Energy Imaging Telescope (LEIT) clean bench

Figure 3 — Integration of second LEIT

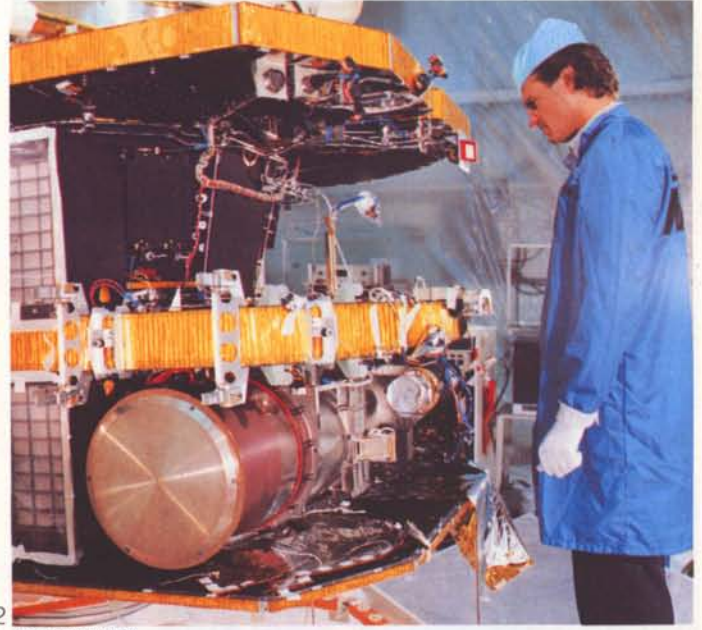


Photo: USAF/NASA



Photo: USAF/NASA

operations. This activity was performed in parallel with satellite mainstream preparatory activities, consisting mainly of:

- internal/external visual inspection of the FM
- preparations for leak measurements
- FM leak measurements

and experiment preparatory activities related to preparation for system integration of the two Low-Energy Imaging Telescopes (LEITs). These had been transported in separate containers for reasons of environmental protection



Photo: USAF/NASA

Figure 4 — Inspection of solar-array orientation mechanism pyrotechnics installation

Figure 5 — Installation of Low-Energy Experiment (LE) flap assembly

Figure 6 — Integration of solar array and its mechanism



Photo: USAF/NASA

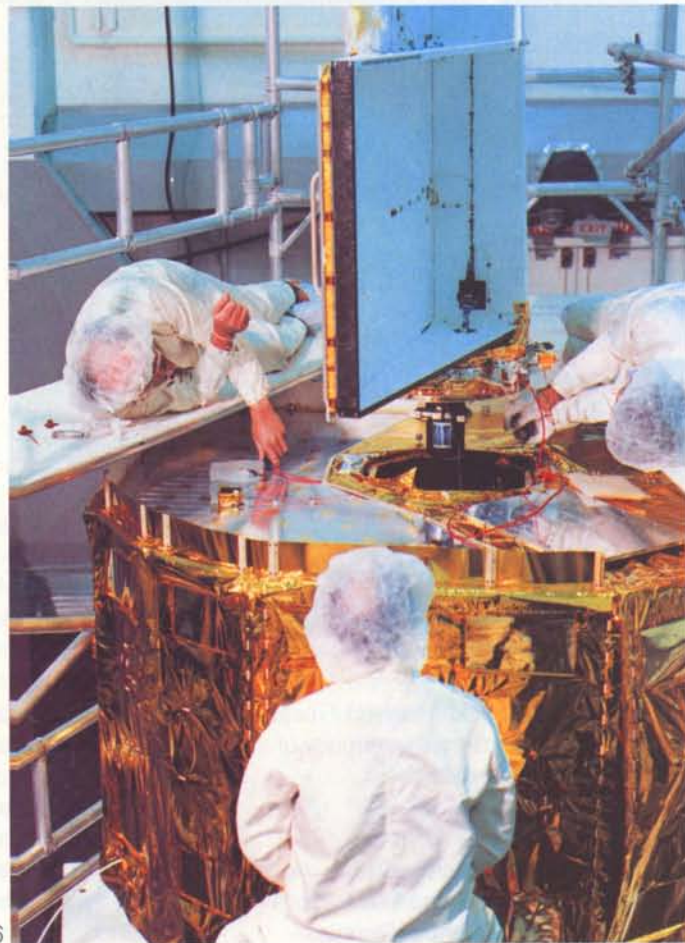


Photo: USAF/NASA

and to facilitate a detailed visual inspection of telescope elements such as detectors, filter wheel and grating, after transport and prior to system integration. After integration of the two LEITs, the satellite was complete except for its solar array, solar-array orientation mechanism, flight batteries and a major part of its multilayer superinsulation. Exchange at the launch range of the radioactive source stimuli of the Medium-Energy Experiment (ME) and Gas-Scintillator Proportional Counter (GSPC) Experiment for scientific reasons, subsequently provoked some anomalies. Detailed investigations later resulted in the reinstallation and realignment of the original stimuli and exchange of the FM GSPC for the flight spare.

Satellite preparations continued on schedule, following the planned sequence. Integrated System Testing (IST),

including supplementary tests (i.e. performance measurements for all subsystems and experiments) and alignment measurements, were performed on a double-shift basis for the functional testing and a night shift for the alignment activities, i.e. 24 h per day working including weekends. The morale and determination of the combined operations team remained high despite the long hours.

An Integrated Test Review Board (ITRB), convened to review the acceptability of the results achieved and satellite status in terms of system performance and integrity concluded that:

- the satellite's functional performance was within specification and comparable to results achieved during FM qualification acceptance and review by the FRR panels and Board

- the leak rate of the Reaction Control Subsystem (AOCS) was well within specification, with adequate margins on both hydrazine and propane elements
- the alignment results were satisfactory and comparable to previous data.

Voice and data links had been established to ESA's Space Operations Centre (ESOC) in Darmstadt early in this phase, so that satellite data could be assessed in parallel at ESOC and WTR.

During the countdown rehearsal, an earthquake occurred at 1643 h PDT on 2 May. Although it partially devastated the town of Coalinga to the northeast, it had no apparent adverse effects on either Exosat or personnel, except a transient sensation of mild disorientation on the part of the latter!

Figure 7 — Hazardous operations, propellant loading

Figure 8 — Final preparations prior to Exosat's transfer to the Dynamic Balance Facility (DBF)



Photo: USAF/NASA

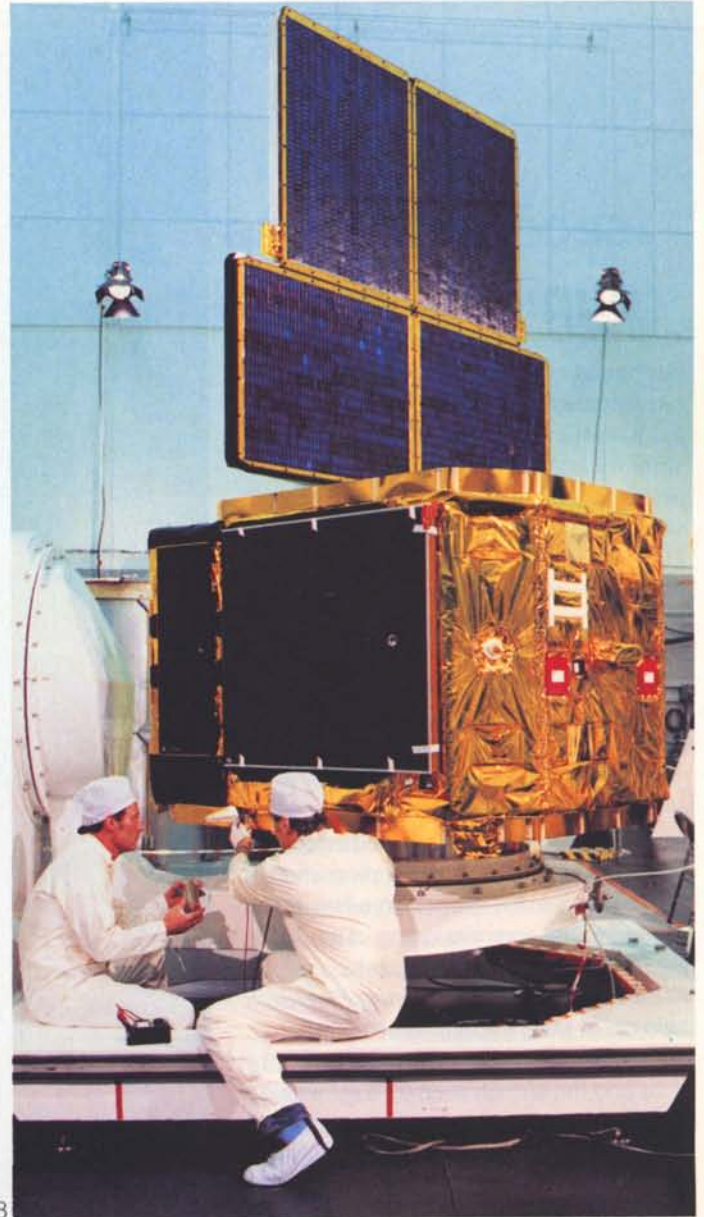


Photo: USAF/NASA

The satellite mechanical/thermal activities prior to transport and progressive internal/external visual inspection were completed by 2400 h on 4 May, and we were thus able to achieve successfully the launch Operations Phase-1 milestone 'Transport to NASA Dynamic Balance Facility' (DBF), ready for the start of Phase-2 'Hazardous Operations' on 5 May.

Hazardous operations

The preparation and validation of both hydrazine and propane propellant loading carts proceeded smoothly and on schedule in the Dynamic Balance Facility (DBF), Bldg 1610. By 10 May Exosat's propane-fuelled Reaction-Control Equipment (RCE) had been filled with 14 kg of propane and the hydrazine RCE with 45 kg of hydrazine.

Other completion activities performed in the DBF prior to propellant loading were:

- installation of the solar array and its orientation mechanism
- checks on attitude and orbit control systems and solar-array optical sensors
- experiment LEITs gas filling and pressurisation
- LEIT leak-rate measurements
- monitoring of the Medium-Energy experiment.

The satellite was then weighed prior to mating with the Delta third stage and the composite installed in an environmentally controlled cannister, ready for its transportation to the launch tower.

Phase-2 was completed and Phase-3 of launch operations initiated when the Delta third-stage composite was

transported to the launch pad. Assembly of the Delta first and second stages and nine solid-fuel boosters had progressed on schedule, in parallel with the above satellite preparations.

Owing to weather conditions on 16 May, with winds in excess of 15 knots, the specified limit for this hoisting operation, the handling can and composite could not be hoisted to the appropriate gantry level. It was returned to the DBF for an approximately 9 h standby period. The hoisting activity was resumed later that same day and the mating operation successfully completed.

Gantry operations and countdown

The gantry operations continued on schedule and no major delays were experienced during the remainder of this phase.

Figure 9 — Lift-off of Delta vehicle 169

An integrated-satellite checkout performed after mating confirmed the functional integrity of the satellite and the launch vehicle. Flight-verification and stray-voltage checks with the satellite active confirmed the electromagnetic compatibility of the composite.

Final hydrazine RCE pressurisation was performed prior to final satellite completion, at which time certain protective covers and other nonflight items were removed prior to fairing installation.

After fairing installation, a second countdown rehearsal was conducted, the prime objectives being verification and optimisation of the launch time-line, and secondly final commissioning of the NASA/GSFC and ESA networks. At the NASA Launch Readiness Review, held on 20 May, the satisfactory completion of all analyses, the final flight data and the launch preparations was assessed and the go ahead given to proceed to launch.

The launch

Trade-off decisions relating to Exosat's orbital parameters, scientific performances and observational lifetime, resulted in the very exacting requirement to launch Exosat during the final minute of the launch window on 26 May. This reduction in the length of the launch window from the original 12 min to 1 min was agreed upon with the intention of extending Exosat's orbital lifetime from the original two-year design lifetime, to almost three years.

Initial difficulties associated with this extremely compressed launch schedule were successfully overcome during the launch campaign, and on a foggy Southern California morning, on 26 May, Exosat was launched at 0818 h PDT (1518 h GMT), after a flawless countdown during which no technical problems or unplanned holds were encountered.

The real-time data routed back to ESOC



Photo: USAF/NASA

some 70 min after lift-off confirmed that Exosat had executed autonomous Sun-acquisition, antenna deployment, and transmitter switch-on.

At a joint revue meeting held at ESOC on 8/9 June, the Mission and Flight-Operations Directors reviewed the status of the mission and concluded that the

Launch and Early Orbit Phase (LEOP) had been satisfactorily completed. Spacecraft operations are now being routinely implemented by the ESOC Operations Department, with the Observatory Team controlling the scientific operations (see preceding article by Dr. B.G. Taylor).



L'apport du programme Météosat opérationnel sur le plan juridique

G. Lafferranderie, Conseiller juridique, ESA, Paris

Lors de sa 2e session tenue à Paris les 21-23 mars 1983, la Conférence intergouvernementale sur un système Météosat opérationnel* a adopté une Résolution par laquelle elle recommandait que l'exécution du programme opérationnel Météosat soit assurée par l'Agence spatiale européenne. Elle a également invité les Gouvernements à prendre les mesures en vue de devenir parties à la Convention Eumetsat telle qu'établie au cours de cette 2e session. De manière à permettre l'adoption de mesures nécessaires au démarrage réel du programme dès le mois de juin, des arrangements intérimaires ont trouvé leur place par le biais des dispositions de la Convention de l'ESA.**

* Y étaient représentés les onze Gouvernements membres de l'Agence plus le Portugal, la Finlande, la Norvège, l'Autriche, la Turquie, la Grèce (Irlande, Autriche, Turquie et Grèce à titre d'observateurs). La Yougoslavie et le Luxembourg, invités, n'ont pu se faire représenter. La Conférence était présidée par Sir John Mason (R-U).

** Convoquée à l'initiative du Gouvernement suisse, la Conférence des Plénipotentiaires pour l'établissement d'un système opérationnel de satellites météorologiques ('Eumetsat') s'est tenue à Genève le 24 mai 1983 sous la présidence de Sir John Mason. Seize pays étaient représentés, treize par des délégués (Allemagne, Belgique, Danemark, Espagne, France, Italie, Norvège, Pays-Bas, Portugal, Royaume-Uni, Suède, Suisse, Turquie), trois par des observateurs (Irlande, Finlande, Grèce). Douze pays ont signé la Convention Eumetsat (sous réserve de ratification): Allemagne, Belgique, Espagne, France, Italie, Norvège, Pays-Bas, Portugal, Royaume-Uni, Suède, Suisse, Turquie et ont accepté la Déclaration relative à la phase intérimaire. Le montant des contributions ainsi souscrites atteint 85,03% de l'enveloppe financière. La participation ultérieure d'autres pays (Finlande, Irlande, Grèce) est attendue.

Que de chemin parcouru depuis cette autre Résolution, celle du Conseil du CERS du 12 juillet 1972 (ESRO/C/XLVII/Res. 1), qui approuve le texte final de l'Arrangement entre certains Etats membres du CERS et le CERS relatif au programme préopérationnel Météosat et qui 'note que plusieurs délégations ont insisté sur le fait que des arrangements appropriés restent à prendre, pour couvrir tant l'exploitation de l'installation centrale que la phase opérationnelle du programme;' et qui 'décide qu'une décision doit être prise rapidement quant à l'organisme qui sera chargé d'entreprendre la phase opérationnelle et note qu'une des possibilités pourrait être de confier cette tâche au CERS.'

La boucle est-elle bouclée? Les décisions qui viennent d'être prises sont au-delà d'une simple réponse positive. Il était en effet cohérent qu'à l'époque de cette première mutation du CERS (1971-1972), qui a vu l'émergence des satellites d'application et une réponse partielle donnée, les Etats membres qui s'engageaient dans la voie d'investissements importants au niveau de programmes de développement s'inquiètent aussi de leur exploitation ultérieure et en général des structures juridiques et industrielles appropriées à mettre en place pour l'exploitation de satellites opérationnels d'application. Le temps qui s'est écoulé démontre que la ou les réponses n'étaient pas aisées, mais ce temps n'a pas été perdu et des efforts continus, intensifs, se sont manifestés en diverses directions. Le Secrétariat du CERS puis de l'ESA, ainsi que les délégations, se sont attachés à cette réflexion.

On n'oubliera pas de mentionner que le programme préopérationnel Météosat n'était pas le seul concerné par cette réflexion; on citera le programme Aérosat, pour l'exploitation duquel une structure associant les utilisateurs et l'Agence était déjà mise en place. On citera aussi le programme de satellites de télécommunications dont une première phase portait sur le satellite 'expérimental' OTS, mais qui instituait déjà une phase opérationnelle consistant dans le satellite ECS. Les administrations des Postes et Télécommunications disposant d'une certaine structuration ont alors oeuvré en vue d'établir le cadre juridique nécessaire: ce fut d'abord la constitution d'Eutelsat intérimaire puis la signature de la Convention portant création d'une Organisation internationale dotée de la personnalité juridique, Eutelsat*. Il faut aussi citer le programme de satellites de communications maritimes, Marots devenu Marecs, la création d'Inmarsat au niveau mondial et les arrangements contractuels pris entre Inmarsat et l'Agence.

La mutation du CERS, évoquée plus haut, s'est concrétisée comme on le sait dans la Convention portant création de l'Agence du 30 mai 1975 qui formellement intègre dans les activités et programmes de l'Agence le développement de satellites d'applications préopérationnels conformément à son article V.1.b. (programmes facultatifs), mais aussi permet à l'Agence de répondre aux

* Ouverte à la signature à Paris le 15 juillet 1982, cette Convention n'est pas à ce jour entrée en vigueur.

besoins d'organismes d'exploitation, c'est-à-dire de traiter pour le compte de ces derniers de tâches relatives à des satellites d'applications opérationnels (article V.2 de la Convention et Résolution no. 5 attachée à l'Acte final de la Conférence des Plénipotentiaires pour la signature de la Convention de l'Agence – voir aussi la Résolution du Conseil au niveau des Ministres de février 1977: 'L'Agence et les systèmes opérationnels').

Quoique la question posée dans cette Résolution du 12 juillet 1972 dépassait en fait le seul cadre du programme Météosat opérationnel, ses caractères spécifiques: contribution à un programme mondial d'observation météorologique – la Veille Météorologique Mondiale (VMM) –, tradition météorologique d'un accès libre et gratuit, une clientèle non identifiée, caractère d'un service public, influençaient la recherche d'une solution.

1ère partie – L'HERITAGE

L'Arrangement Météosat de 1972* avait pour seul objectif la conception, le développement, la mise en orbite et le contrôle d'un satellite météorologique géostationnaire, y compris les installations sol associées, pour satisfaire les besoins de la communauté météorologique européenne. Il s'arrêta après une période de six mois après la mise en orbite pour permettre la vérification du bon fonctionnement de l'ensemble du système. Le premier Météosat fut lancé en novembre 1977.

Phase d'exploitation de Météosat

Sans attendre l'expiration de la période couverte par l'Arrangement Météosat, la Conférence des Directeurs des Services Météorologiques des Etats parties à l'Arrangement proposait que soient prises les dispositions nécessaires pour couvrir

la phase d'exploitation de Météosat de manière à ne pas provoquer d'interruption dans sa gestion et son contrôle. Le Conseil du CERS acceptait cette demande le 14 mars 1975 et donnait mandat à l'Agence de se charger de l'exploitation de Météosat pour une période de deux ans et demi (c'est-à-dire trois ans à partir de la mise en orbite). Les Gouvernements parties à l'Arrangement Météosat furent amenés à franchir un premier pas en mettant au point un 'Protocole portant sur l'exploitation d'un satellite préopérationnel météorologique' le 17 décembre 1975. Ouvert à signature du 1.1 au 30.9.1976, le Protocole, signé par l'ensemble des Participants à l'Arrangement Météosat, à l'exception de la Suède, est entré en vigueur le 29 avril 1977. L'objectif de la prise en charge de la gestion du *système opérationnel* par un organisme représentatif des autorités météorologiques européennes demeurait et se trouve d'ailleurs inscrit dans le préambule de ce Protocole. L'association de ces autorités météorologiques à la gestion du système préopérationnel se fait de plus en plus évidente: l'Agence exploite le système Météosat 'en accord étroit avec les autorités météorologiques'. Les Gouvernements parties au Protocole sont invités à veiller à ce que la composition de leur délégation au Conseil directeur du programme reflète le caractère météorologique de la phase d'exploitation. L'Agence veille aussi à ce que les services météorologiques de ces Gouvernements aient une représentation appropriée dans les réunions internationales de coordination entre systèmes de satellites météorologiques.

Ce Protocole de 1975 a dû faire l'objet d'amendements pour refléter d'une part le fait qu'un deuxième satellite Météosat préopérationnel avait été mis sur orbite en juin 1981 sur le vol Ariane L03 (la candidature de F2 sur le vol Ariane L02 avait été acceptée en 1977 par le Conseil) et d'autre part l'acceptation par le Conseil de l'Agence de prolonger le mandat de l'Agence pour une nouvelle période de trois ans, 'étant entendu que l'exploitation

de Météosat sera transférée à l'entité représentant les services météorologiques dès sa constitution'.

Le Protocole relatif à l'exploitation du système Météosat (deux unités de vol) venait à expiration le 23 novembre 1983. Par ailleurs, une deuxième unité de vol Météosat avait été mise sur orbite. Les satellites Météosat avaient démontré tous les bénéfices qu'ils peuvent apporter à la météorologie et à ses applications. Il devenait impératif d'étudier les mesures pour la mise en place d'un système opérationnel prenant leur relais et pour établir une entité représentative des services météorologiques chargée de l'exploitation de ce système.

Des initiatives sérieuses étaient prises à la mi-1978 par les Directeurs des services météorologiques des Etats participant au programme Météosat. Ils s'organisaient pour préparer la création d'une entité météorologique européenne. Cette Conférence des Directeurs des services météorologiques constituait en octobre 1978 deux groupes de travail, l'un pour définir le cadre juridique d'Eumetsat, l'autre pour définir les relations avec l'Agence. Le Groupe de travail juridique préparait un projet de Convention Eumetsat, largement inspiré des dispositions de la Convention du Centre européen.

Les Directeurs des services météorologiques s'adressaient à l'Agence pour obtenir une proposition technique et financière ainsi que pour étudier le type de relations fonctionnelles qui pourraient être établies. L'Exécutif étudiait un projet d'Accord-cadre entre l'Agence et une réunion des services météorologiques intéressés ('Eumetsat intérimaire'). Une évaluation financière préliminaire, provisoire, leur était fournie au début 1980. Le Conseil de l'Agence était saisi au printemps 1980 d'une demande visant à l'exécution par l'Agence de la prestation qui lui serait demandée par Eumetsat intérimaire, au titre de l'article V.2 de la Convention de l'Agence. Lors de sa

* Signé par l'Allemagne, la Belgique, le Danemark, la France, l'Italie, le Royaume-Uni, la Suède et la Suisse, l'Arrangement est entré en vigueur le 29 septembre 1972 et amendé le 29 mars 1973 puis le 11 mars 1977.

42ème session (26 juin 1980), il autorisait l'Agence à offrir ses bons offices pour l'organisation d'une Conférence intergouvernementale. Finalement tous ces efforts convergeaient vers la convocation d'une Conférence intergouvernementale sur un système Météosat opérationnel.

La Conférence intergouvernementale de 1981

La Conférence intergouvernementale se réunissait à Paris au siège de l'Agence les 28-29 janvier 1981. Elle examinait en particulier l'offre technique et financière de l'Agence. Elle recommandait l'étude d'un programme plus modeste que les cinq satellites proposés et contenant seulement trois satellites mais avec une durée de vie plus longue.

En ce qui concerne le cadre institutionnel, la Conférence entendait un rapport sur les solutions étudiées: recommandation de créer une Organisation, aussi légère que possible, s'appuyant sur le CEPMMT, 'la solution d'un accueil par l'OMM ou par l'Agence spatiale européenne a été en principe écartée'.

Un consensus s'établissait sur la création d'un organisme qui devrait être doté de la personnalité juridique, 'même s'il devait être plus ou moins incorporé à un organisme existant'. La Conférence établissait un 'Groupe de travail Météosat opérationnel', sous la présidence de M. Mittner (France).

Le Groupe de travail sur le programme Météosat opérationnel recevait le mandat de:

- (a) préparer les grandes lignes des spécifications techniques du système, compte tenu des impératifs et des ressources des participants éventuels,
- (b) établir quel serait le cadre institutionnel le plus acceptable pour un système Météosat opérationnel et préparer un projet

- d'Accord portant création d'une telle institution,
- (c) proposer la convocation d'une Conférence de Plénipotentiaires en vue de l'approbation de l'Accord,
- (d) étudier l'opportunité de prendre certains arrangements intérimaires dans le cas où la Conférence des Plénipotentiaires subirait un retard excessif,
- (e) créer les sous-groupes éventuellement nécessaires, ...

Le Groupe de travail s'attela aussitôt à cette lourde tâche et créa à cet effet deux sous-groupes: un sous-groupe technique [présidé d'abord par M. K. Stewart (Royaume-Uni) puis par M. J. Morgan] et un sous-groupe institutionnel (présidé par M. Alt, France).

Le Groupe de travail a tenu au total neuf réunions; chacun des sous-groupes s'est également réuni à plusieurs reprises. Des membres de l'Exécutif de l'Agence qui assuraient le secrétariat étaient invités à suivre les travaux à titre d'experts.

Si un accord se réalisait sans trop de difficultés sur les questions techniques (définition du secteur spatial et du secteur terrien), il n'en allait pas de même sur les questions juridiques et financières, difficultés qui d'ailleurs allaient entraîner une mise en sommeil du Groupe de travail et de ses sous-groupes en novembre 1981. En effet, en mai 1981, la Délégation de l'Allemagne annonçait qu'elle n'était pas en mesure de prendre position quant à sa participation au programme et remettait en cause le consensus de la Conférence sur la création d'une nouvelle Organisation dotée de la personnalité juridique. Elle proposait de lier les gouvernements intéressés par un Accord de coopération multilatérale, du type Accord NAOS, géré par un Conseil, et de confier l'exploitation à une Organisation existante (en l'espèce le Centre européen). Le sous-groupe institutionnel avait commencé à travailler sur un projet de Convention créant une Organisation internationale légère.

Aussi, à la mi-novembre 1981, le Groupe de travail suspendait ses travaux dans l'attente de décisions positives permettant d'atteindre le seuil de contributions nécessaires à l'exécution du programme.

Finalement, le sous-groupe institutionnel était amené à travailler sur deux hypothèses et à élaborer deux séries de documents juridiques:

- ou bien la création d'une Organisation nouvelle, dotée de la personnalité juridique, autonome mais légère, et de ce fait s'appuyant sur les services d'une Organisation existante;
- ou bien la mise en place d'une simple structure de coopération multilatérale. Mais dans ce cas il était clair que la décision sur l'organisme chargé de l'exécution des travaux revêtait une certaine urgence et que la conclusion de l'Accord correspondant entre ce dernier et les Gouvernements parties à l'Accord de coopération, devait aller de pair avec la conclusion dudit Accord de coopération multilatérale. Formule complexe dont les avantages pour certains Gouvernements (absence de ratification parlementaire semble-t-il) ne l'emportaient pas sur les inconvénients (la ratification était une nécessité pour la plupart des Gouvernements intéressés en raison des engagements financiers pris, l'absence de personnalité juridique rendait nécessaire de trouver une solution de repli, comme d'utiliser celle d'un Gouvernement qui aurait conclu les actes juridiques pour le compte des autres...).

Restait à définir, dans les deux cas de figure, l'Organisation extérieure chargée de l'exécution du programme. Diverses solutions furent étudiées. La solution d'un 'accueil' de cette Organisation nouvelle par le Centre européen, bien que ne soulevant pas a priori de difficultés techniques, n'était plus retenue car elle aurait demandé entre autres la révision de la Convention de ce Centre.

Figure 1 — Une vue de la 2e session de la Conférence intergouvernementale sur un système Météosat opérationnel (ESA, Paris, 21-23 mars 1983)

Fut écartée également une autre possibilité, après étude, celle de recourir aux services d'une société de droit privée, 'Eurosat' en l'espèce. Le sous-groupe institutionnel proposait au groupe plénier de retenir finalement l'Agence spatiale européenne. Par ailleurs, le sous-groupe institutionnel examinait les diverses possibilités d'arrangements intérimaires. Ici aussi il proposait qu'il soit recouru aux dispositions de la Convention de l'Agence.

Les difficultés précédemment évoquées surmontées, les travaux du sous-groupe pouvaient reprendre en septembre 1982 et se concluaient par la présentation au Groupe de travail d'un projet de Convention portant création d'une Organisation dénommée Eumetsat. Le Groupe de travail à son tour acceptait ce projet de Convention au début de 1983 et pouvait ainsi le transmettre au Président de la Conférence intergouvernementale. Par ailleurs, le Groupe de travail recommandait à l'unanimité qu'Eumetsat fasse appel aux capacités de l'Agence. Les organes délibérants de l'Agence (AFC, Conseil) répondaient favorablement. L'Exécutif prenait les mesures nécessaires pour présenter une nouvelle proposition technique et financière conforme aux objectifs du programme définis par le sous-groupe technique*.

Ainsi, au début de 1983, les conditions étaient remplies pour la convocation de la seconde session de la Conférence intergouvernementale.

2ème partie: EUMETSAT

Le schéma juridique proposé pour le système opérationnel associe une Organisation internationale nouvelle,



représentative de la communauté météorologique européenne 'Eumetsat' et une Organisation existante. Parmi les Organisations existantes, le choix s'est porté sur l'Agence spatiale européenne. Eumetsat et l'Agence auront donc à conclure un Accord de coopération pour la gestion du système initial tel que décrit en Annexe de la Convention Eumetsat.

La Convention Eumetsat

Eumetsat présente des traits classiques de toute Organisation internationale intergouvernementale. On se limitera à souligner certains particularismes.

La Convention lui assigne comme *objectif principal* la mise en place, la maintien et l'exploitation de systèmes européens de satellites météorologiques opérationnels. Le système initial est constitué par la prolongation du système Météosat préopérationnel développé par l'Agence spatiale européenne: trois satellites qui seront des versions améliorées de Météosat et un jeu de pièces de rechange au sol**.

La Convention est donc ouverte à la mise en place et à l'exploitation d'autres

systèmes de satellites météorologiques au-delà de ce système initial. Elle est également ouverte à d'autres systèmes d'observation météorologique. Elle autorise ainsi une évolution, une adaptation des activités d'Eumetsat de manière à répondre au mieux aux besoins de la météorologie en tenant compte des techniques disponibles.

Eumetsat par contre n'a pas vocation de recherche et de développement; elle assure la continuation opérationnelle des programmes qui ont démontré leur réussite technique et leur rentabilité. Ceci démontre la complémentarité recherchée avec une Organisation comme l'Agence. Aussi Eumetsat doit-elle s'appuyer sur les capacités d'Organisations existantes exerçant des activités dans un domaine similaire. L'Agence n'a pas d'exclusivité et il lui appartiendra dès lors de développer ses travaux en relation avec les besoins d'Eumetsat et de continuer à faire la preuve de sa capacité de gestion.

Les organes d'Eumetsat sont d'une part le Conseil, composé de représentants de chaque Etat membre 'dont l'un devrait être un délégué de son service météorologique national' (ce qui rappelle la disposition similaire du Protocole d'exploitation de Météosat) et d'autre part le Directeur. Ce dernier est assisté d'un

* La proposition de l'Agence se fondait sur l'application intégrale des règles financières. A la demande des Services météorologiques, le Conseil de l'Agence accordait une certaine réduction lors de la session de février 1983.

** Lancements prévus en mai 1977, août 1988 et novembre 1990 par Ariane.

secrétariat. On sait que par définition il ne peut s'agir que d'un secrétariat léger, de l'ordre d'une dizaine de personnes, qui sera chargé de suivre les travaux de l'Organisation mandatée pour l'exécution du programme défini.

L'article 5 de la Convention Eumetsat qui définit les *pouvoirs du Conseil et les règles de vote* a été un de ceux les plus difficiles à établir et ce n'est qu'après de longs débats, d'allers et retours, qu'un compromis a été trouvé. Ce compromis se base sur quatre niveaux de règles de vote:

- les décisions prises à l'unanimité de tous les Etats membres (amendement des Annexes, définition d'un nouveau système de satellites météorologiques, dissolution ou non-dissolution d'Eumetsat);
- les décisions prises à la majorité des 2/3 des Etats membres présents et votants, représentant au moins deux tiers des contributions (vote du budget annuel ou du plan triennal des dépenses et recettes);
- les décisions prises à la majorité des deux tiers des Etats membres présents et votants (nomination du Directeur, approbation d'Accord avec une Organisation internationale);
- enfin, les décisions prises à la majorité des Etats membres présents et votants (création d'organes subsidiaires).

On aura remarqué cette référence aux Etats membres 'présents et votants' qui a eu pour raison d'éviter un blocage du fonctionnement d'Eumetsat avec un effet incitatif à être représenté aux sessions du Conseil d'Eumetsat. Mais le quorum est toutefois représenté par la présence de la majorité de tous les Etats membres ayant droit de vote.

Le financement d'Eumetsat est assuré à la fois par les contributions financières des Etats membres et par les autres recettes éventuelles. L'Annexe II de la Convention contient l'enveloppe financière globale pour la réalisation du système initial (estimée à 400 millions

d'unités de compte, au niveau des prix de la mi-1982, taux de conversion 1983), pour la période visée c'est-à-dire 1983-1995*. Les Etats membres y contribuent selon un barème exprimé en pourcentage qui est le résultat de la prise en compte de facteurs divers. Ce barème est fixe pour la durée de cette période mais il peut faire l'objet d'ajustement dans certaines circonstances (adhésion d'un Etat ou retrait d'un Etat membre). Le budget est établi en unités de compte européennes (ECU). Son établissement et son exécution suivent les règles classiques des budgets des Organisations internationales; une vérification des comptes est également instituée.

Un autre article qui a fait l'objet de débats approfondis est l'article 8 sur la *responsabilité internationale d'Eumetsat*. L'accord a pu se faire sur le libellé à retenir dans le cas de dommages 'spatiaux', liés à la mise en place du secteur spatial d'Eumetsat (sur la base des précédents des Conventions d'Eutelsat ou d'Inmarsat). Par contre, le problème est plus délicat en ce qui concerne la responsabilité éventuelle issue d'une utilisation des données météorologiques. Ici il faut souligner les différences fondamentales qui existent entre le rôle d'une Organisation comme Eumetsat et celui d'Eutelsat par exemple. Les données météorologiques sont accessibles par tous d'une part et à titre gratuit d'autre part; n'importe quelle personne peut donc faire l'acquisition – sans autorisation d'Eumetsat – d'une station de réception des données du satellite dans la zone de visibilité de ce dernier (plus de 200 stations sol dans la zone de couverture).

Certaines données météorologiques appelées produits sont par ailleurs injectées dans les circuits mondiaux de

télécommunications météorologiques. Aussi sont-ce les raisons qui ont milité en faveur d'une absence de responsabilité d'Eumetsat pour les utilisations qui pourraient être faites des données météorologiques délivrées. Une prévision reste une prévision et l'outil est accessible à titre gratuit. Le bon fonctionnement de cet outil n'est pas non plus garanti. Il n'y a de ce fait aucune relation contractuelle instituée, aucune obligation prise par Eumetsat.

Eumetsat disposera de la personnalité juridique, pourra détenir des biens, ester en justice, etc. Eumetsat disposera aussi de certains *privilèges et immunités* mais ceux-ci restent à définir et à inscrire dans un Protocole séparé.

La Convention institue une procédure arbitrale de *règlement des différends*. On retrouve ici une particularité déjà apparue lors des négociations sur la Convention d'Eutelsat et qui est due aux difficultés d'un Gouvernement de reconnaître une compétence de principe au seul Président de la Cour internationale de Justice pour désigner un arbitre qui ne l'aurait pas été.

La Convention Eumetsat est ouverte à la signature des Etats invités à participer à la Conférence des Plénipotentiaires (en fait les Etats parties à la Convention du Centre européen). Elle *entre en vigueur* 60 jours après la date à laquelle sont devenus parties à la Convention les Etats dont la somme des contributions atteint 85% de l'enveloppe financière du système initial.

La Convention prévoit par ailleurs un mécanisme de consultation, à l'initiative du dépositaire, si elle n'est pas entrée en vigueur 24 mois après sa date d'ouverture à signature. Les Gouvernements qui sont déjà devenus parties à la Convention peuvent décider de la mettre en vigueur entre eux, ce qui suppose bien sûr une révision du barème prévu. Ce point est également lié aux arrangements intérimaires examinés plus loin.

* En effet, cette enveloppe prend en compte l'exploitation des satellites Météosat en orbite à compter du 24 novembre 1983, ainsi que d'autres activités d'Eumetsat et le fonctionnement de son secrétariat.

On signalera aussi une disposition qui a pour objectif de presser les Gouvernements à entrer dans le système le plus tôt possible, y compris dès son régime intérimaire; un Gouvernement qui attendrait l'entrée en vigueur de cette Convention aurait en effet à effectuer un versement spécial y compris au titre des investissements réalisés au titre du régime intérimaire et repris par Eumetsat.

Un Etat membre ne peut se retirer qu'à l'expiration d'un délai de six ans à compter de l'entrée en vigueur de la Convention. Si l'on tient compte de la durée prévisible de la phase intérimaire, ce n'est donc qu'une fois que les investissements majeurs auront été faits, qu'un Etat membre pourrait se retirer, ce qui réduit très largement la portée d'une telle disposition.

Par contre, Eumetsat peut être dissoute à tout moment soit par une décision du Conseil prise à l'unanimité de tous ses membres, soit dans le cas où à la suite de dénonciation (selon les dispositions précédentes) les contributions des Etats membres sont accrues de plus de 20%; encore le Conseil peut-il à ce moment-là, par décision unanime, s'opposer à cette dissolution automatique (l'Etat membre ayant dénoncé la Convention ne prenant bien sûr pas part au vote en question).

Au moment de la rédaction de cet article, la décision sur *le siège* n'est pas encore prise. Il n'est pas exclu qu'une formule transitoire soit finalement inscrite dans la Convention ouverte à la signature: un siège fixé provisoirement dans les locaux de l'Agence spatiale européenne, son implantation définitive étant laissée à une décision du Conseil Eumetsat.

Les arrangements intérimaires

Un certain nombre de contraintes imposent le démarrage effectif du programme opérationnel dès le mois de juin 1983 (l'offre du consortium industriel, les prix de lancement d'Arianespace, etc.). Aussi fallait-il trouver un mécanisme à cet effet, sans attendre l'entrée en vigueur

formelle de la Convention Eumetsat.

Le sous-groupe institutionnel du MOPWG s'est penché sur ce problème, a étudié diverses solutions (du type Eutelsat intérimaire, etc.) et a finalement retenu l'idée d'utiliser les dispositions de la Convention de l'Agence, c'est-à-dire d'entreprendre le programme, à titre intérimaire et par anticipation, sous le couvert d'un *programme facultatif de l'Agence* (article V.1.b.). Formule qui peut paraître quelque peu audacieuse, car par nature le rôle de l'Agence se situe bel et bien dans le cadre de l'article V.2, c'est-à-dire une activité opérationnelle conduite pour le compte d'un client extérieur. Toutefois cette 'audace juridique' se justifiait par divers arguments auxquels le Conseil de l'Agence, sur recommandation de l'AFC, se rendait en adoptant la Résolution du 9 décembre 1982.

D'une part, le Conseil accepte que l'Agence apporte son concours à l'exécution du programme Météosat opérationnel (article V.2 de la Convention de l'Agence), mais en même temps accepte, en vue de faciliter la mise en oeuvre de ce programme, que 'cette activité opérationnelle de l'Agence soit entreprise par anticipation dans le cadre de l'Agence à titre de programme facultatif'.

Aussi, cette Résolution doit-elle être aussi vue comme la Résolution dite 'habilitante' d'un programme facultatif de l'Agence. Un premier problème surgissait, découlant d'un décalage de calendrier. On sait qu'une Résolution habilitante ouvre une période de trois mois à l'issue de laquelle tout Etat membre de l'Agence qui ne s'est pas déclaré non intéressé à participer, acquiert la qualité d'Etat participant audit programme. Or la date de la seconde session de la Conférence intergouvernementale n'était pas encore arrêtée définitivement, ni bien sûr celle de la Conférence des Plénipotentiaires.

C'est dire qu'il n'était pas totalement assuré que le programme accepté par

cette Résolution du Conseil de l'Agence voit le jour. Aussi la solution a-t-elle été de lier la période de trois mois à la date de la seconde session de la Conférence et de la faire débiter deux mois auparavant (c'est-à-dire le 21 janvier 1983) laissant ainsi aux Etats membres de l'Agence un mois de réflexion pour tirer les conclusions des débats de cette seconde session.

En attendant, les Etats participants 'potentiels' se réunissaient pour établir les deux textes requis par l'Annexe III de la Convention de l'Agence: un projet de Déclaration et un projet de règlement d'exécution. Les textes étaient élaborés à temps pour pouvoir être présentés à la seconde session de la Conférence intergouvernementale.

En élaborant ces textes, les rédacteurs devaient veiller à concilier diverses contraintes, à mettre en place un système par anticipation mais en respectant la nature profonde, celle d'une activité opérationnelle. C'est ainsi que le contenu technique du programme couvert par la Déclaration n'est pas autre chose que celui de l'Annexe I de la Convention Eumetsat.

Le Conseil de l'Agence accepte également de déléguer ses compétences à un Conseil directeur de programme qui préfigure le Conseil Eumetsat; ce Conseil directeur voit ses fonctions calquées sur celles du Conseil Eumetsat et prendra ses décisions selon les dispositions établies pour ce dernier et qui sont souvent en dérogation des règles de vote stipulées dans la Convention de l'Agence.

C'est ainsi que l'Agence, responsable de l'exécution du programme, accepte de mettre en place une unité de soutien, de trois personnes, qui préfigure le secrétariat d'Eumetsat. Cette unité de soutien suivra les travaux de l'Agence et sera placée sous l'autorité fonctionnelle du Conseil directeur de programme. La 'distance' entre cette unité et l'équipe de l'Agence est par ailleurs marquée par le

Figure 2 — Présidence de la Conférence des Plénipotentiaires tenue à Genève le 24 mai 1983. De gauche à droite: M. J. Bärlocher, organisateur (Affaires étrangères, Suisse); Dr A. Junod, Secrétaire général de la Conférence (Directeur de l'Institut suisse de Météorologie); Sir John Mason, Président

de la Conférence (Directeur du Service météorologique du Royaume-Uni); M. Lafferranderie (Conseiller juridique de l'ESA).



fait que cette unité, quoique recrutée par l'Agence, ne résidera pas dans ses locaux mais dans ceux du service météorologique français.

Par contre, l'engagement financier des Etats participants se limite aux dépenses exposées par l'Agence – 378 MUC – (et non pas à l'ensemble de l'enveloppe financière fixée dans l'Annexe II de la Convention Eumetsat).

De même que cette dernière, la Déclaration prévoit un rendez-vous 24 mois après la date d'ouverture de la signature de la Convention Eumetsat pour faire le point. Faudra-t-il poursuivre encore sur la base de l'article V.1.b? Ou bien n'y a-t-il pas de chance raisonnable de voir la Convention Eumetsat entrer en vigueur?

Pour sa part, la Déclaration entrera en vigueur lorsque les Etats participants dont la somme des contributions représente au moins 80% du montant global l'auront acceptée; il n'est pas déraisonnable d'exclure que cette condition soit remplie dès avant la tenue de la Conférence des

Plénipotentiaires pour la signature de la Convention Eumetsat. Mais en principe les Etats participants disposent de la période se terminant à la date de cette Conférence pour annoncer qu'ils n'acceptent pas la Déclaration et de ce fait ne participent pas au programme. Dans ces conditions, la tenue même de cette Conférence des Plénipotentiaires serait compromise.

Par ailleurs, la possibilité pour un Etat non membre de l'Agence de participer à cette phase intérimaire en acceptant la Déclaration correspondante est expressément prévue. L'objectif est en effet que tout Etat signataire de la Convention Eumetsat soit aussi un Etat participant à la phase intérimaire. Le Conseil de l'Agence s'est toutefois réservé le droit d'examiner la demande de participation de ces Etats non membres (le Portugal, la Finlande, la Grèce, la Yougoslavie sont concernés, la Norvège et l'Autriche ayant déjà par leur statut de membre associé la possibilité de pouvoir participer à un programme facultatif de l'Agence).

Conclusion

Nous n'essaierons pas de conclure car ce qui vient d'être fait demande en premier lieu à être mis en oeuvre, expérimenté, développé; une porte s'est ouverte à la fois pour la communauté météorologique européenne et pour l'Agence. A elles d'oeuvrer pour que tout ceci soit un succès. Ce qui est important à relever c'est d'une part la continuité assurée entre un programme développé par l'Agence et un programme opérationnel défini et financé par les utilisateurs, une continuité dans laquelle l'Agence jouera un rôle important. C'est d'autre part la constitution d'une Communauté d'utilisateurs, aidée par l'Agence conformément aux objectifs assignés notamment dans la Résolution du Conseil ministériel de février 1977. C'est enfin cette symbiose, ce dialogue entre une Organisation de recherches et de développement et une Organisation d'exploitation qui s'institue.

Démonstration est ainsi apportée que l'Agence peut devenir le bras exécutif d'une Organisation d'exploitation. Cette symbiose accroît le potentiel européen dans son ensemble. Elle peut aussi servir d'exemple à d'autres projets qui présentent des similitudes; on songe par exemple à l'exploitation de satellites opérationnels d'observation de la Terre. Peut-être y verra-t-on plus tard le signe d'une deuxième mutation de l'Europe spatiale.





The Meteorological Product: Cloud Analysis

R.R. Warner, Meteosat Data Management Department, European Space Operations Centre (ESOC), Darmstadt, Germany*

In previous issues of the ESA Journal and Bulletin many of the meteorological products derived from the routine processing of Meteosat images have been described. Here, a more recently developed product of the system is described – the so-called 'Cloud Analysis'.

The cloud-analysis product is a coded representation of the cloud present in Meteosat thermal infrared (IR) and visible (VIS) images, for a specific time. At present it is produced routinely, four times a day, from images close to the nominal times of 00, 06, 12 and 18 UT, but for internal reasons the results are disseminated to the meteorological community three times daily only.

Up to the present time (May 1983) the product has been produced routinely for about a year and users are still in the experimental stage of its utilisation. In concept, however, it was designed principally for use in atmospheric mathematical models and for cloud climatological purposes. Other uses foreseen include rainfall studies, radiative-energy-transfer studies and input to synoptic-analysis schemes.

In common with many of the other products, the analysis is made on a segment basis and it is derived from the general segment processing scheme which forms the basis for the meteorological product extraction.

Segment processing

Segment processing uses the cluster-analysis technique, which has been described by Tomassini**, and therefore only a brief description is presented here for completeness.

A segment comprises an array of 32×32 IR pixels, cut from an image in such a way that the centre of each segment is always at a fixed geographical location and an array of 80×80 segments adequately covers the Meteosat field of view, although the analysis is restricted to complete segments within a 50° great-circle arc of the subsatellite point.

Over each Meteosat segment (i.e. an approximately 200 km square) are built two-dimensional IR/VIS histograms (consisting of $32 \times 32 = 1024$ IR pixels). The radiances forming these histograms tend to be grouped into clusters corresponding to the physical bodies located within the satellite's field of view. It is therefore possible to extract these clusters to find the radiance properties of the source bodies. The techniques used for cluster extraction must be fairly sophisticated to cope with the effects of cluster overlap, finite spatial resolution of the detector, and instrumental noise. Following cluster extraction, each cluster is, where possible, identified by comparing the measured cluster radiances with a cluster identification table and trying to match each cluster radiance with its expected 'spectral signature'. The cluster identification table is initially based on a set of climatological radiances derived for each expected physical body; however, in order to follow the frequently large diurnal variations found in reality, a diurnal variation based on the Sun/satellite/scene geometry is imposed on the table, and a feedback loop using the results of previous runs of the cluster-extraction/identification scheme makes adjustments to the identification table to

* The author has since returned to the UK Meteorological Office.

** Tomassini, C., Objective Analysis of Cloud Fields, Satellite Meteorology of the Mediterranean, in ESA Special Publication SP-159, 1980.

Figure 1 — Idealised relationship between IR and WV radiance counts for a standard atmosphere

follow accurately the true local diurnal development.

In order to identify cloud clusters, the feedback loop used to derive the interpretation table for the identification of the extracted clusters is of great importance since over desert areas, for example, a diurnal temperature cycle of over 50°C for the land surface is not unknown, making it difficult to distinguish between land and low-level cloud at night, and the shape of the heating/cooling curve varies considerably with local conditions (e.g. with soil moisture content, cloudiness, etc.).

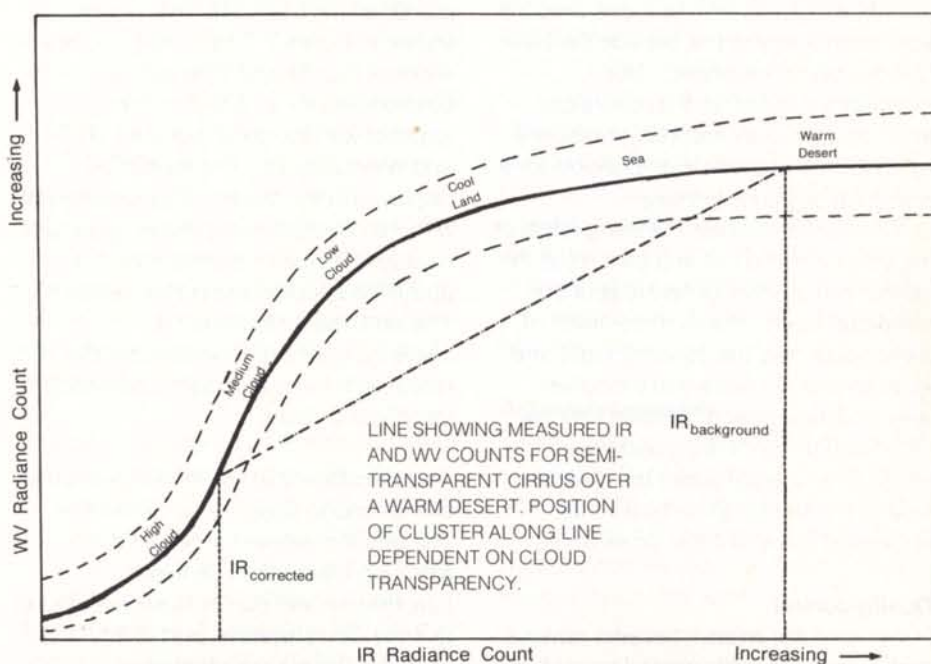
Once cloud clusters have been identified, there remain two corrections to be performed to the cluster IR radiance. One is for the effect of absorption by atmospheric water vapour lying above the cloud top. This correction is applied by using the output of a global forecast model to describe the expected state of the atmosphere at each segment. Each forecast temperature/humidity profile is used indirectly to assign a radiatively similar model atmosphere profile for which all relevant radiative calculations have been precomputed and stored in tabular form, thereby avoiding prohibitive real-time radiative computation. The corrected IR radiances are simply stored as a function of measured IR radiance and satellite zenith angle for each allocated model atmosphere. The set of model atmospheres is large (>100) and was originally generated from a large set of actual radiosonde ascents in such a way that the use of the assigned model atmosphere for the derivation of the absorption correction instead of the original forecast temperature/humidity profile results in an error of less than 1°C. The correction obviously becomes less important with increasing cloud-top height.

The other correction is for the semi-transparency of thin high cloud (cirrus) so that the temperature corresponding to the semi-transparency corrected IR radiance

is exactly equivalent to that of a sheet of cirrus of emissivity 1. The temperature attributed to the cirrus can be used to estimate height by finding the height corresponding to the cloud temperature in the forecast temperature/height profile. This correction is in fact applied to the clusters before identification so that they can be correctly classified and so that the water-vapour absorption correction is properly applied. The basis of this correction is to compute the relationship between the IR radiances and water-vapour (WV) radiances for cloud layers at different vertical levels in a standard atmospheric profile and for different surface temperatures.

A typical curve is shown in Figure 1. Assuming the mean model atmosphere is representative of local atmospheric conditions, pairs of IR and WV values will tend to be clustered about the curve shown, provided they arise from a land surface or from a completely opaque cloud layer. Where a semi-transparent cloud overlies a warmer background (i.e. land/sea surface or a lower opaque cloud layer), the measured IR/WV radiance pair will lie in a straight line joining the points

corresponding to an unobscured background and a completely opaque cirrus layer, with the displacement along this line being determined by the degree of cloud transparency (the same situation can also arise, incidentally, with subpixel-resolution cloud). To correct for this effect, the background radiance point is represented by the radiances of the warmest cluster (in the IR) extracted. All other clusters are tested to see whether they can be considered to lie on the idealised curve or whether they lie in the area below the curve corresponding to a semi-transparent cloud cluster. The correction is performed provided they show sufficient contrast from the background radiance point. The mechanism is simply to check whether the line joining the background radiance point with the supposed semi-transparent cloud cluster point intersects the idealised curve and if so the corrected IR value is read off at the intersection point. There are several safeguards in the form of additional checks not described here which prevent this correction being applied indiscriminately to unsuitable clusters.



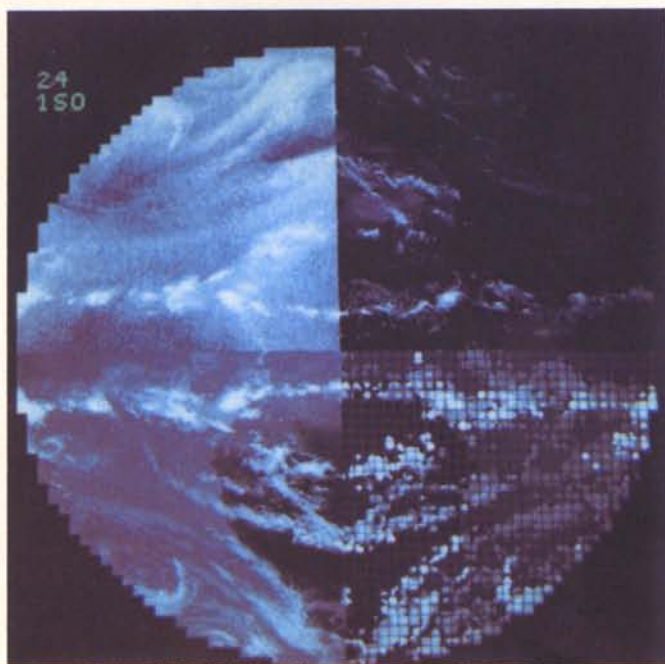


Figure 2 — Normal display of cloud analysis showing clockwise from top right: visible, pseudo-image, infrared and water-vapour images

The final product for each segment is a cloud amount and its associated cloud-top temperature for up to three layers of cloud. The cloud amount is the percentage of the total number of pixels in a segment identified as cloud, whilst the temperature is derived from the IR radiance corrected for both semi-transparency and water-vapour absorption as appropriate. It is important to note that the percentage cloud cover relates only to that part of the layer seen from space and that higher cloud can obscure parts of lower layers.

These two measurements, cloud amount and mean temperature, provide the basic cloud-analysis information, but experience has shown that errors can arise during cluster analysis, particularly when the VIS channel is unavailable for a particular segment. In these circumstances the discriminating effect of the VIS channel is lost and as a result the system can at times generate spurious low-cloud layers. The most common of these occur over the desert at night and at times over the sea when difficulties arise in differentiating between very low cloud and the underlying surface, although to a great extent the feedback loop to the identification tables has eliminated many of these gross errors.

Quality control

In view of these errors it became obvious that a manual quality-control procedure

was required, but it was not immediately clear how this could be achieved in the quick and economical manner that would be required for operational use. Various methods were tried, but eventually it became clear that it would be necessary to create a pseudo-image from the basic cloud-analysis information which could be displayed on the Meteorological Information Extraction Centre (MIEC) consoles and compared with the original images.

Pseudo-images

An algorithm was developed which produced the 512×512 raster image shown in Figure 2. This image, one of a series of four, displays the pseudo-segment results for one quadrant, together with the corresponding VIS, IR and WV quadrants. The results are displayed in the correct relative quadrant with the corresponding image quadrants displayed as mirror images reflected about the equator and prime meridian. This arrangement enables a meteorologist to readily compare the results with the real images and hence identify anomalies.

The difficulties involved in the production of the pseudo-image deserve mention. The problem relates to the fact that, although information on mean temperature and percentage cover for up to three cloud layers is available for each segment, there is no information

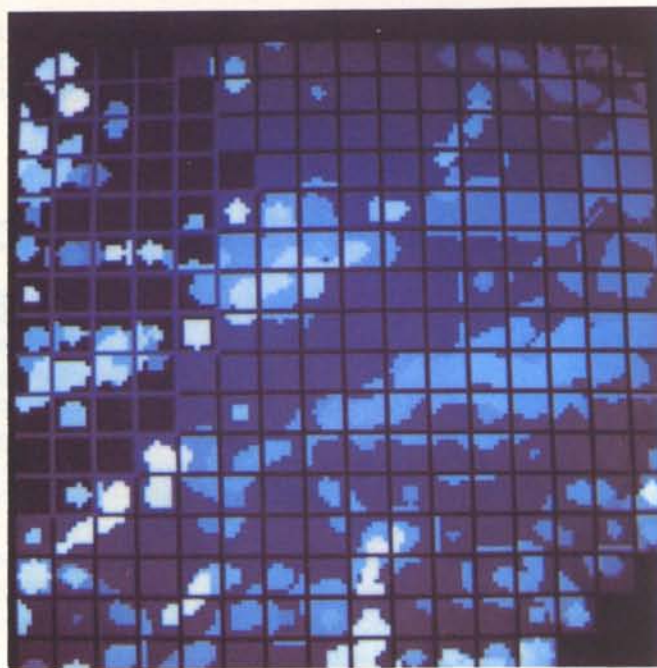


Figure 3 — Cloud representation in the pseudo-image at segment level

whatsoever regarding the positions of these layers. Nevertheless, each layer must be allocated in the correct proportion to the 7×7 array of image points available to each segment in such a manner as to reproduce as closely as possible the appearance of the original image.

The approach was first to compare the mean temperatures of the cloud layers present in each segment with those of the layers in the eight neighbouring segments and match the first two layers whose temperature difference was within 10°K . This is an arbitrary limit, but the results give reasonable justification. Thus for each cloud layer in the segment under consideration, the corresponding coverage in the eight neighbouring segments has been extracted.

The next step is to fit a nine-term bivariate polynomial to the data for each cloud layer in the segment under consideration, such that, if the polynomial was evaluated at the centres of any of the nine segments, it gave the exact coverage of that layer.

The display positions for the various cloud layers are assigned in ascending order of cloud temperatures, on the grounds that the coldest layer is normally the highest, and continuous high cloud can obstruct the satellite's view of continuous lower cloud. Having first calculated n , the

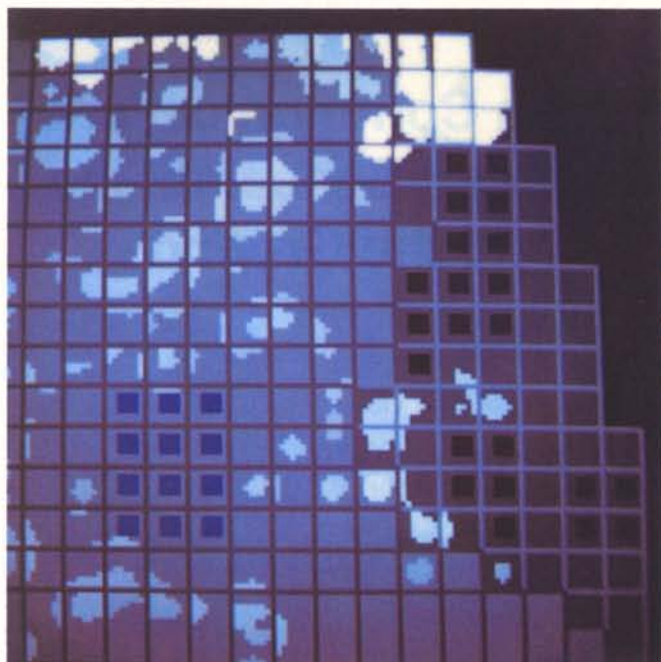


Figure 4 — Quality control of the pseudo-image

number of display positions to be assigned to the cloud layer, the polynomial is evaluated at all display positions (except those to which cloud from another layer has already been assigned) and the n having the highest value of the polynomial is assigned to that cloud layer.

The success of the method is evident in Figure 2 where, apart from some location errors within the segment, the general agreement is remarkably good. Of interest is the zoomed pseudo-quadrant (Fig. 3), where the various shapes allocated to the different cloud layers are clearly visible, with some layers extending across segments and others limited to one segment only.

Interactive quality control

The cloud analysis is displayed on a VDU where it can be quality-checked by a meteorologist. In this display the cloud is positioned within the segment according to correlations with the cloud temperatures in neighbouring segments, so that the display looks realistic in the sense that it resembles a somewhat low-resolution image.

In principle, the interactive quality-control procedure for cloud analysis is very similar to those for other products. It is implemented at segment level and results for the whole segment are either accepted or rejected. In addition, however,

a further level has been added to allow the meteorologist to insert a 'no-cloud' result. This second alternative was introduced to allow for the circumstances when spurious low cloud had been developed by the cluster-analysis program. Figure 4 shows a quality-controlled image and here the meteorologist has marked suspect segments in the pseudo-quadrant, either in red or blue, to indicate either a deletion or a substitution of a 'no-cloud' result, respectively.

The full quality-control procedure therefore consists of the meteorologist displaying four images in turn, comparing the pseudo-quadrant in each with the associated IR, VIS and WV quadrants and marking via the display keyboard any suspect segments. This action not only sets the colours over the suspect segments, but also sets appropriate bits in two 64×64 bit masks held in the computer supporting the display. Next, as a check, the full pseudo-image (Fig. 5) is displayed showing all quality-controlled segments.

The bit masks are next transferred to the computer mainframe where they are compared with the original cloud-analysis results and suspect values either deleted or a 'no-cloud' substitution made. Finally, a coded version according to World Meteorological Organisation SATOB code format is automatically produced and

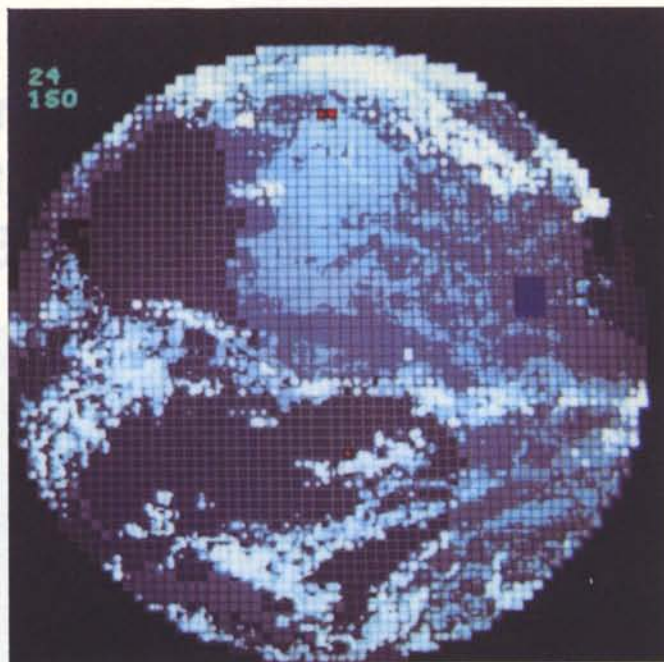


Figure 5 — Check of quality-control mask before dissemination

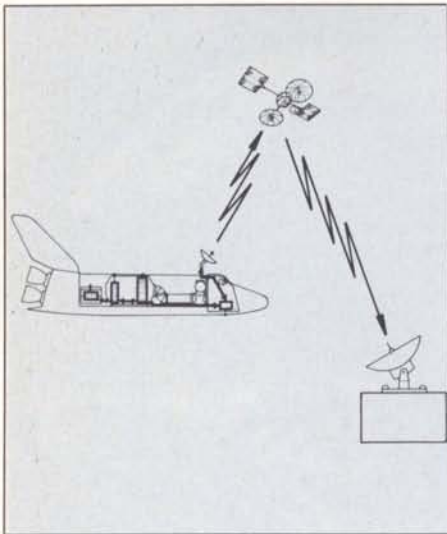
transferred to the Meteorological Centre at Offenbach (Germany) for onward transmission on the Meteorological Global Telecommunications System. This gives the product exposure to the worldwide meteorological community.

Validation of the product

There is no objective validation procedure for the cloud-analysis product other than the manual quality-control procedure just described. In general it is difficult to obtain suitable data, since most observing systems are on a relatively local scale and clouds are observed from below, whereas the satellite product covers a large area and is observed from above. A further and more objective validation of the product could stem from its use by a sophisticated weather-forecasting numerical model which uses cloudiness as an input field to the numerical analysis. It is felt that the interactive quality-control procedure is more than adequate, since the meteorologist can estimate cloud amount and height subjectively with reasonably high accuracy.

Acknowledgements

The cloud-analysis product is one of the end products of a system that has been developed by past and present members of ESOC/MDMD over many years. The author's contribution has been mainly at the quality-control level.



Experiment Data Communications (48 Mbit/s) between Spacelab, the Space Shuttle and the Ground

R.J. Selg, Spacelab Sustaining Engineering Division, European Resident Team, Kennedy Space Center, Florida, USA
G.A. Weijers, Spacelab Sustaining Engineering Division, European Space Research and Technology Center (ESTEC), Noordwijk, The Netherlands

Tests have been performed at Johnson Space Center in Houston to verify the end-to-end data-transmission performance of the NASA Space Transportation System's high-rate data downlink (48 Mbit/s) with the European Spacelab multiplexing and demultiplexing equipment to be used at the link's input and output. The aims of the tests were to check equipment compatibility and the overall performance of the link and to establish operational procedures and constraints in time for the first Spacelab flight.

Introduction

In 1975 ESA decided to develop a High-Rate Multiplexer/Demultiplexer (HRM/HRDM) as part of the Spacelab Command and Data Management Subsystem. The HRM/HRDM design had to be transparent to experiment data streams, i.e. experiment data input (asynchronously and simultaneously) to the HRM (Fig. 1) were expected to be outputted from the HRDM (Fig. 2) at the same frequency in near-real-time.

The upper data-rate limit was constrained by the Space Transportation System to be 48 Mbit/s.

The limited experience available at the time with data transmissions in the 50–100 Mbit/s range making use of three spacecraft (Orbiter, TDRSS and

Spacelab), made it necessary to negotiate reasonable interface requirements at the outset for interfacing equipment and to institute tight control over these interfaces during hardware development.

An end-to-end test with hardware from the different projects was planned to verify compliance with interface requirements and to establish the overall link performance of the transmission system. This test had originally been planned to take place in time to correct any design deficiencies that might emerge. Equipment nonavailability, however, delayed the start of the test, which could only be performed in early 1983, seven months prior to the first Spacelab mission.

The test was performed in the Electronic Systems Test Laboratory (ESTL) at

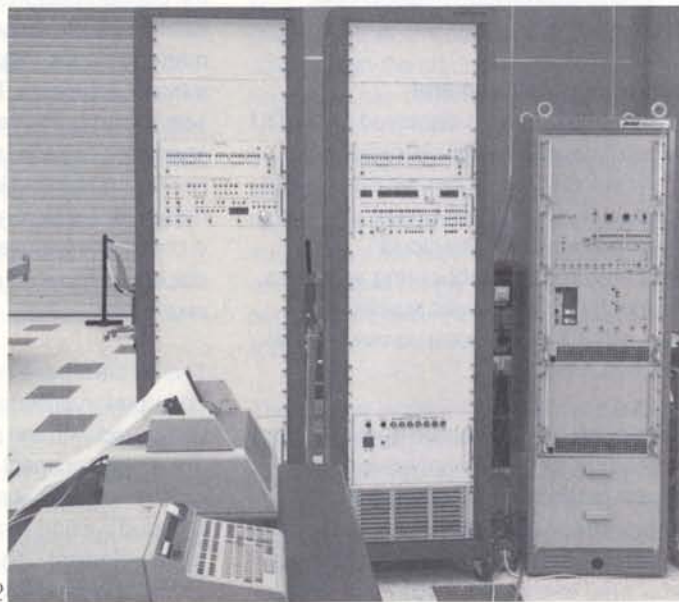
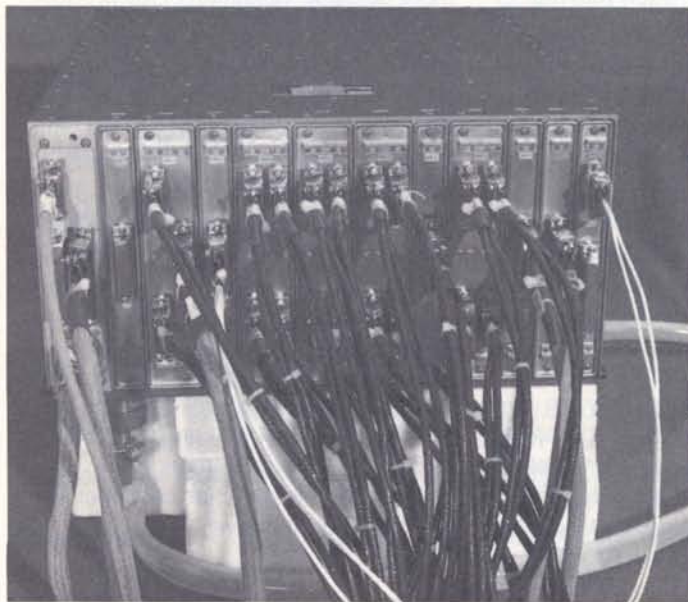


Figure 1 – The High-Rate Multiplexer (HRM), which collects experiment data onboard Spacelab

Figure 2 – The High-Rate Demultiplexer (HRDM) (left), its unit tester, and the HRM unit tester (right)

NASA/JSC in Houston, Texas (Fig. 3). The NASA and Lockheed test teams were responsible for the overall test and the installation/operation of the flight-representative Shuttle-Orbiter Ku-Band Signal Processor (KUSP), the Tracking and Data Relay Satellite (TDRS) simulator, the TDRS System (TDRSS) Ground Terminal, the NASA Communications Network (NASCOM) simulator and the ground recorders (Fig. 4).

The ESA/MBB-ERNO/Matra support team from Europe was responsible for the flight-representative Spacelab hardware and software at the input (multiplexer, tape recorder, intercom) and output (demultiplexer) of the downlink.

Flight configuration

Spacelab experiment data are inputted to the HRM. Two bit streams are output to the Orbiter Ku-Band Signal Processor, one (Channel-3) with an upper limit of 48 Mbit/s and one (Channel 2) with an upper limit of 2 Mbit/s. The composition of the data streams is determined by software commands loaded into the HRM (Fig. 5).

The Orbiter Ku-Band System convolutionally encodes the 48 Mbit/s data (rate 1/2), combines it with the 2 Mbit/s data and Orbiter operational data (192 kbit/s), and modulates it onto a 15 GHz carrier for transmission to the TDRS.

The TDRS then demodulates the signal and modulates it onto a 14 GHz carrier for transmission to the TDRSS Ground Terminal at White Sands, New Mexico.

At the Ground Terminal the signal is again demodulated and rearranged for transmission via the NASCOM network. The high-data-rate link (48 Mbit/s) is converted to a 50 Mbit/s stream by means of a statistical multiplexer. At the receiving station at JSC, a corresponding demultiplexer reconstitutes the original bit stream.

Figure 3 – View of the Electronic Systems Test Laboratory (ESTL) control room for the Orbiter Communications System

Figure 4 – The High-Density Recorder (HDR) which records the 48 Mbit/s data stream on the ground

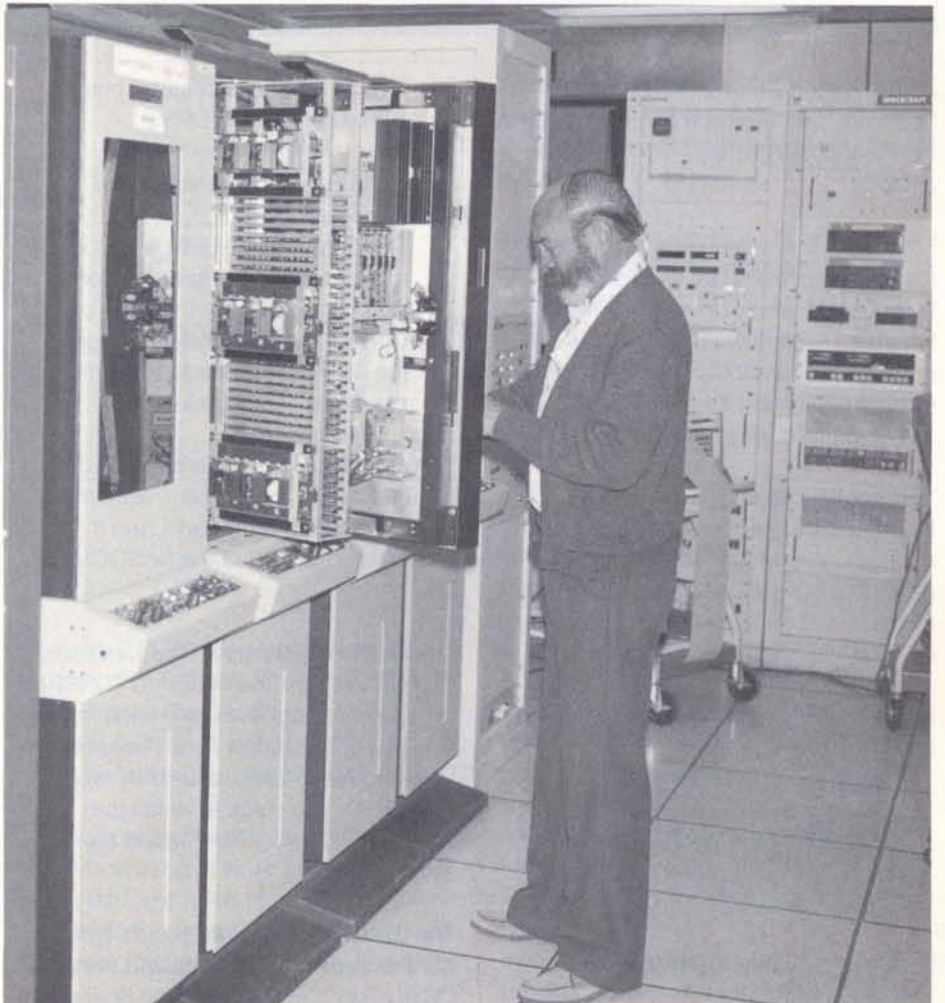
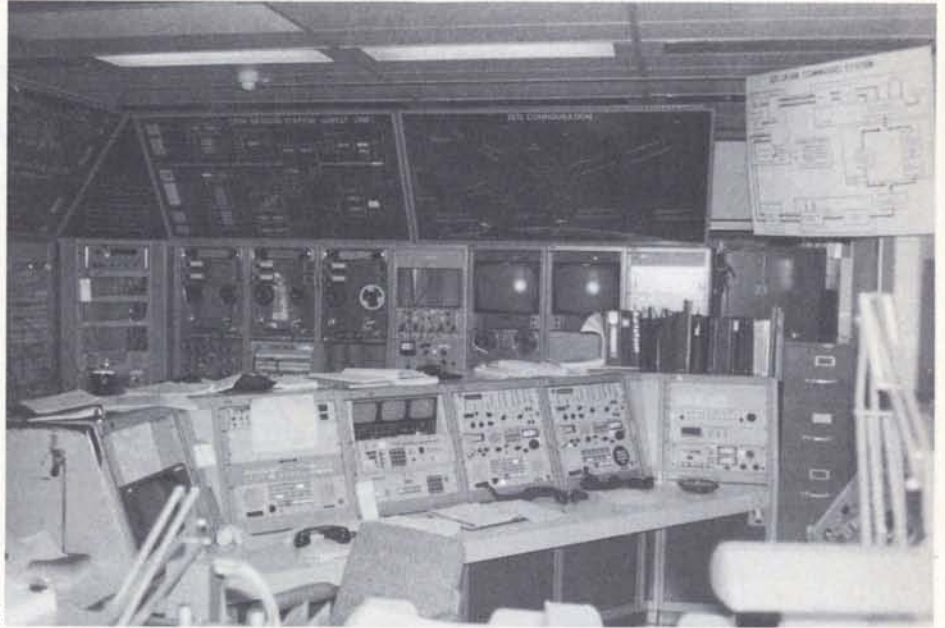
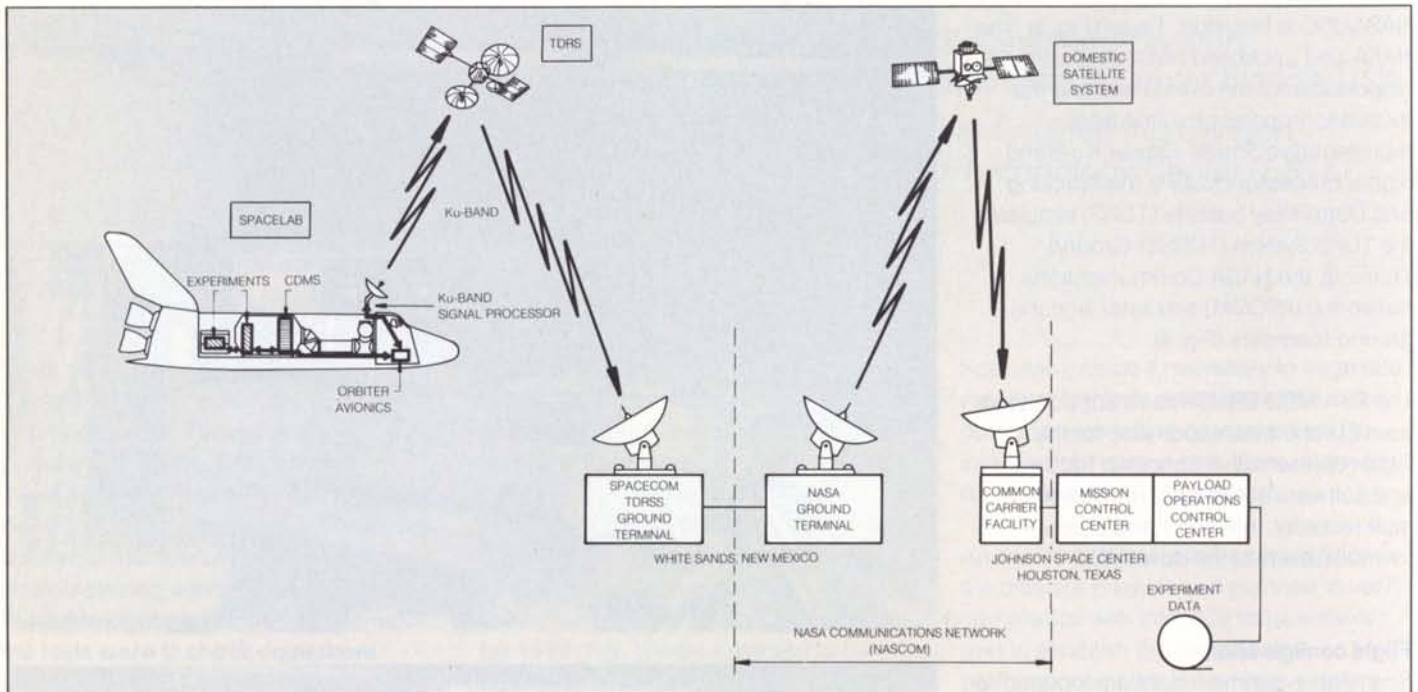


Figure 5 — Spacelab experiment data transmission to the Payload Operations Control Center, at Johnson Space Center in Houston



At the Mission Control Center, the Spacelab data are routed to the HDRM in the Payload Operations Control Center (POCC).

The data-stream decomposition and routing to the users are controlled by software commands in the HDRM. Individual experiment data streams are provided to the appropriate experiment ground equipment for quick-look assessments during the mission.

Test configuration

Figure 6 shows the overall test configuration, which allowed interface parameters (signal characteristics) to be measured without significant distortion with the test equipment connected.

Bit Error Rate (BER) measurements were taken on three links:

1. *HRM input to HRDM output*
This measurement gives the end-to-end BER of the system that will be experienced in practice by the Spacelab user.
2. *HRM output to Convolutional-Decoder output*

This measurement establishes the BER through the TDRSS.

3. *HRM output to Convolutional-Decoder input*

The output of the HRM is encoded in a Ground Convolutional Encoder and compared with the input of the Convolutional Decoder. This gives the BER of the encoded information bits in the TDRSS link.

The difference in BER between 2 and 3 establishes the coding gain, while the difference in BER between 1 and 2 establishes the BER of the NASCOM data link.

To establish BER curves as a function of RF field strength, the Orbiter to TDRSS RF signal attenuation was increased from the 90.3 dB.Hz calculated Total Received Power to Noise Spectral Density ratio (TRP/NSD) to a value at which the specified BER of 1×10^{-5} would be exceeded.

The BER measurements also included data recorded and reproduced using the Orbiter Payload Recorder, the Spacelab

High-Data-Rate Recorder, and the NASA Ground High-Density Recorders.

Test results

Signal parameters of the High-Rate Multiplexer at the Spacelab/Orbiter interface are summarised in Table 1. All parameters met their specification.

HRM clock stability

The HRM oscillator-stability and clock-pulse asymmetry and jitter requirements are driven by the Ku-Band Signal Processor's clock multiplier, which uses a Phase-Lock-Loop (PLL) to double the HRM clock for convolutional encoding (Fig. 7). To eliminate the effects of bit-to-bit jitter, the PLL loop filter's upper frequency limit is less than 50 kHz. Long-term HRM clock variations have therefore to be less than 10^{-4} .

The available measuring equipment allowed the maximum and RMS phase error of the HRM clock to be established up to 8 Mbit/s only. For higher bit rates, the clock signal could only be observed on an oscilloscope to establish the bit-to-bit jitter. The latter method, which was used for equipment qualification, is

Figure 6 – Test configuration for the high-data-rate link

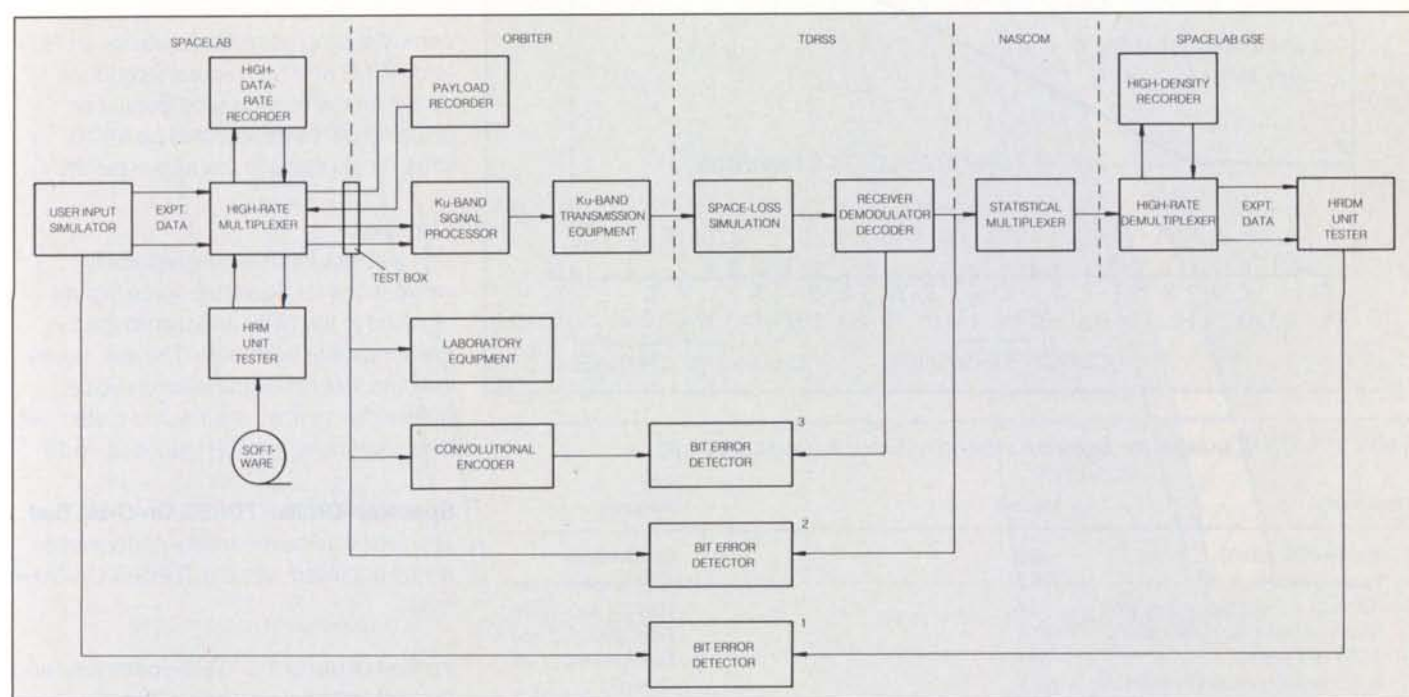


Table 1 – HRM signal characteristics

Link	Channel-3 (48 Mbit/s)		Channel-2 (2 Mbit/s)	
	Required*	Measured	Required	Measured
Data rise time	≤ 3.5 ns	< 2.0 ns	≤ 25 ns	5.0 ns
Data fall time	≤ 3.5 ns	< 3.0 ns	≤ 25 ns	5.0 ns
Clock rise time	≤ 3.5 ns	< 2.5 ns		
Clock fall time	≤ 3.5 ns	< 3.0 ns	no clock	no clock
Clock asymmetry	not specified	2.6% of bit period		
Data/clock phase	≤ 12.5% offset	1.5% of bit period	≤ ± 5% jitter	≤ 0.7% of bit period
Signal-to-noise ratio	≥ 35 dB	≥ 51.2 dB	≥ 35 dB	> 39 dB

* 20–80% rise/fall times

acknowledged as not being very satisfactory, but there is no available alternative. No attempt was made to measure long-term HRM clock stability.

Bit transition density

A minimum number of bit transitions (logic '0' to '1' or vice versa) are required by the ground stations for satisfactory communications.

Channel-3 (48 Mbit/s): Requirement 8 transitions in 4096 bits. No performance degradation was observed with 1

transition in 1500 bits.

Channel-2 (2 Mbit/s): Requirement 64 transitions in 512 bits, and 1 transition every 64 bits. The design of the HRM includes a Cover Sequence Generator, which provides for sufficient transitions.

This test has verified that no bit-transition requirements have to be imposed on the Spacelab user, other than 1 transition in 1500 bits for a Direct Access Channel user bypassing the multiplexing function in the HRM.

Link bit-error-rate measurements

The signal-to-noise ratio budget for the Shuttle Ku-Band return link (dedicated) is summarised in Table 2.

The transmission link has been calibrated for a TRP/NSD ratio of 90.3 dB.Hz from KUSP to TDRSS and 100.3 dB.Hz from TDRS to Ground Terminal.

BER curves were obtained for 48, 32 and 2 Mbit/s (Channel-3) and 2 Mbit/s (Channel-2).

From Figure 8 it can be seen that sufficient margins (7.1–14.7 dB) are available for the transmission system.

Coding-gain measurements

The coding gain was established for Channel-3 48 Mbit/s and 2 Mbit/s data from the convolutional coding system (rate 1/2, constraint length 7).

A coding gain of 4.8 dB was measured, for the 2 Mbit/s data rate, while for the 48 Mbit/s data rate a figure of 5.1 dB was noted (Fig. 9). The 96 Mbit/s curve does not follow the theoretical curve of an optimum (matched filter) receiver. Effects from the

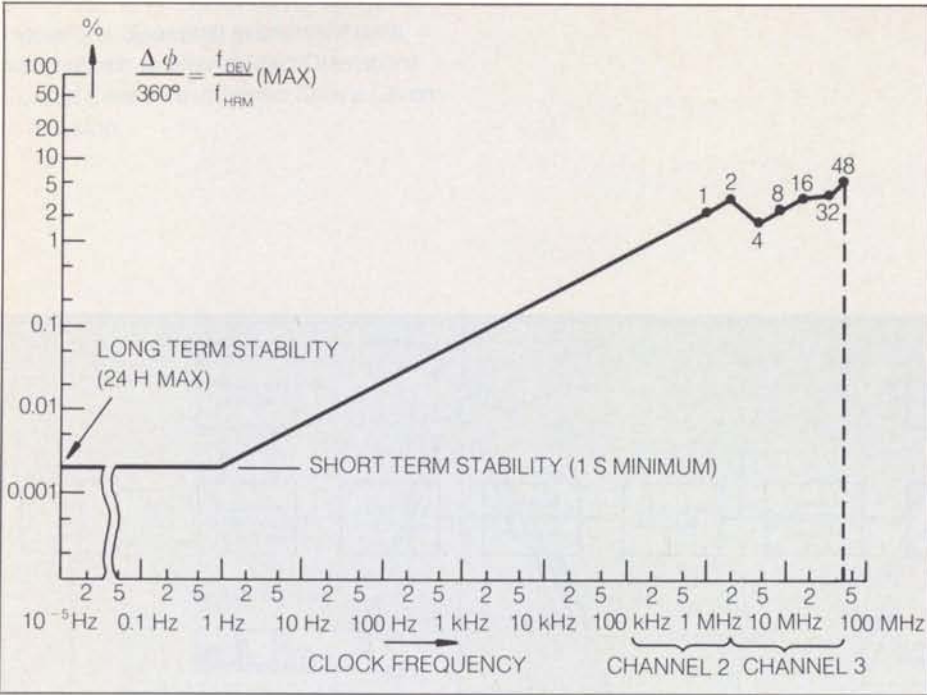


Figure 7 – HRM long- and short-term clock-stability requirements/results

demultiplexing (record/reproduce on PLR and HRRR and two record/reproduce cycles on the ground recorders). The resulting BER was found to be 4×10^{-5} , which is still close to the above results.

Voice tests
This test included voice-intelligibility verifications for Spacelab voice signals digitised in the HRM and transmitted in the composite bit stream. The test results indicate that no degradation in voice quality due to the transmission system will be experienced for BER values up to 10^{-2} .

Table 2 – E_b/N_0 budget for Shuttle Ku-band return link (dedicated link)

Parameters	Mode-1			Remarks
1. Shuttle EIRP (dBW)	48.8			Rockwell spec.
2. Space loss (dB)	209.2			TDRSS users' guide
3. Pointing + Polarisation loss (dB)	1.0			TDRSS users' guide
4. Received power at TDRS (dBW)	-161.4			From items 1, 2 and 3
5. TDRS G/T (dB/K)	23.1			TDRSS users' guide
6. Boltzmann's constant (dBW/Hz/K)	-228.6			Constant
7. C/N_0 at TDRS (dB/Hz)	90.3			From items 4, 5 and 6
8. Power split loss (dB)	Channel-1 -14.0	Channel-2 -8.0	Channel-3 -1.0	Equal power split
9. Information bit rate (dB)	(192 kbit/s) 52.8	(2 Mbit/s) 63.0	(50 Mbit/s) 77.0	S-805-1, specification
10. E_b/N_0 TDRS filter (dB)	23.5	19.3	12.3	From items 7, 8 and 9
11. Required E_b/N_0	9.6	9.6	5.5	Theoretical
12. Total allowable losses including margin (dB)	13.9	9.7	6.8	From items 10 and 11
13. Ground stations & downlink degradation (dB) ● Despreader/demodulator ● Bit synchroniser ● Phase noise ● Interference ● Convolutional decoder	TBD	TBD	3.8	Preliminary simulation results
14. TDRS satellite degradation (dB) ● IM degradation				
15. Clear weather/rain margin (dB)	TBD	TBD	3.0	From 12, 13 and 14

Spacelab-Orbiter-TDRSS On-Orbit Test
The final verification of link performance will be achieved with the TDRS-A On-Orbit Test.

Instead of using the TDRS-space-loss and ground-terminal simulators, the real TDRS-A satellite, the White Sands Ground Terminal, the NASCOM network and the JSC MCC/POCC facilities will be used for the On-Orbit Test to be conducted in August 1983.

The Spacelab HRM will be located in the Electronic Systems Test Laboratory at NASA/JSC in Houston and the HRRM in the adjacent Payload Operations Control Center. The Orbiter Ku-band antenna will be located just outside the ESTL facility. This On-Orbit Test is intended to confirm the link margins measured previously and will establish the final link performance that can be expected during the SL-1 mission.

Conclusion
The tests described here have successfully verified that all parameters at the Spacelab/Orbiter interface meet the appropriate requirements. The specified link bit error rate of 10^{-5} has been met, with sufficient margins available. The results of the tests performed so far indicate that user data generated by Spacelab experiments will suffer no significant degradation due to the Spacelab/STS transmission system.

BER detection equipment (Fig. 10) at 96 Mbit/s are suspected of being responsible for the curve's 'tail-out' at low BERs.

BER test with the NASCOM link
The results of the test established a 0.5–1 dB loss for transmissions via the statistical multiplexer/demultiplexer of the NASCOM link.

Recorder tests
Data reproduced from the Spacelab High-Data-Rate Recorder (HRRR) and Orbiter Payload Recorder (PLR) at nominal TPD/NSD ratios confirmed that the recorders have BERs in the 10^{-5} – 10^{-6} range (Fig. 11). These tests verified full compatibility of data reproduced directly into the KUSP for the HRRR. One particular test was performed with double

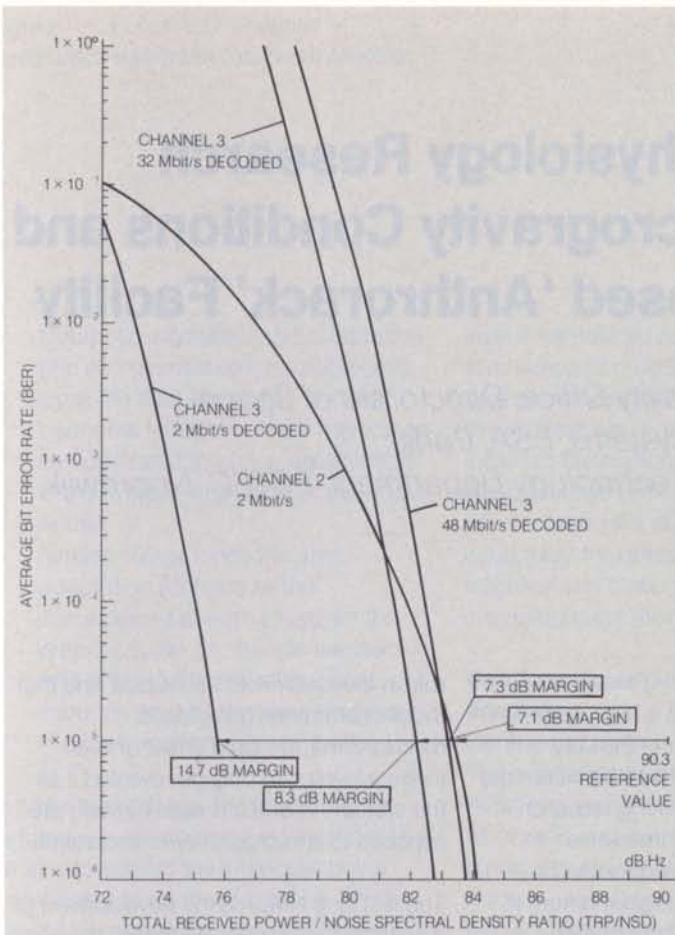


Figure 8 – Bit-error-rate (BER) curves versus TRP/NSD

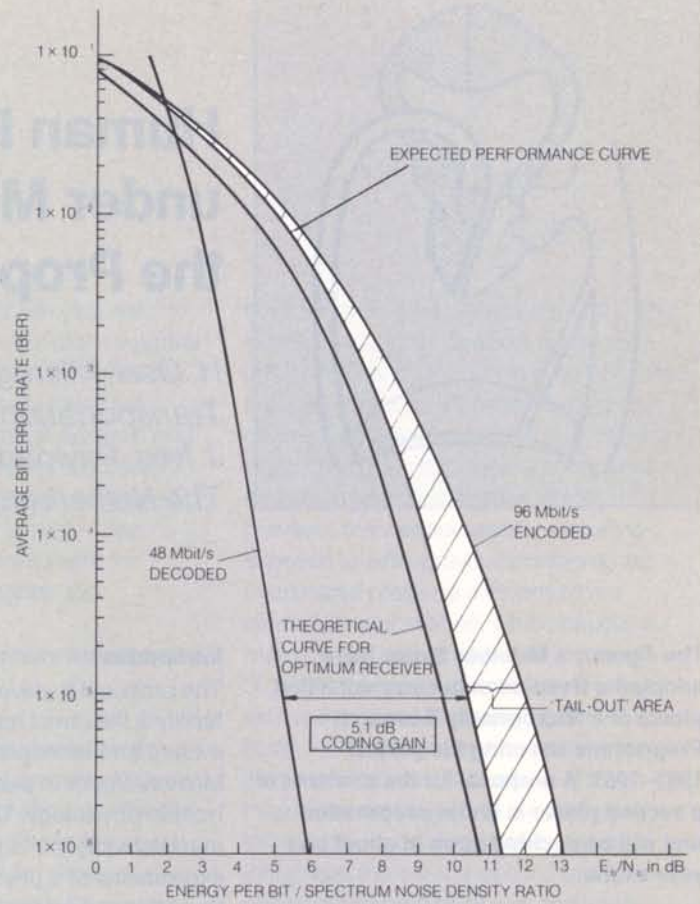


Figure 9 – Bit-error-rate (BER) curves as a function of E_b/N_0



Figure 10 – The bit-error detectors used to establish the overall and link BERs

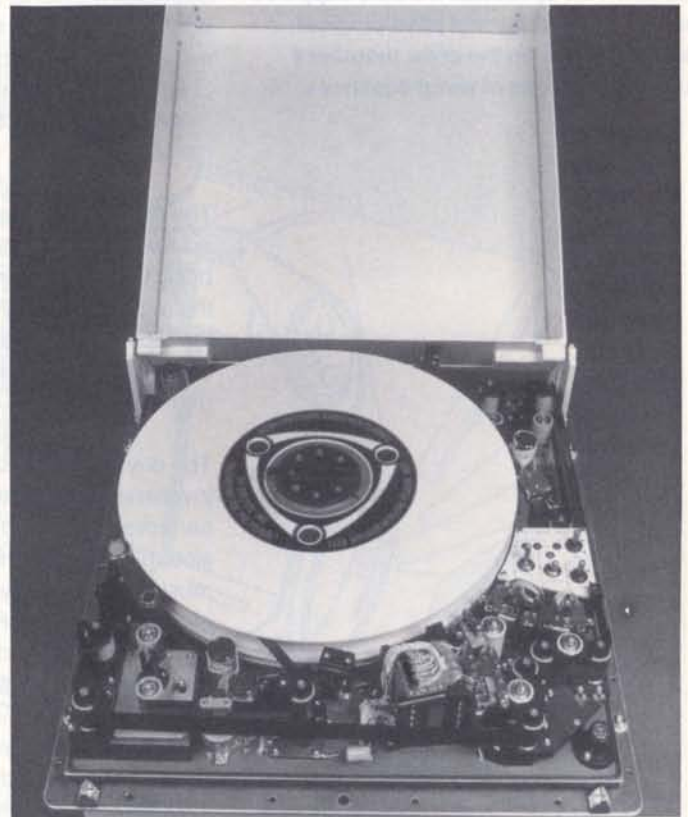
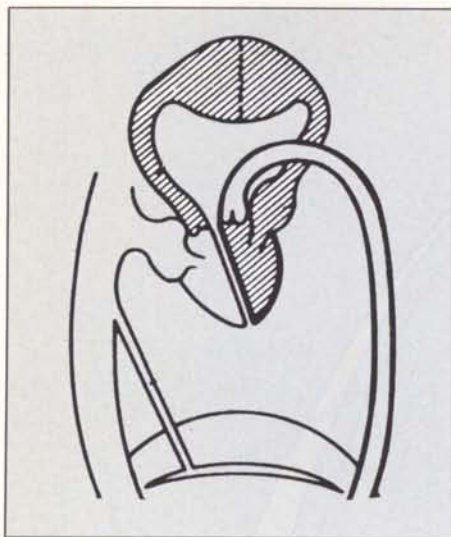


Figure 11 – The Spacelab 32 Mbit/s High-Data-Rate Recorder (HDDR) transport unit



Human Physiology Research under Microgravity Conditions and the Proposed 'Anthrorack' Facility

H. Oser, Microgravity Office, Directorate of Space Transportation Systems, ESA, Paris

J. Ives, Payload Technology Department, ESTEC, Noordwijk, The Netherlands

The Agency's Member States have adopted a Resolution to carry out a first phase of a Microgravity Research Programme covering the period 1982–1985. A proposal for the contents of a second phase is under preparation and will be decided upon in about one year's time.

A major element on this second phase is proposed to be the development of a multi-user facility, called 'Anthrorack', to be flown on Spacelab. It would support a wide variety of human physiological investigations on the crew members under conditions of weightlessness.

Introduction

The proposal to develop a multi-user facility is the direct result of the very evident and widespread interest within the Member States in performing research in human physiology. This interest is manifested by the high proportion of experiments of a physiological nature to be performed on the First Spacelab Mission; by the large response to the earlier preliminary call for experiment proposals for the then planned follow-on Spacelab missions; and by the high priority assigned to this area of microgravity research by the ESA Life-Science Working Group, representing the research interests of life scientists within the Member States.

The research areas that should be addressed involve numerous problems of basic interest to physiologists; perhaps the most interesting to emerge so far is the biological significance of gravity effects on man, a subject that is still poorly understood.

The physiological events briefly referred to involve significant sectors of cardiovascular, body fluid, renal, electrolyte, endocrine, and sensori-motor, muscle and bone systems in human physiology. Some changes occur relatively rapidly and are reversible on return to Earth. Others develop more slowly, and there is valid concern that continuing processes, if permitted to go on long and far enough, may result in irreversible patho-physiological changes. The scientist's main concerns are centred around those research areas where the investigators know that gravity plays a key

role in the systems to be studied and that these interactions (processes, mechanisms, etc. on a direct or even indirect level) can only be revealed if all the systems in one (i.e. man himself) are exposed to a microgravity environment.

The first step towards the development of a suitable tool to support these investigations has now been completed. This has been achieved by means of two parallel studies, performed within industry, to develop a system concept for a multi-user, reusable physiological research facility to be flown on Spacelab, and to demonstrate the resulting concept feasibility.

The following paragraphs describe more fully the above areas of scientific interest and the typical measurement techniques to be applied. Finally, the outcome of the industrial feasibility studies on the Spacelab 'Anthrorack' facility is presented.

Scientific Objectives and Procedures

The general scientific objectives for physiological experimentation on man under microgravity conditions are summarised in ESA Brochures BR-01 and BR-09 and ESA Special Publication SP-180. A recent concept and feasibility study resulted in a concept for a facility (Anthrorack) that can serve for the study of three main fields of human physiology under microgravity:

- Cardiovascular/pulmonary function and adaptation (subgroups: central circulation, peripheral circulation, and respiration)

Figure 1 — Possible concept for Anthrorack within the Spacelab Module

- Metabolic processes and adaptation (the energy metabolism, global and local, the fluid-electrolyte and the hormonal functions which have been demonstrated to play a decisive role in the overall adaptation of the above fields)
- Sensori-motor functions and adaptation [defined as the interactions between visual, tactile, proprioceptive (= muscle feedback), and other (artificially stimulated) impulses on the one hand and the muscular responses on the other].

In order to challenge the physiological regulatory mechanisms it is important to be able to subject the individual being investigated to controlled stimuli, which may be either natural stimuli (e.g. as during muscle function and exercise) or

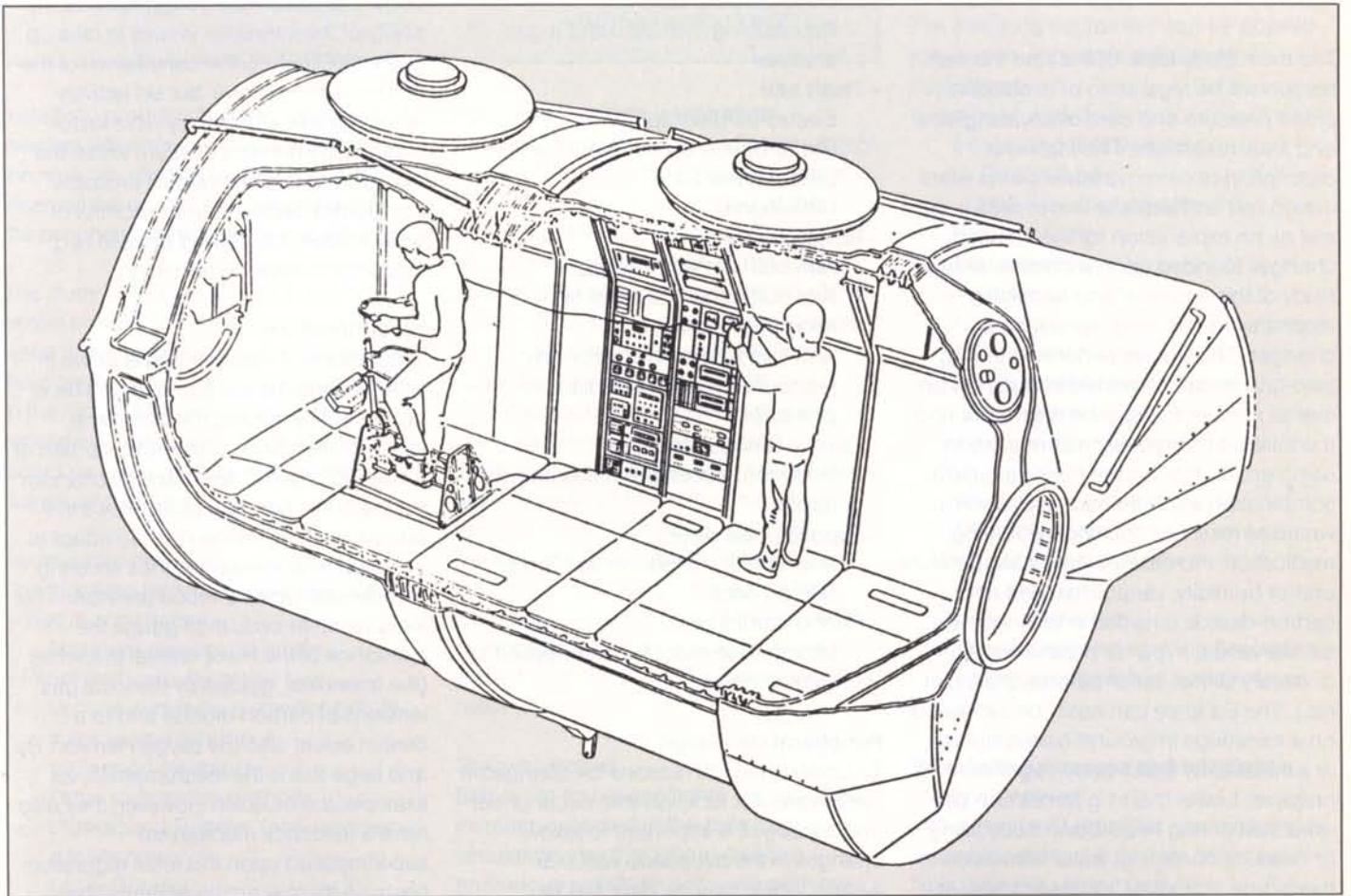
stimuli introduced artificially (e.g. electric stimulation of muscle, alteration of partial pressure of oxygen or carbon dioxide in the inspired air). The study therefore included the equipment for dynamic and static exercise (arm and leg ergometer, which can be set at a certain work load), equipment for optical, acoustic, and electrical stimulation, equipment for changing respiratory gases, etc.

Cardiovascular/pulmonary function and adaptation

Central circulation

The arterial pressure produced by the heart secures an adequate blood flow to all organs and is the driving force for the blood circulation. Hydrostatic forces are added to the intravascular pressures, hence creating an outward diffusion of fluid (= oedema formation) in the parts of

the body below heart level, especially the legs, in the upright position under the influence of 1 g. During his evolution, man has developed a reflex mechanism via contracting arteries and veins in the lower part of the body to counteract oedema formation to a very large extent. If, however, the cardiovascular system is exposed to zero-gravity conditions, the hydrostatic pressure differences are immediately abolished, which causes a rapid displacement of about 2 litres of blood and tissue fluid from the lower extremities towards upper regions of the body, leading to distension of the central veins and the heart chambers. This massive redistribution of blood directly interferes with cardiac activity, reflexly influences the control of circulation, and changes the pattern of salt and water excretion by the kidneys.



Blood circulation is of decisive importance for the optimal functioning of any organ in the body. It is therefore difficult to separate the overall physiological study objectives into themes concerning a single organ or organ system. The central and peripheral circulations 'collaborate' to achieve the desired arterial flow and pressure to the organs they serve, and to establish feasible homeostasis. These processes are mediated through the nervous system at different levels of integration, ranging from local nerve traffic, which does not pass through the 'relay stations' of the spinal cord or higher centres, to emotionally released effects upon heart rate and distribution of blood (e.g. blushing). The investigations of circulatory parameters must, therefore, be interpreted against a certain 'noise' background, which during spaceflight will depend upon many known and unknown factors.

The main study topic of this and the next section will be *regulation of circulation, blood pressure and cardiovascular global and local resistance*. This implies a *description of cardiovascular parameters during rest and exercise under zero-g*, as well as an explanation for the induced changes founded upon a comprehensive study of the *neuronal and hormonal mechanisms inducing reproducible changes*. The studies performed during zero-gravity can be considered part of an overall attempt to describe the nature and modalities of cardiovascular regulation using gravity (Gz) as the main variable in combination with other acute or chronic variables (exercise, training, detraining, medication, increased or lower temperature and/or humidity, variable oxygen and carbon-dioxide tensions in the inspired air, starvation, hypo- or hyper-hydration or dietary stimuli, fat or carbohydrate diet, etc.). The Gz force can easily be increased on a centrifuge in ground-based studies or simulated by lower-body negative pressure. Lower than 1 g forces can be simulated during head-down body tilting or head (or chest)-out water immersion in thermo-neutral water. However, these last

two methods for simulating decreased or zero-gravity do not completely abolish residual hydrostatic gradients. Hence studies during true weightlessness become of prime importance for the interpretation of ground-based results and for the ultimate trial of current hypotheses on cardiovascular regulation.

Investigative methods

In the choice of methods the degree of invasiveness must be considered. Typically a noninvasive test will be preferred over an invasive procedure, but considering the long-range aspects a certain degree of invasiveness might be more liberally accepted.

Typical methods of investigating the above system(s) (or objectives) would include:

- Cardiac output
 - Echo-cardiography
 - Rebreathing method using a gas analyser
- Heart rate
 - Electro-cardiography
 - Photo-optical sensor (ear lobe)
 - Laser sensor (skin)
 - Ultrasound
- Blood pressure
 - Arm cuff with stethoscope
 - Arm cuff with ultrasound or microphone sensor
 - Arm-cuff system with automatic readout of systolic and diastolic pressures
- Central venous pressure
 - Intravenous pressure-measurement device
- Carotid pulse wave
 - Mechanical transducer applied to skin on neck
- Phono-cardiogram
 - Microphone pick-up head applied to skin on chest.

Peripheral circulation

To understand the reasons for changes in cardiovascular function that occur under microgravity, it is important to follow changes in the peripheral vascular system, which may be identified by

measurement of: flow, resistance, venous compliance and volume, and swelling or dehydration of subcutaneous and muscle tissue.

Whereas disturbances of arterial haemodynamics, with possible deleterious consequences for the proper blood supply to the brain, heart and kidneys, were not expected, the observation of a dramatic shift of blood into the cephalad regions of the low-pressure system (Fig. 2) came as a great surprise.

Anthropometric measurements show that, immediately after the weightless state has been attained, about 2 l of blood and interstitial fluid are translocated from the lower portions of the body. This is much more than can be expected from the disappearance of hydrostatic pressure differences along the long axis of the body. The observation suggests that the ability of the interstitial tissues to take up and expel fluid, i.e. the compliance of the tissues is not passive but set actively along the axis of the body. This factor presumably remains obscure within the 1 g environment, although it probably contributes decisively to the control of body fluids in health and disease (e.g. tendency to oedema formation).

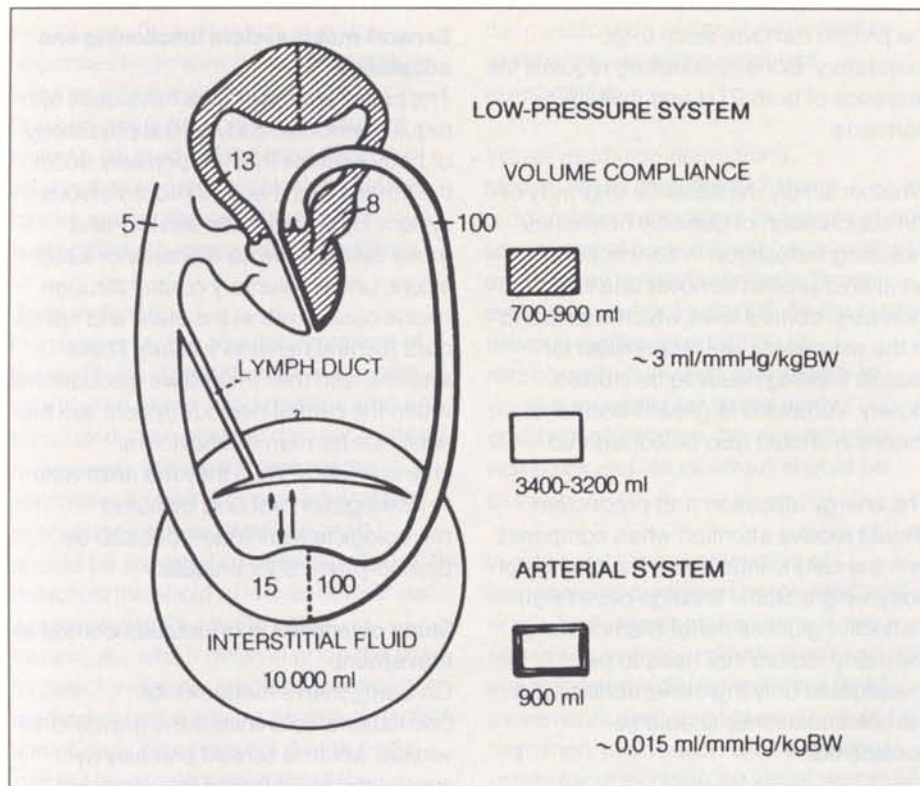
Study objectives

The peripheral vascular bed is active in redistributing the cardiac output. This is performed by varying the peripheral vascular resistance in the vascular bed of a specific organ. A feedback mechanism via the aortic baroreceptors allows the pumping activity of the heart to adapt to the peripheral resistance, thus securing an adequate arterial blood pressure. The local vascular beds then gauge the resistance of the finest arterial branches (the arterioles), guided by the local gas tensions of carbon dioxide and to a certain extent also the oxygen tension. By and large this is the mechanism in, for example, the muscles. However, they also have a feedback mechanism superimposed upon this local regulation, because there is ample evidence that

Figure 2 — Distribution of blood volume and distensibility of the various compartments of the circulation in man. Numerals in various sections indicate mean pressure in mmHg in the supine position at normal gravity. The low-pressure system consists of the systemic veins, the right heart, and the shaded

area comprising the pulmonary circulation and the left ventricle in diastole. The low-pressure system holds 85% of the total blood volume, and the distribution of blood within the distensible walls of this system is greatly influenced by the direction of the force of gravity. In weightlessness, about 2 l of blood and

interstitial fluid are displaced from the legs into thoracic and cephalad portions of the low-pressure system (from Gauer, 1972)



metabolic products building up during exercise influence fine nerve endings in the muscles, eliciting a reflex that will increase the cardiac output and modify the peripheral cardiovascular resistance.

The study objectives should, therefore, centre around flow measurements and water fluxes in the peripheral tissues, and the interpretation of these measurements in the light of hormonal and nervous regulation. The regions to be studied would be brain, muscle, liver/spleen, kidney, and bone.

Investigative methods

The following techniques are available:

- Tissue compliance
 - Miniature ultrasound probe
- Peripheral vascular blood flow
 - Venous occlusion plethysmography
 - Indocyanine clearance
 - ¹³³-xenon clearance
 - Other radioactive methods
 - Ultra-sound Doppler (one- and two-dimensional)
 - Laser Doppler

Pulmonary system, respiration

The cephalad shift of fluid affects not only the heart, but also the lungs, the vascular bed of which is also distended at the expense of the air-filled parts. This will reduce the gas-exchange of the lung to an unknown degree. The right half of the heart pumps blood into the lung vascular bed, where it is oxygenated and then passed on to the left heart. The pulmonary vascular system has a low pressure (varying between 0 and 20 mmHg) and a low resistance, but the same amount of blood is pumped through this system as through the greater peripheral system. However, variations in the lung arterial pressure influence the functioning of the left heart as well as the cardiovascular reflexes elicited from the pulmonal artery and the heart chambers.

Study objectives

Before the first spaceflights, the pressure increase expected in the pulmonary circulation was thought to create a hazardous condition with lung oedema

and deteriorated lung function, threatening the life of the astronaut. Evidently this pressure increase is below the oedema-producing limit, but still very little is known about the inflight conditions of the pulmonary system. It is therefore important also to study events in the filling pressure of the lung cardiovascular system, the blood volume in the lungs, the diffusion capacity of the lungs, the tidal volume of air, the volumes during forced and maximal breathing, etc.

It is also known that hormonal and nervous mechanisms act upon the lung cardiovascular bed. The studies of these events will also be of importance for the deeper understanding of the cardiovascular function, not only in space, but also to elucidate the adaptive mechanisms under 1 g.

Investigative methods

The following equipment can be applied to measure important pulmonary parameters:

- Lung volumes
 - Integrating airflow meter
 - Fleisch tube
 - Hot-wire anemometer
 - Gas analyser
 - Dry spirometer
- Lung diffusion
 - Gas analyser
 - CO gas analyser
- Lung tissue and blood volume
 - Gas analyser
- Lung compliance and respiratory work
 - Air-pressure sensors
 - Magnetometers
- Lung capillary blood flow
 - Gas analyser
- Oxygen uptake rate
 - Gas analyser, integrating flow meter, ambient temperature and pressure.

Metabolic processes and adaptation

Study objectives

The absence of gravity is associated with a translocation of fluid from the lower limbs into the central vascular

compartment. It is thought that this induces a loss of sodium and water through the urine and a suppression of the thirst sensation, leading finally to a reduction in body weight. In the later phase of spaceflight, a seemingly inexorable and progressive loss of skeletal mass is observed. Furthermore an increased protein catabolism and muscle wasting lead to a further slight reduction in body weight. It needs to be pointed out here that bone and muscle wasting could not be prevented by vigorous training programmes, though these apparently gave relief as far as the central blood engorgement was concerned.

Five main problem areas may therefore be identified which need to be investigated in more detail, since they are of fundamental interest for terrestrial physiology, and can only be studied under zero gravity.

Food and fluid intake patterns are changed profoundly. Whether these changes are influenced by a decreased fluid demand and/or by disturbed day/night variations needs to be investigated.

Several mechanisms have been proposed to be responsible for the altered salt and water handling of the kidneys:

- change of haemodynamics in the kidneys
- suppression of the RAAS (Renin-Angiotensin-Aldosterone System)
- suppression of the ADH (antidiuretic hormone)
- increased secretion of natriuretic substance.

A persistent loss of calcium in the urine and faeces indicate the negative calcium balance. Hitherto unknown factors seem to influence both bone formation and bone reabsorption. Phosphorus balance parallels calcium findings and is consistent with increased bone resorption. Studies of the parathyroid hormone (PTH), calcitonin and the active metabolite of vitamin D in connection with

the protein turnover seem to be mandatory. Bone remodelling requires the presence of both PTH and thyroid hormone.

Whether simply the absence of gravity or the suppression of gonadal hormones including testosterone in connection with an altered protein turnover due to an increased cortisol level, which was found in the astronauts, are responsible for muscle wasting needs to be studied closely. Variations in growth-hormone secretion should also be considered.

The energy utilisation and production should receive attention when compared with the caloric intake and the change of body weight. Some findings point to an ineffective glucose metabolism. Among the many factors that need to be investigated only thyroxine, cortisol and the catecholamines should be considered.

Investigative methods

To obtain a better understanding of the metabolic changes in the human body, some astronauts should be allowed to establish their own food and fluid intake patterns within certain limits. Furthermore, their systems should be stimulated, for instance, by exercise. The blood samples should be drawn in relation to the food and fluid uptake, as well as before, during and after exercise. It is intended to store blood and urine samples in a freezer and to avoid inflight analyses as far as possible. For the near future, this procedure seems far more promising than providing the spacecraft with a very sophisticated biochemical laboratory and forcing the crew to perform difficult biochemical analytical procedures. Nevertheless, certain basic equipment will be mandatory:

- blood-sampling kits
- equipment for biopsy techniques
- centrifuge (1500 g)
- freezer/cooler (4°C, –15°C)
- urine collection equipment
- blood-density measurements.

Sensori-motor-system functioning and adaptation

The previous paragraphs have dealt with requirements for studying the physiology of body systems that are primarily under the control of the autonomous nervous system. By contrast, the sensory and motor systems are, to a greater or lesser extent, under voluntary control through neural centres within the brain and spinal cord (central nervous system). These systems, and their integrative mechanisms within the central nervous system, are the substrate for man's behavioural characteristics. Thus they are amenable to investigation not only by purely physiological techniques, but also by psycho-physical techniques.

Study objectives in orientation/control of movement

On Earth, man's fundamental orientational reference is the gravitational vertical, which is sensed primarily by specialised receptors of the vestibular apparatus. These vestibular cues are complemented by information from other somatosensory mechanoreceptors and by vision. Indeed, in a conventionally structured visual environment, orientation and postural equilibrium can be maintained solely by visual cues.

In microgravity the coherence of mechanoreceptor and visual cues, exhibited in terrestrial life, is disturbed. Information from the semicircular canals and the eyes is largely unchanged, but the signals transmitted by otolithic, proprioceptive and tactile receptors will be appreciably modified. Thus orientational function and the control of movement are likely to be disturbed until new neural associations and response hierarchies are elaborated in the process of adaptation to microgravity.

The study of microgravity neural mechanisms concerned with orientation and the control of movement may be classified as follows: (a) study of specific (primarily otolithic and somatosensory) sensory systems using psycho-physical

procedures; (b) evaluation of motor responses engendered by these sensory systems; (c) assessment of interactions between visual and nonvisual sensory systems; (d) study of the organisation of volitional movement; (e) study of causal factors and individual differences in susceptibility to space motion sickness.

Sensory function

In microgravity the otolithic receptors of the vestibular apparatus fail to provide information about head position and are stimulated in an atypical manner by head movements. Means to measure the sensitivity of otolithic receptors and the processing of their afferent signals should be provided by determination of the detection threshold of whole-body linear accelerations. Psycho-physical techniques, which depend upon the time to detect a step acceleration or upon a method of limits utilising oscillatory motion stimuli, may be employed. As the body cannot be accelerated without the application of force and the stimulation of cutaneous (and other somatosensory) mechanoreceptors, additional experiments should be carried out to determine if changes in the threshold for the detection of forces applied to the skin, occur in the absence of any stimulation of vestibular receptors. In addition to measures of threshold, subjective scaling techniques could be employed to study the perception of supraliminal stimuli in this sensory field.

Motor responses

The vestibular system exercises appreciable control over eye movements and, to lesser extent, the somatic musculature. The measurement of motor responses to vestibular stimuli can hence provide important information about the organisation of the neural system. A number of infrared techniques are available for recording eye movements which can be employed during stimulation of the semicircular canals and otoliths, by angular and linear accelerations, respectively. Responses to otolithic stimuli are of primary interest, but

the modification of canal responses by otolithic inputs is also worthy of investigation.

Visual-vestibular interactions

Moving visual (optokinetic) stimuli produce eye movements (nystagmus) and sensations of body motion (vection) that are in many respects similar to those evoked by vestibular stimuli. As the central nervous system, in adapting to microgravity, is likely to give priority to visual over vestibular (particularly otolithic) information, the interaction of vestibular and visual stimuli should be studied.

In addition to the examination of responses to combined optokinetic and whole-body linear-motion stimuli, the patterning and co-ordination of head and eye movements during volitional head movements and visual pursuit should be examined. Information on the effect of vestibular stimulation on visual perception may also be obtained by study of the visual illusions of movement that occur when the test subject observes a head-fixed visual display whilst exposed to whole-body linear or angular accelerations.

Volitional movement

The complex sequence of muscle activity involved in the generation of precise and coordinated movement of the limbs and fingers will differ in microgravity from that which occurs in a normal gravity (normogravic) environment. Not only will proprioceptive information from muscle, tendon and joint receptors be different, but the forces required to move the limbs and stabilise position will be altered. Visual monitoring of the movement permits the rapid development of new motor strategies, but it is of interest to determine the time scale of adaptation and when precise movements can be achieved in the absence of vision.

Dissection of some of the factors influencing the performance of fine volitional movements can come from

psycho-physical experiments to investigate: (a) the accuracy of the test subject's perception of his own orientation within Spacelab and the location of objects within the vehicle; (b) his perception of the relative orientation of his body segments (proprioceptive function); and (c) his perception of the size and mass of objects that he is given to handle (mass discrimination).

Investigative methods for orientation/control of movement

Methods available for these investigations include the following:

- Stimulation of the vestibular system can be achieved either by active (voluntary) head movements or by mechanical devices which expose the test subject to controlled linear or angular motion stimuli. For the study of sensory thresholds using oscillatory motion, linear accelerations of approximately 0.2 m/s (pk half amplitude) or angular velocities of approximately 3°/s (pk half amplitude) are needed. Motion stimuli with an intensity about one order of magnitude greater are required when evoked vestibular responses are to be studied.

Optokinetic stimuli, in particular visual motion stimuli which induce vection, should subtend a large angle (not less than $\pm 45^\circ$) and excite a substantial area of the peripheral retina. Visual stimuli presenting motion cues in translation or rotation can be generated by purely optical techniques (e.g. projected image) or electronically with display on a cathode-ray tube or opto-electronic device, with or without additional optics. Stimulation of cutaneous receptors for the proposed psycho-physical experiments can be achieved by a range of electro-mechanical, or fluid-powered devices of varying complexity in their electronic control. However, like the mechanical equipment required to

produce passive movement of the limbs and fingers (for the study of proprioceptive perception), there is no 'standard' experimental hardware.

- Several techniques exist for the recording of eye movements. Electro-oculographic (EOG) and IR reflection methods transduce only vertical and lateral movements. To record eye movements in roll (i.e. about the x-axis) an image of the eye has to be recorded either by a photographic or TV technique, preferably with IR illumination of the eye as the presence of a visible target suppresses eye movements induced by vestibular stimuli. A coil or coils mounted on a contact lens with the head positioned in an AC field is a highly sensitive method of recording eye movements in all three axes, but the technique may not be acceptable on Spacelab because of electromagnetic interference.

Study objectives in posture

In the normogravic environment, man maintains his upright posture and equilibrium by the sustained and coordinated activity of muscle groups (the agonists and antagonists), which are under continuous dynamic control from neural centres in the spinal cord, brain stem, cerebellum and higher centres. These, primarily, reflex mechanisms are dependent upon afferent information from somatosensory mechanoreceptors (in muscles, joints and skin), from the vestibular apparatus (of the inner ear) and from the eyes. With the exception of vision, these afferent systems utilise mechanoreceptors which are stimulated in an atypical manner by the force environment of microgravity. Studies carried out following exposure to microgravity have demonstrated appreciable disturbance of postural equilibrium, with recovery taking two to three weeks. To date, however, only very limited experiments have been carried out during orbital flight which identify the nature and time course of the adaptive

modifications of neural mechanisms subserving the maintenance of posture.

Analysis of postural mechanisms is facilitated by the experimental manipulation of variables that are known to be involved in the control of posture. The experimental approaches that could be employed in Spacelab are:

- *Study of static posture.* Measurements are made of postural activity of a test subject who attempts to maintain a normal 'upright' posture when his feet are fixed to the floor of Spacelab.
- *Effect of loading by endogenous and exogenous forces.* The modification of postural activity when the body is loaded by a sustained external force (e.g. by elastic cords) will provide further information and also generate significant reactive forces that are amenable to stabilometric analysis. In addition to the study of 'static' postural activity, dynamic responses to transient endogenous and exogenous perturbations, produced by active movement of, say, the upper limb of the test subject and by a briefly applied external force, should be examined. Such experiments differentiate between postural reactions that are anticipatory to voluntary movement and those that are engendered by movement. In view of the known importance of joint receptors (particularly ankle-joint receptors) in postural control, responses should be recorded of a subject fixed to a stabilometric platform which can be tilted or translated to give a transient controlled displacement of the feet and hence a more specific stimulus to mechanoreceptors of the ankle joint and associated musculature.
- *Effect of visual stimuli.* The importance of visual stimuli in the hierarchy of neural systems regulating posture is well established and it is postulated that in the initial stages of adaptation to microgravity, visual information plays a pre-

eminent role. The effect of the presence or absence of vision on the static and dynamic assessments of postural function (detailed above) can be readily determined by carrying out the tests with eyes open and closed. In addition, stimulation of the ambient visual system by optokinetic patterns that are capable of inducing illusory sensations of body movement (vection) can be used to challenge postural control mechanisms.

Investigative methods for posture

A number of techniques, appropriate for use in Spacelab, are available for the study of posture and the nature of postural responses to perturbations of relevant afferent and efferent systems:

- The position and movement of the whole body can be recorded on cinefilm or by closed-circuit TV for subsequent photogrammetric analysis.
- The spatial co-ordinates of LED markers fixed to specific points on the surface of the body can be directly transduced by an optoelectronic system ('Selspot').
- Deflection and movements of limbs can be transduced by angular or linear potentiometers (or equivalent inductive devices) appropriately coupled to the limb segment.
- Movements involved in postural adjustments can be transduced by accelerometers (angular and linear) or angular-rate gyros fixed to the body, head or limbs of the test subject.
- Activity of muscles involved in postural activity may be recorded by means of surface or needle electrodes and appropriate biological amplifiers. These electromyographic (EMG) responses are more easily quantified if the EMG is rectified and integrated.
- Shifts in the direction and intensity of reactive forces may be detected by load cells fitted to a stabilometer

(posture) platform. This type of device is commonly used on Earth for the study of postural stability and in shifts in the centre of mass. However, in microgravity external forces have to be applied to the body (e.g. by elastic cords) in order to generate reactive forces between the subject's feet and the instrumented platform.

Stimuli to be applied

One of the main objectives in human physiology is to describe the regulatory mechanisms behind homeostasis. One way that has been extensively used is to observe the reaction of the system to different stimuli. Microgravity is of course the predominating stimulus, but the study should also allow for the use of other stimuli such as: bicycle ergometers (arm- or leg work), strength dynamometers and other stimulation devices, such as electric optical and acoustic stimulation equipment. The stimuli should be controllable, reproducible, and measurable. In addition, 'biochemical stimulations', e.g. glucose-tolerance or ACTH response, should be possible. Many of these stimulation techniques have already been identified in earlier sections.

The Multi-User Facility Concept

Resulting from this broad and widespread scientific interest, the Agency conceived of the development of a multi-user, general-purpose facility, to be flown on Spacelab, providing the necessary stimulus and measurement equipment to support these physiological investigations under weightless conditions.

The main objectives for this facility, now known as Anthrorack, are:

- to provide the tool to support many individual investigations from all the previously mentioned subdisciplines of human physiology, in particular
 - cardiovascular/pulmonary function and adaptation
 - metabolic processes and adaptation

- sensori-motor function and adaptation,
- to be capable of reflight on several Spacelab missions,
- to provide, as part of the facility, a basic set of stimulus and measurement equipment common to many investigations and accommodation for add-on equipment more specific to a particular investigation
- to offer the capability to adapt the complement of equipment between missions so as to meet better the scientific goals selected for a particular mission and to take advantage of new innovations in measurement techniques
- to centralise and automate as far as possible the coordination, control, data collection and display functions of the many individual instruments so as to achieve an integrated functioning of the complete facility. This approach offers the possibility of increasing the number of instruments accommodated within the facility by minimising the duplication of such service functions within each instrument. In addition, it offers savings in crew time by minimising the manual tasks involved in experiment preparations.

These prime facility objectives were further qualified by a number of additional requirements:

- to provide a simple and ergonomically designed human interface, thereby further minimising crew-time requirements
- to provide simple interfaces to the add-on equipment
- to accommodate the required complement of equipment within a Spacelab double rack and some limited additional passive storage space
- to take advantage of well-established terrestrial measurement methods and techniques in as far as these are compatible with the specific requirements of manned spaceflight

(e.g. safety, volume and power requirements, etc.)

- to seek cost-effective use of existing commercial equipment.

Concept feasibility

Two parallel studies have been performed within industry to develop these initial objectives into a preliminary concept, to investigate its general feasibility, and to establish a preliminary development programme and cost estimate.

As no definitive experiment proposals are available at present, the inputs to these feasibility studies were the description of the general scientific objectives and the facility technical objectives as listed above. In addition, the contractors were provided with a list of equipment to be accommodated within Anthrorack. This list of equipment was divided into two categories, 'Service Elements' and 'Experiment Specific Equipment', defined as follows:

- Service Elements: items of equipment employed by all or, at least, many of the conceived investigations from all three major scientific subdisciplines
- Experiment Specific Equipment: items of equipment required by only a single or a limited number of investigations.

According to the facility objectives, the Service Elements would be provided as part of the facility, whereas the Experiment Specific Equipment would be developed and provided by the individual investigator(s) requiring that equipment. The facility, however, would accommodate and provide centralised services (power, control, data display and recording, etc.) to the Experiment Specific Equipment.

The list of equipment, subdivided into these two categories, is presented in Table 1. The three right-hand columns of this table attempt to justify the division of equipment between the two categories by allocating a relative importance for each

item under each of the three major areas of scientific investigation.

The generalised study logic employed to demonstrate the feasibility of the Anthrorack concept is shown in Figure 4.

In the course of the studies, it was necessary to investigate further the interrelationships between the different items of equipment and between these and the various areas of investigation. This required the preparation of a number

of 'model' experiments representing typical investigations from all three major scientific subdisciplines. The definition of these model experiments was developed to the point where equipment requirements could be identified and likely operational procedures and timing established. These model experiments were then grouped into 'model' payloads, thus allowing typical mission equipment complements and typical mission operational sequences to be developed.

Several groupings were considered, including missions that included investigations from all areas of interest as well as missions that limited their objectives to only one or two of these major areas.

In parallel, potential candidates for each item of equipment were identified, allowing the resource requirements for each to be established. To do this, possible alternative measurement techniques were assessed and selected according to their measurement capabilities and with respect to the constraints imposed by their use in manned spaceflight. Thereafter, actual items of equipment were identified, making use where possible of already flight-qualified equipment or commercial equipment capable of being modified cost-effectively to flight standard. Where no such items could be found, initial design concepts and associated resource requirements were prepared.

Finally, the results of the typical mission complements and operational sequences, developed from the model experiments, were combined with the information on the selected items of equipment, to develop physical accommodation concepts and to derive overall system resource requirements, such as average and peak power requirements, total energy and crew time requirements.

The major conclusions of this work may be summarised as follows:

— A feasible concept for Anthrorack, in

Table 1 — Anthrorack equipment list and identification of Service Elements and Experiment-Specific Equipment

Equipment	Topic of investigation		
	Cardio-vascular	Biochemical, normal	Sensori-motor
<i>Service Elements</i>			
Facility computer	+	+	+
Displays (alphanumeric, oscilloscope, video)	+	+	+
Data and voice recording	+	+	+
Power supplies	+	+	+
Modular support system for expt.-specific equipt.	+	+	+
Orbiter mid flight deck temp.-controlled storage	+	+	0
General Spacelab stowage	+	+	+
Module ambient condition monitoring	+	+	+
<i>Experiment-Specific Equipment</i>			
Centrifuge	+	+	0
Blood sample collection kit	+	+	0
Urine sample collection kit	+	+	0
Freezer, cooler	+	+	0
Respiratory gas analysis system	+	+	0
Special gas supplies for rebreathing exercises	+	+	0
Sensors (e.g. ECG, EOG, EMG, EEG, etc.) + amplifiers	+	+	+
High-resolution TV camera	0	0	+
Peripheral blood-pressure measurement	+	+	0
Plethysmograph	+	+	0
Electrode impedance meter	+	+	+
Manual response recording device (joystick)	0	0	+
Ergometer	+	+	+
Dynamometer	+	+	+
Muscle electrical stimulation pulse generator	0	0	+
Eye stimulation visual pattern generator	0	0	+
Visual task generator	0	0	+
Ocular pressure-measurement device	+	+	0
Ophthalmoscope	+	0	0
Central venous pressure measurement	+	+	0
Tissue compliance measurement (ultrasound)	+	+	0
Central and peripheral blood flow (Doppler ultrasound)	+	+	0
Blood-density measurement	+	+	0
Echocardiographic system	+	0	0
Eye-movement measuring system	0	0	+
Skin blood flow (e.g. laser Doppler)	+	+	0
Rotating chair	0	0	+
Linear-motion device	0	0	+
Posture platform	0	0	+
Arm-movement stimulation and recording device	0	0	+

+++ Highly applicable

0 Not applicable

Figure 3 — Typical accommodation concept for the Anthrorack facility

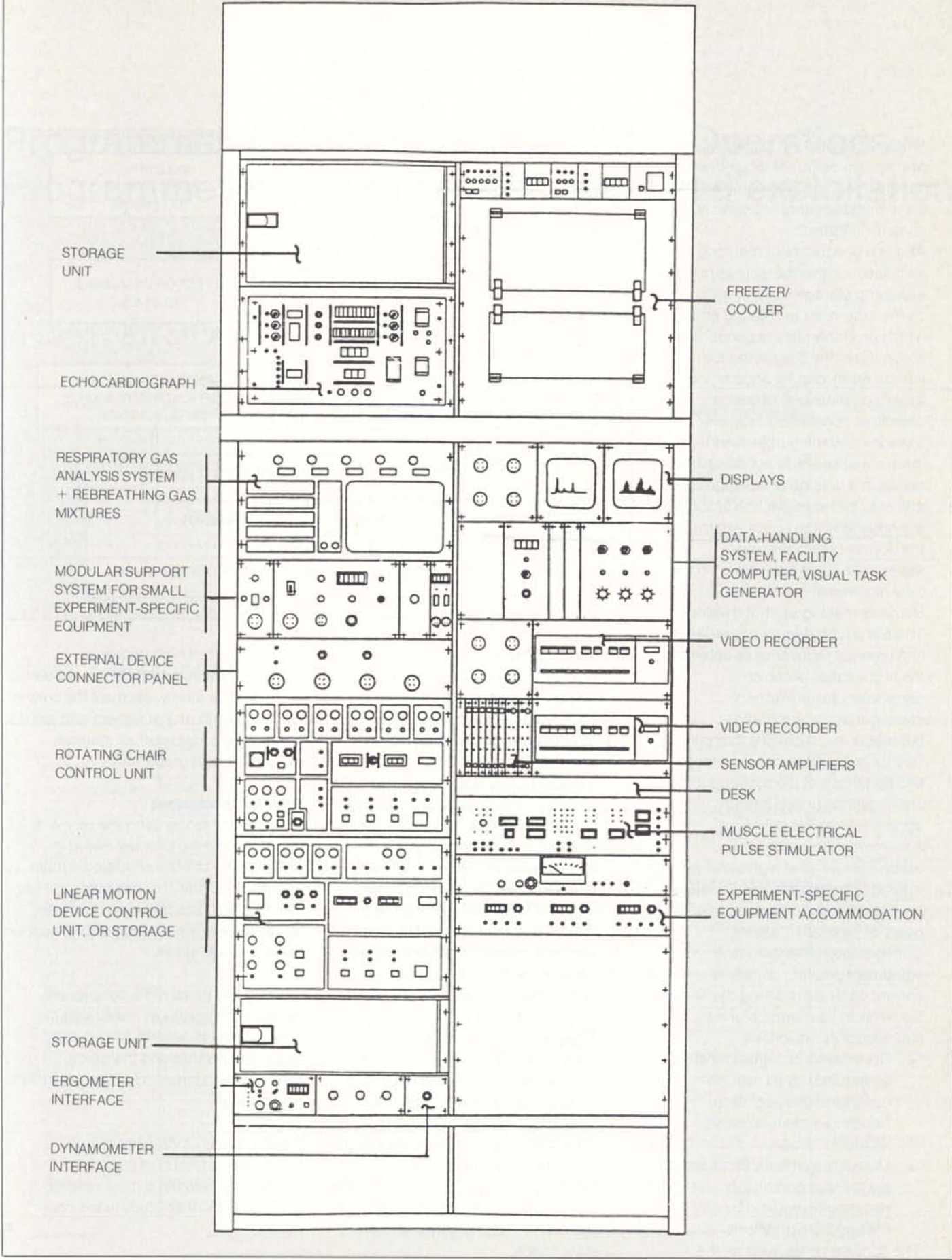
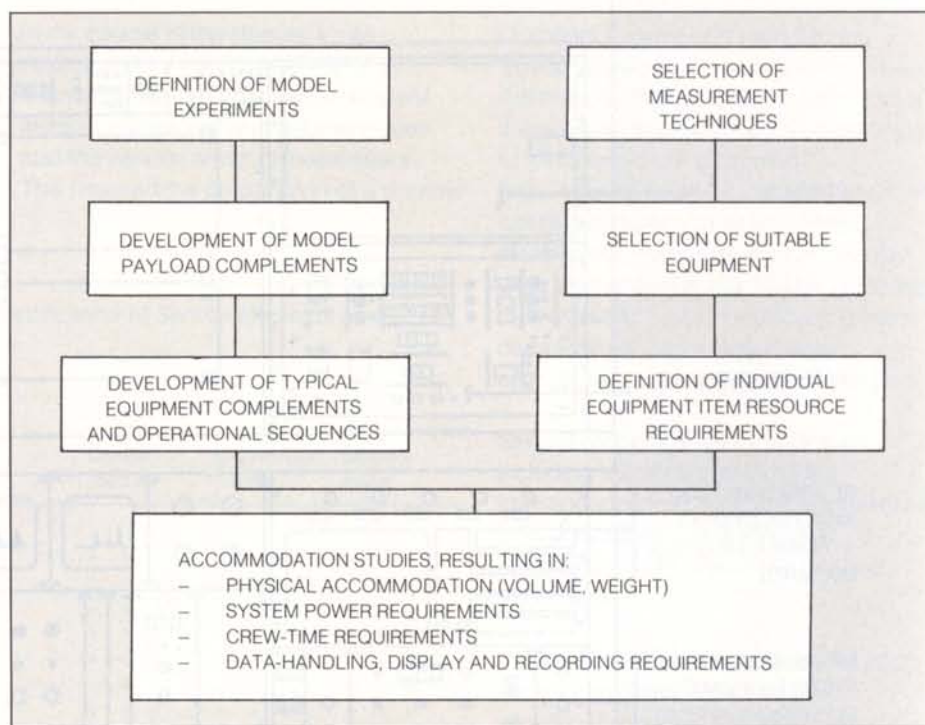


Figure 4 — Study logic



terms of physical accommodation and system-resource requirements, is achievable. Typical accommodation for a multidisciplinary mission is shown in Figure 3.

- All items of equipment requiring installation within the double rack, i.e. excluding storage items or such items as the ergometer or rotating chair which probably require permanent mounting in the Spacelab module (centre aisle), can be accommodated for all combinations of mission objectives considered. However, a mission combining objectives from all three major scientific subdisciplines results in a volume of stowage items that may be excessive (the amount of available stowage space external to the double rack is mission-dependant, since it depends on the total requirement of all payload elements making up that mission).
 - There is a high degree of overlap in instrumental requirements between the two subdisciplines of cardiovascular/pulmonary investigations and metabolic processes investigations, but only very limited overlap between these two and those of the sensori-motor investigations (this is already apparent from Table 1). Accommodation problems associated with the high stowage volume requirements can therefore be alleviated by limiting the scientific goals of separate missions.
 - Configurational flexibility and equipment packing density is enhanced by considering the Service Elements to be made up of two subcategories, as follows:
 - Core elements: items identified to be required by all mission configurations (e.g. data-handling system, displays, recorders, etc.).
 - Multiuser elements: items serving a wide user community, but not necessarily required by all mission configurations.
- The core elements, such as the

facility computer, centralised data display and recording devices, would be permanently installed within the rack, whereas the multiuser elements may be replaced either by other equipment or by additional storage lockers. To make such reconfigurations possible, a degree of modularity and easy accessibility must be incorporated into the design of the multiuser elements, which tends to lower the packing density achievable for these items. The permanent installation of the core elements makes possible a higher packing density, enhancing the accommodation capacity for the other equipment.

- The concepts developed have made possible a high degree of centralised, automated control, data acquisition, recording and display, with the possibility of some centralised preprocessing of data. Furthermore, the concept enables the extension of these services to Experiment-Specific Equipment mounted within the rack by means of standard control and data buses.

- Despite this high degree of automation, Anthrorack is a crew-intensive facility, because the crew is used both as test subject and also for considerable residual manual experiment preparation.

General conclusions

The Agency, recognising the very wide interest within the Member States in investigating human physiology under weightless conditions, has taken the first step towards establishing a multi-user facility to be flown on Spacelab to support these scientific goals.

Industry has prepared a conceptual design for Anthrorack, confirming the latter's ability to achieve the scientific goals and establishing the typical resource requirements for and constraints on its design.

It is the Agency's intention to pursue further the definition of this facility concept by initiating a more detailed concept evaluation study in the near future.

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

In Orbit / En orbite

PROJECT	1983	1984	1985	1986	1987	1988	1989	COMMENTS
SCIENTIFIC PROGRAMME								
ISEE-B	-----							
IUE	-----							
APPLICATIONS PROGRAMME								
OTS-2	-----							
MARECS-A	-----							
METEOSAT-1	-----							LIMITED OPERATION ONLY (DCP)
METEOSAT-2	-----							

Under Development / En cours de réalisation

PROJECT	1983	1984	1985	1986	1987	1988	1989	COMMENTS
SCIENTIFIC PROGRAMME								
EXOSAT	-----							LAUNCHED 26 MAY
SPACE TELESCOPE	-----							LIFETIME 11 YEARS
ISPM	-----							LIFETIME 45 YEARS
HIPPARCOS	-----							PRELIMINARY SCHEDULE
GIOTTO	-----							HALLEY ENCOUNTER MARCH 1986
APPLICATIONS PROGRAMME								
ECS-1 & 2	-----							ECS-1 LAUNCHED 16 JUNE
ECS-3, 4 & 5	-----							LAUNCH/OPERATION ONLY IF REQUIRED TO REPLACE ECS-1 & 2
MARECS-B2	-----							LIFETIME 5 YEARS
L SAT-1	-----							LIFETIME 5 YEARS
ERS-1	-----							LAUNCH END SECOND QUARTER 1988
SPACELAB PROGRAMME								
SPACELAB	FLIGHT 1	FLIGHT 2	FLIGHT 3	FLIGHT 4				
SPACELAB FOP	-----							
IPS	-----							
FSLP	-----							
MICROGRAVITY	-----							
EURECA	-----							
ARIANE PROGRAMME								
ARIANE PRODUCTION	-----							L11 ARIANESPACE LAUNCH
ARIANE 3 - FOD	-----							
ARIANE 4	-----							
ELA 2	-----							

= DEFINITION PHASE

> PREPARATORY PHASE

▣ MAIN DEVELOPMENT PHASE

■ STORAGE

◇ HARDWARE DELIVERIES

~ INTEGRATION

↑ LAUNCH/READY FOR LAUNCH

* OPERATIONS

- ADDITIONAL LIFE POSSIBLE

↓ RETRIEVAL

OTS-2

A la mi-mai, OTS-2 est entré dans sa sixième année d'exploitation. Tous les sous-systèmes, tant de la charge utile que de la plate-forme, continuent de bien fonctionner. Un programme chargé d'exploitation normale, d'essais spéciaux et de démonstrations est prévu pour le reste de l'année. La transmission de programmes de télévision entre pays européens, relayés par OTS-2, se poursuit jusqu'à ce que les satellites de la série ECS entrent en service et reprennent cette activité.

Bien que l'on ait initialement envisagé pour OTS une durée de vie en orbite de trois ans, les marges de masse ont permis de lancer la satellite avec environ cinq années d'ergols. Les réserves sont suffisantes pour poursuivre les opérations jusqu'à la fin de 1983. Après la prochaine manoeuvre de maintien à poste nord-sud, on réservera les quantités d'ergols nécessaires aux manoeuvres de maintien à poste est-ouest, qui demandent moins d'ergols, aux cas d'urgence et à l'exécution des essais prévus pour la fin de vie du satellite. On pourra ainsi, éventuellement, prolonger la vie opérationnelle du satellite jusqu'à la fin de la durée de vie prévue de 1984.

Météosat

Programme préopératoire

Secteur spatial

L'intégralité de la mission continue d'être assurée au moyen de Météosat-1 pour la mission de collecte de données et de Météosat-2 pour les missions de prise d'images et de dissémination. Quelques anomalies sont survenues mais aucune n'a été aussi sérieuse que celles de l'an passé. Le satellite P2 est toujours entreposé chez le contractant principal.

Secteur sol

Les opérations courantes se sont poursuivies selon leur cours habituel avec les deux satellites. La première manoeuvre de changement d'inclinaison de l'orbite de Météosat-2 a été exécutée en avril.

Le nombre des produits météorologiques sortis reste élevé: plus de 95% des produits prévus ont été distribués.

Programme opérationnel

La deuxième session de la Conférence

intergouvernementale sur un système Météosat opérationnel s'est déroulée au siège de l'ESA du 21 au 23 mars, avec pour résultat l'acceptation de l'offre faite par l'ESA de faire suivre le programme préopératoire d'une phase opérationnelle utilisant trois autres satellites pour la fourniture de services jusqu'à la fin de 1995. Cette offre a été officiellement acceptée par douze délégations à une Conférence que les plénipotentiaires ont tenue à Genève le 24 mai.

Exosat

Voir dernière information pages 14 et 18.

Télescope spatial

NASA

La NASA n'a pas encore pris de décision officielle sur la nouvelle date de lancement du télescope spatial mais un planning détaillé basé sur un lancement à mi-1986 est en cours d'élaboration. M. Jim Odom a remplacé le Dr F. Speer comme responsable NASA du projet de télescope spatial au MSFC.

Réseau solaire

L'analyse de la défaillance qui s'est produite sur le jeu de rechange des cassettes 'bi-stem' ayant suscité des doutes sur la qualité des cassettes de vol, les travaux ont été suspendus sur le mécanisme secondaire de déploiement.

Les essais dynamiques de système effectués avec la nouvelle électronique de commande du réseau solaire ont été concluants. Les essais de préqualification de l'électronique effectués avec un modèle d'identification ont eux aussi été couronnés de succès.

Les six échantillons de nappe soumis à des essais de cyclage sous vide thermique au MSFC ont supporté avec succès 15 000 cycles, ce qui correspond à l'équivalent de deux ans et demi d'exploitation en orbite.

Chambre pour objets de faible luminosité (FOC)

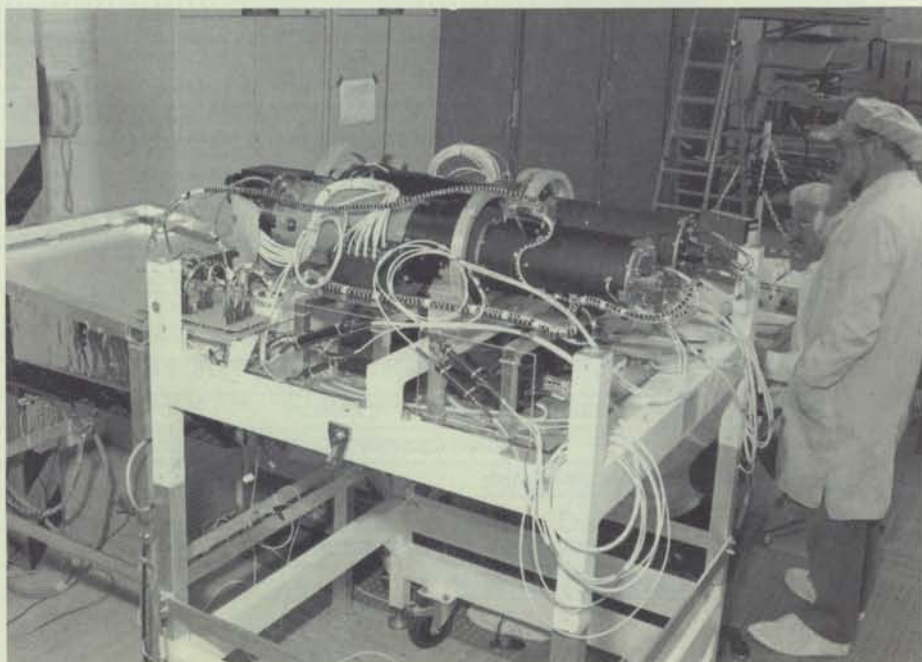
Les essais de système sur le modèle électrique du détecteur de photons, comprenant des essais de compatibilité électro-magnétique, ont été menés à bien. Le modèle de vol de la FOC a atteint le stade de l'alignement optique final et les préparatifs sont en cours pour l'installation du modèle de vol du détecteur de photons.

Détecteur de photons

Au cours des trois derniers mois, le modèle de vol du détecteur de photons a

Space Telescope Photon Detector Assembly/Electronic Bay Assembly compatibility test at Dornier, Friedrichshafen (Germany)

Essai de compatibilité entre le détecteur de photons et la baie électronique du Télescope spatial chez Dornier, à Friedrichshafen (Allemagne)



OTS-2

OTS-2 is now into its sixth year of operation, having completed five years in orbit in mid-May. All subsystems, both in the payload and the bus areas, continue to operate very satisfactorily, and a heavy programme of regular utilisation and special tests and demonstrations is planned for the rest of this year. Television transmission between European countries via OTS is continuing, until the ECS series of satellites take over this function once they are in operation.

Although OTS was designed originally for a three-year lifetime, mass margins made it possible to launch it with approximately five-years' worth of propellant on board. There is still enough fuel remaining, however, to continue operations throughout the remainder of 1983. After the next north-south stationkeeping manoeuvre, the remaining propellant will be reserved for the less demanding east-west manoeuvres, for emergencies, and for end-of-life test requirements. In this way, operating life well into 1984 can be projected, if required.

Meteosat

Preoperational programme

Space segment

A full service is still being provided, using Meteosat-1 for data-collection and Meteosat-2 for imaging and dissemination. A few anomalies have been experienced, but none as severe as last year's. The P2 satellite is still in storage at the prime manufacturer's facility.

Ground segment

Routine operations have been conducted as usual with both satellites. The first inclination manoeuvre with Meteosat-2 took place in April.

The output of meteorological products remains high, with more than 95% of scheduled products being distributed.

Operational programme

The second session of the Intergovernmental Conference on an Operational Meteorological Satellite System was held in ESA Headquarters on 21-23 March, and resulted in acceptance of ESA's offer to continue the pre-operational programme with an operational phase utilising three more

satellites for service until the end of 1995. The offer was formally accepted by twelve delegations at a meeting of plenipotentiaries which took place in Geneva on 24 May 1983 (see 'In Brief' for further information).

Exosat

For latest information, see pages 14 and 18.

Space Telescope

NASA

NASA have not yet taken a formal decision on the new launch date for the Space Telescope, but detailed planning is being established on the basis of a mid-1986 launch. Mr. Jim Odom has succeeded Dr. F. Speer as the NASA Space Telescope Project Manager at Marshall Space Flight Center.

Solar array

Due to some doubts about the quality of the flight bi-stem cassettes, which arose from the analysis of the failure that occurred in the spare bi-stem cassette unit, the programme for the secondary deployment mechanism has been put on hold.

The system dynamic tests conducted with the redesigned solar-array-drive electronics have been successful. The pre-qualification tests on the electronics, conducted with an engineering model, have also been completed satisfactorily.

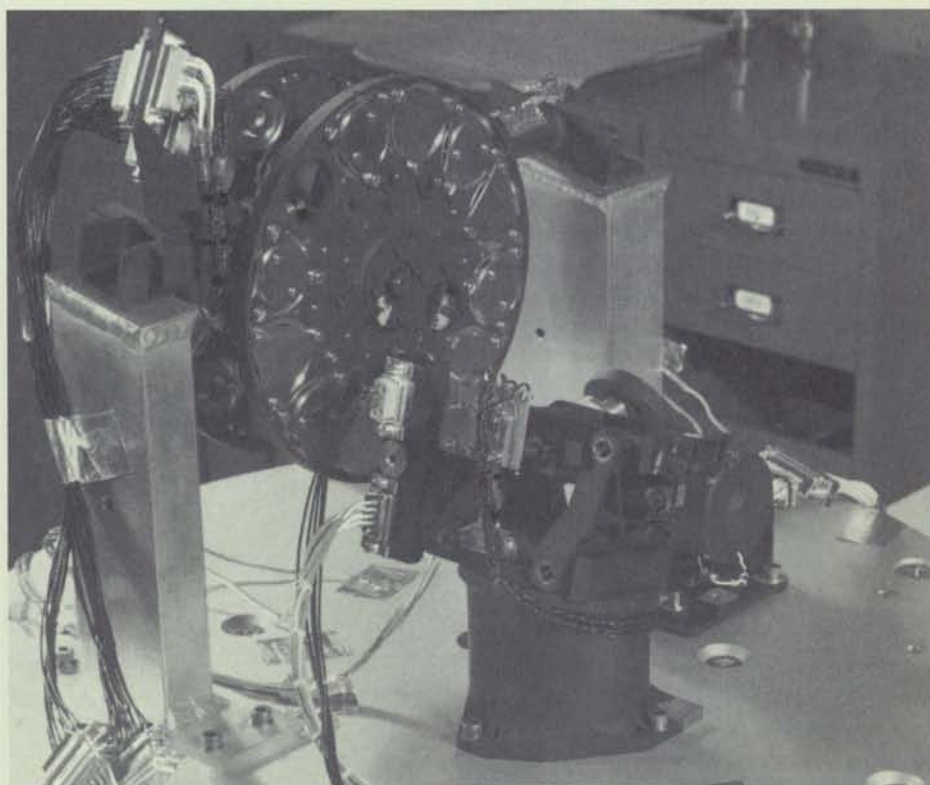
The six blanket samples undergoing thermal vacuum cycling tests at Marshall Space Flight Center have successfully passed 15 000 cycles, which is the equivalent of 2.5 years of operation in orbit.

Faint Object Camera

The FOC system tests with the electrical model of the Photon Detector Assembly have been finalised satisfactorily. These included EMC tests. The flight FOC is now undergoing final optical alignment and is being made ready for receipt of the flight PDA.

Le dispositif porte-filtres et le modèle de qualification de la chambre pour astres de faible luminosité du Télescope spatial au cours des essais d'endurance à l'ESTL, à Risley (R-U)

Space Telescope FOC qualification/life-test model filter-wheel mechanism undergoing life-testing at ESTL, Risley (UK)



été intégré et tous les essais d'ambiance prévus ont été menés à bien.

Les derniers essais de performances scientifiques de la deuxième chaîne du détecteur de photons sont en cours et la livraison du modèle de vol au contractant responsable de la FOC est prévue pour la mi-juin.

ISPM

Les activités du programme ISPM ont suivi leur cours et un certain nombre d'étapes importantes ont été franchies en juin.

A la mi-Juin a eu lieu aux Etats-Unis une série de réunions portant sur le lanceur et l'exploitation, notamment des réunions sur les interfaces gestionnels et techniques, les opérations au sol et la mission ainsi qu'une revue complémentaire de sécurité de phase 2.

La définition détaillée des interfaces entre les divers centres intéressés de la NASA et l'ESA a continué de bien progresser au niveau technique et au niveau des

procédures et on a rattrapé une grande partie du temps perdu du fait des incertitudes concernant les véhicules de lancement. L'esprit de coopération continue à se renforcer entre toutes les parties concernées.

Le programme d'intégration et d'essai du véhicule de vol s'est terminé chez le contractant principal. Le véhicule a été transporté le 6 juin au CNES pour les essais thermiques sous vide et les essais d'équilibrage thermique. Après un court essai fonctionnel pratiqué avec succès sur le véhicule spatial, on a commencé à installer sur le véhicule les équipements spéciaux nécessaires à l'exécution et au contrôle des essais thermiques sous vide devant commencer dès la deuxième semaine de juillet. Les travaux sur le sous-système de télécommunications ont progressé et le matériel aux normes de vol a maintenant été livré et intégré dans le véhicule spatial. La livraison de l'autre répéteur aux normes de vol, prévue pour le 20 juin, devait intervenir avant le début des essais thermiques sous vide en vue de remplacer l'unité utilisée pour les essais électriques qui, par suite de la modification tardive de la conception de l'émetteur en bande S, n'est pas

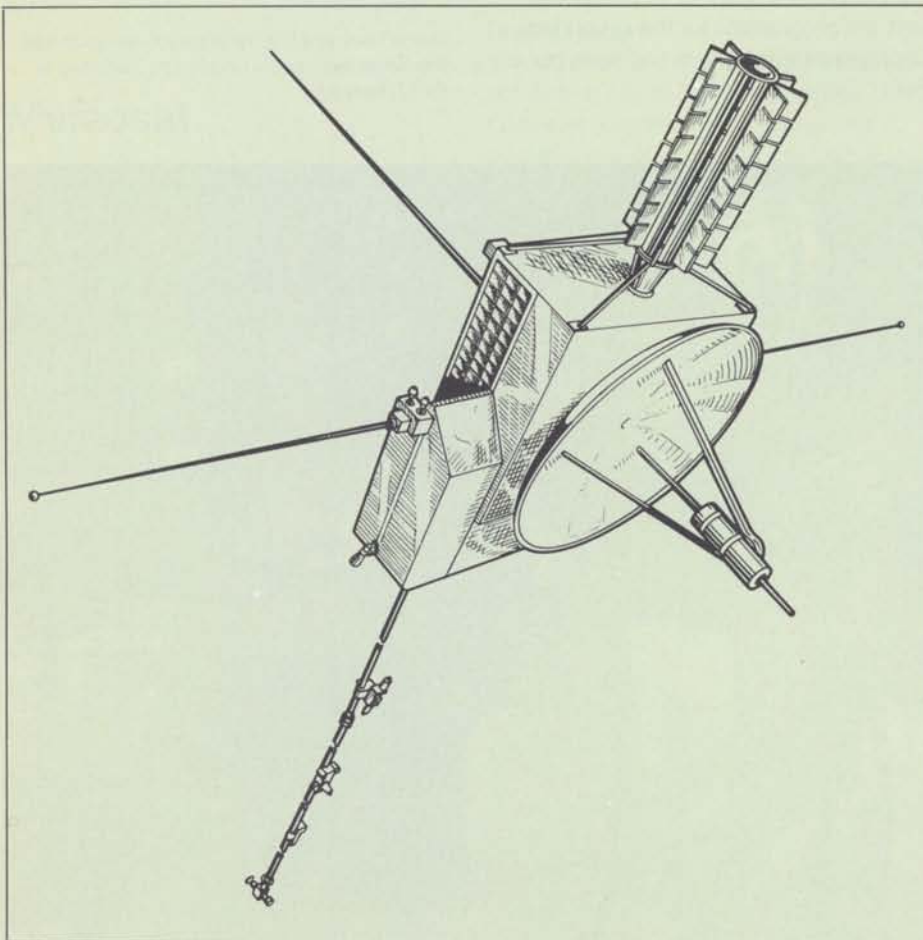
considérée comme conforme aux normes de vol eu égard aux impératifs rigoureux d'essais d'environnement.

Hipparcos

L'examen de définition des sous-systèmes d'Hipparcos, qui a eu lieu en décembre 1982, a confirmé que la définition technique avait évolué sur une base saine et qu'aucun problème majeur ne nécessitait la modification des directives données au contractant. Cet examen a également permis de fixer des priorités précises pour les activités de définition restant à exécuter au cours de la phase B2. Le calendrier de référence des phases B2 et C/D a été révisé et le démarrage de la phase C/D est actuellement prévu pour janvier 1984, la phase B2 étant prolongée jusqu'à fin 1983. L'examen préliminaire de la conception au niveau du système est fixé à juillet, les examens préliminaires de conception au niveau des sous-systèmes devant se dérouler courant octobre et novembre. La proposition formelle de l'industrie pour la phase C/D est désormais attendue pour fin septembre.

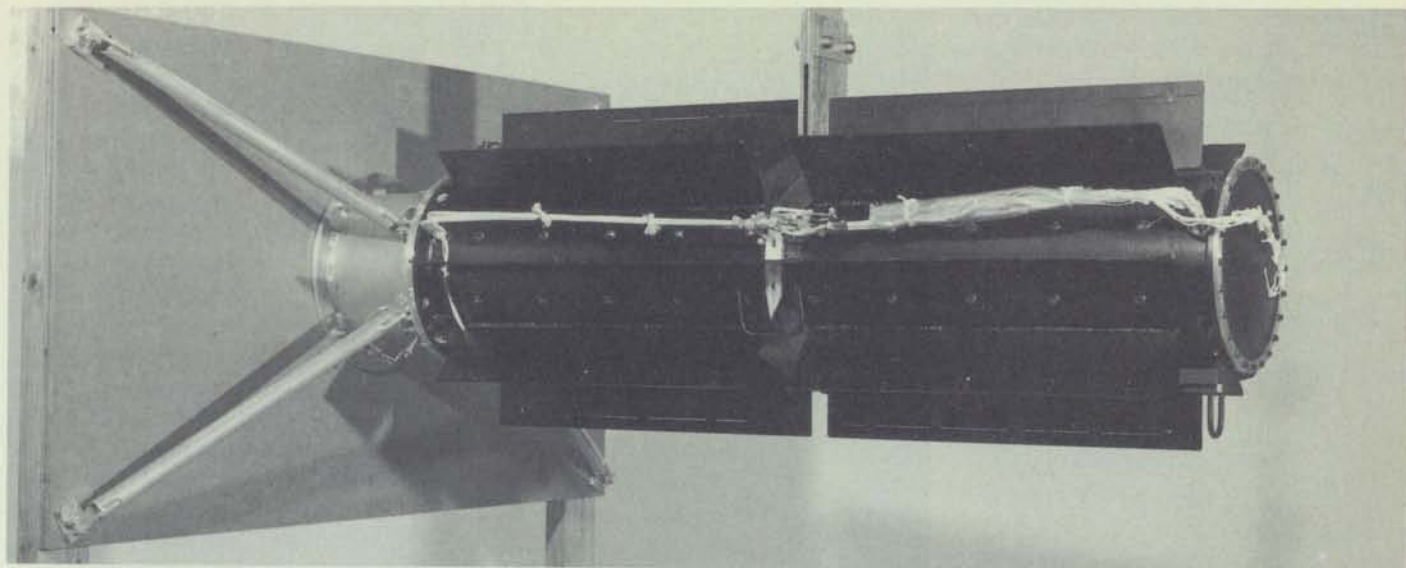
La sélection des objets célestes à inclure dans le catalogue principal des étoiles à observer a été effectuée à partir de 200 propositions couvrant une large gamme de disciplines scientifiques et émanant de plus de 20 pays.

L'Agence a approuvé une proposition d'analyse des données de l'expérience Tycho émanant du Consortium responsable de cette expérience. Cette proposition couvre le traitement et le dépouillement des données astrométriques et photométriques d'au moins 400 000 étoiles pendant la mission Hipparcos. Le consortium regroupe 15 instituts représentant huit pays.



The ISPM spacecraft, scheduled for launch in May 1986

Le véhicule spatial ISPM (lancement prévu en mai 1986)



Photon Detector Assembly

Over the last three months, the flight-model PDA has been integrated and has passed all its planned environment tests satisfactorily.

Final scientific performance tests on the second PDA chain are in progress and delivery of the flight model to the FOC contractor is expected to take place by mid-June 1983.

ISPM

ISPM programme activities have followed their planned course, with a number of significant events occurring during June.

A series of meetings concerned with the launcher and operations were held in the USA in the middle of June. These included managerial and technical interface meetings, ground and mission operations meetings, and a delta Phase II Safety Review. Good progress on all the interfaces between the various NASA centres involved and ESA continued to be made at detailed technical and procedural levels, with much of the ground lost due to earlier indecision over the launch vehicle being made up. The spirit of cooperation between all parties continues to strengthen.

The flight spacecraft completed its integration and test programme at the prime contractor's premises and was transported on 6 June 1983 to CNES for thermal-vacuum/thermal-balance testing. Following a successful short functional test of the spacecraft after transportation,

work started on installing on it the special equipment needed to conduct and monitor the thermal-vacuum test, which is planned to start in the second week of July. Work on the telecommunications subsystem has progressed to a point where flight-standard hardware has been delivered and integrated into the spacecraft. The remaining flight-standard transponder, required before the thermal-vacuum test starts, will be delivered on 20 June and exchanged for the unit used for electrical testing which, due to the late redesign of the S-band transmitter, is not considered of flight-standard with respect to the demands of rigorous environmental testing.

Hipparcos

The Hipparcos Sub-System Definition Review (SSDR), which took place in December 1982, confirmed that the technical-definition work had progressed on a sound basis and that there were no major areas of concern requiring contractor re-direction. It also provided the opportunity to establish clear priorities for the remaining definition activities to be carried out during Phase-B2. The baseline schedule for the B2 and main-development (C/D) phases has been revised and the Phase-C/D start is now planned for January 1984, with Phase-B2 extended to the end of 1983. The Preliminary Design Review (PDR) at system level is scheduled for July 1983, with subsystem-level PDRs to be carried out during October and November 1983. The formal industrial proposal for Phase C/D is now expected at the end of September 1983.

Modèle thermique du générateur thermoélectrique radio-isotope d'ISPM

ISPM Radio-isotope Thermoelectric Generator (RTG) thermal model

The selection of celestial objects for inclusion in the Hipparcos main mission Input Catalogue has been made, from some 200 proposals covering a wide range of scientific interests submitted from more than 20 countries.

A proposal from the Tycho Data Analysis Consortium to undertake the analysis of data from the Tycho experiment has been approved by the Agency. This submission deals with proposals for handling and reducing astrometric and photometric data on at least 400 000 stars during the Hipparcos mission. The Consortium represents 15 institutes in eight countries.

Giotto

The Giotto programme remains on schedule, with the contractors maintaining their forecast delivery date for the flight-model spacecraft of 31 January 1985, for a launch in July 1985.

The structural-mode integration and test programme has been successfully completed on schedule (early June) and work has started on the next spacecraft development model, the electrical model (EM). This activity at British Aerospace (Filton) will continue throughout the summer, with integration of EM subsystems and experiments, and will be

Giotto

La calendrier du programme Giotto est toujours respecté, les contractants maintenant leur prévision de date de livraison du modèle de vol, fixée au 31 janvier 1985, en vue d'un lancement en juillet de la même année.

Le programme d'intégration et d'essais du modèle de structure a été mené à bonne fin dans les délais prévus (début juin) et les travaux ont commencé sur le prochain modèle de développement du véhicule spatial, le modèle électrique. Ces activités se poursuivront à l'établissement de Filton de la British Aerospace tout au long de l'été avec l'intégration des sous-systèmes et expériences du modèle électrique; ils s'achèveront d'ici la fin de l'année par un programme d'essai au niveau système. Le calendrier étant très serré, le programme du modèle de vol prendra immédiatement la suite en janvier 1984.

A la suite d'une décision prise par le Conseil en février 1983, Giotto bénéficiera d'un lancement simple d'Ariane-1 au lieu de partager un lancement double sur Ariane-3 comme il avait été précédemment prévu.

Les activités internationales associées à Giotto et à l'exploration de la comète de Halley ont consisté principalement en discussions avec l'URSS afin d'examiner si les données observées par le véhicule spatial russe Vega, qui rencontrera Halley quelques jours avant Giotto, permettront de corriger efficacement les erreurs de trajectoire de ce dernier. Cette possibilité ayant été confirmée à l'analyse, des discussions entre organisations spécialisées sur la possibilité de mettre en oeuvre ce projet doivent se tenir à Tokyo courant novembre 1983.

ECS

Voir dernière information page 12.

Marecs

Le 1er mai, Marecs-A achevait avec succès sa première année de service opérationnel pour Inmarsat. Le fonctionnement de tous les sous-

systèmes est nominal et les paramètres de performances ne donnent pas le moindre signe de dégradation.

Les Etats participants ayant décidé de remplacer le satellite Marecs-B perdu au lancement, l'intégration et les essais de Marecs-B2 ont commencé à la mi-mars avec pour objectif que le satellite soit prêt à être lancé début 1983. Dans le même temps, un avenant au contrat initial de location avec Inmarsat a été signé afin d'inclure ce satellite de remplacement. Des négociations contractuelles et des discussions techniques sont maintenant en cours avec Arianespace pour déterminer le rang du lancement de Marecs-B au moyen d'un véhicule Ariane-3.

L-Sat

Les travaux dans l'industrie ont essentiellement porté sur la conduite des examens des bases de référence de développement au niveau équipement et

Giotto structural model undergoing vibration testing at IABG, Munich

Modèle de structure de Giotto au cours des essais aux vibrations chez IABG à Munich

sous-système. Plus de la moitié des examens prévus au niveau équipement ont été exécutés en vue du passage à la fabrication des équipements destinés au modèle d'intégration électrique du satellite. Des examens ont déjà eu lieu au niveau système pour la structure, le réseau solaire et la régulation thermique dans le cadre de l'examen de la base de référence de développement prévu pour le dernier trimestre de 1983.

La fabrication du modèle de structure du satellite est bien avancée et le démarrage des essais statiques est prévu pour le début du troisième trimestre.

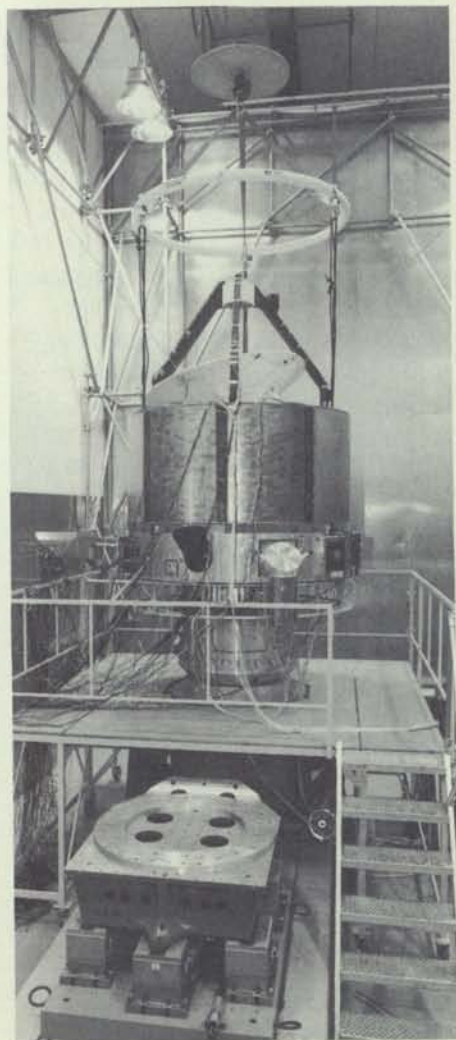
La définition des impératifs concernant les opérations en orbite pour le secteur sol est achevée et une demande de prix a été adressée à Telespazio. Les phases



concluded with a system test programme by the end of the year. Due to the tight overall schedule for Giotto, the flight-model programme will follow immediately in January 1984.

Following a Council decision last February, as reported in Bulletin 34, the launch vehicle for Giotto will now be a dedicated Ariane-1 vehicle, rather than a shared Ariane-3.

International activities associated with Giotto and the exploration of Halley's Comet have included discussions to determine whether observational data from the Russian Vega spacecraft, which will encounter Halley a few days before Giotto, would contribute to a significant improvement in Giotto targeting errors. Analysis has shown that significant targeting improvement could be achieved with this technique and consequently inter-Agency discussions concerning its possible implementation are scheduled to be held in Tokyo in November.



ECS

For latest information, see page 12.

Marecs

On 1 May Marecs-A successfully completed its first year of operational service for Inmarsat. All of the satellite's subsystems are working nominally and performance parameters show no signs whatsoever of degradation.

Following the Participating States' decision to replace Marecs-B, which was lost during launch, integration and testing of Marecs-B2 was initiated in mid-March, with the intention of having it ready for launch early in 1984.

In the meantime, a rider to the original lease contract with Inmarsat has been signed to incorporate this replacement satellite.

Contractual negotiations and technical discussions are now going on with Arianespace to arrive at a launch date for Marecs-B2 on an Ariane-3 vehicle.

L-Sat

The work in industry has been mainly concerned with conducting the development baseline reviews at equipment and subsystem level. More than half of the planned equipment-level reviews have been completed in order release the manufacture of equipment items for the engineering integration-model spacecraft. Subsystem-level reviews have already been held for the structure, solar-array and thermal-control subsystems as part of the plan leading to the System Level Development Baseline Review scheduled for the last quarter of 1983.

Modèle de structure de Giotto au cours des essais aux vibrations chez IABG à Munich

Giotto structural model undergoing vibration testing at IABG, Munich

Manufacture of the structural-model spacecraft is well advanced and the static tests are planned to start early in the third quarter of the year.

Definition of the requirements for the ground segment operations during the in-orbit phase has been completed and a Request for Quotation is being issued to Telespazio. The offer and negotiation phases are expected to be completed in time to release a contract by the end of the year.

Meetings have been held between the European Broadcasting Union (EBU) and ESA to discuss L-Sat utilisation. The EBU Executive is now preparing a formal request for using the L-Sat-1 broadcast payload.

Negotiations with Arianespace concerning the L-Sat launch contract are continuing with a view to signature in the near future.

Telecommunications Preparatory Programme

In May, the Agency's JCB (Joint Communications Programme Board) voted the funds necessary to start ESA's new Telecommunications Preparatory Programme (TPP). This is a three year programme of industrial and internal studies to define the post-Olympus (L-Sat) activities of the Agency in the field of telecommunications satellites. In addition, studies will be initiated within the TPP to assist European industry in preparing for competitions on non-ESA satellite procurements. These could include, for example, procurements by Eutelsat, Inmarsat, and Intelsat for their future-generation systems, as well as a number of anticipated national/commercial satellites.

The TPP will also serve to identify areas of technology requiring development in order to meet the needs of future communications satellites. These developments could then be undertaken within the Agency's Technological Research Programme (TRP), or as part of the telecommunications Advanced Systems and Technology Programme (ASTP).

d'offre et de négociation devraient être terminées en temps utile pour que le contrat reçoive le feu vert d'ici la fin de l'année.

L'Union européenne de Radiodiffusion (UER) et l'ESA se sont réunies à différentes reprises pour s'entretenir de l'utilisation de L-Sat. l'Exécutif de l'UER prépare actuellement une demande officielle d'utilisation de la charge utile de radiodiffusion de L-Sat 1.

Les négociations avec Arianespace concernant le contrat de lancement de L-Sat se poursuivent en vue d'une signature prochaine.

Programme préparatoire de télécommunications

Au mois de mai, le JCB (Conseil directeur commun des Programmes de Satellites de Communications) a voté les fonds nécessaires au démarrage du nouveau Programme préparatoire de

télécommunications (TPP) de l'ESA. Ce programme d'études, qui doit se dérouler sur trois ans, dans l'industrie et au sein de l'Agence, a pour but de définir les activités de cette dernière après Olympus (L-Sat) dans le domaine des satellites de télécommunications. En outre, d'autres études vont être lancées dans le cadre du TPP pour aider l'industrie européenne à se préparer à répondre à des appels d'offres d'approvisionnement de satellites n'émanant pas de l'ESA mais, par exemple d'Eutelsat, d'Inmarsat et d'Intelsat pour leurs systèmes des prochaines générations, ainsi que d'un certain nombre de satellites nationaux et commerciaux prévus.

Le TPP permettra également d'identifier des secteurs de la technologie à développer pour répondre aux besoins des futurs satellites de télécommunications. Les travaux de développement correspondants pourraient alors être entrepris dans le cadre du programme de recherche technologique de l'Agence (TRP) ou dans celui du Programme de systèmes et de technologies de pointe (ASTP, Élément 'Télécommunications').

Télédétection

Campagne SAR-580

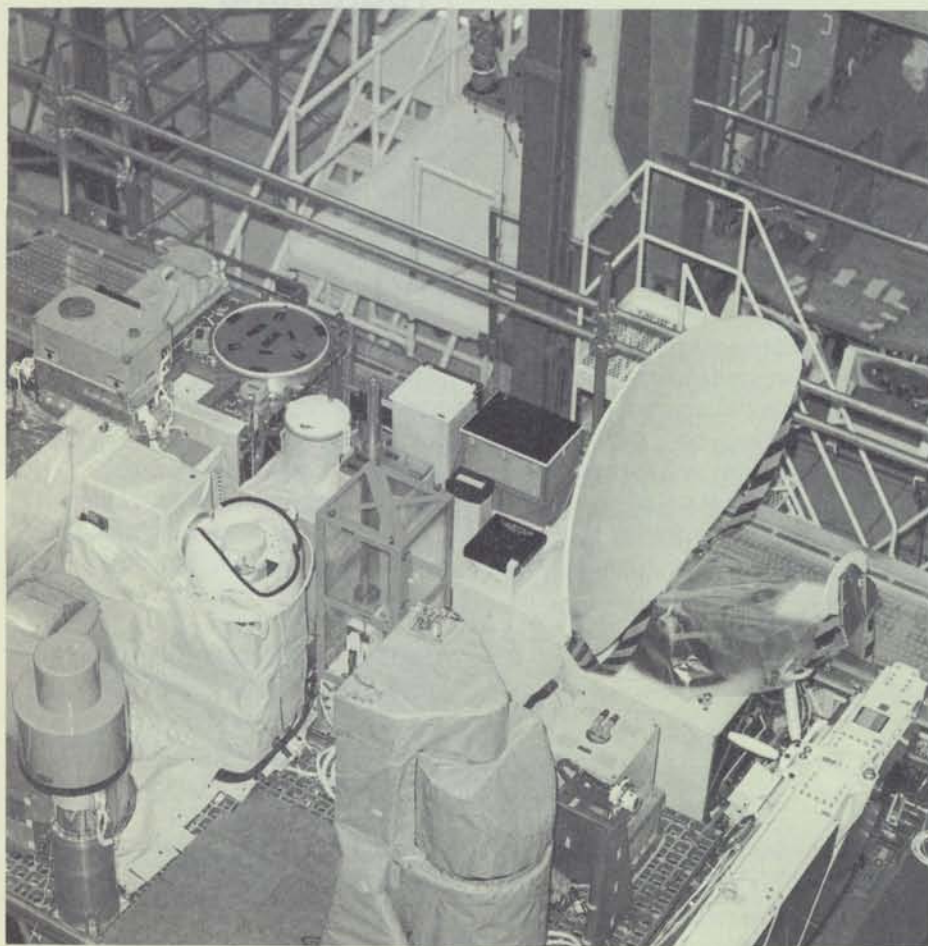
Un atelier organisé par le JRC a réuni les expérimentateurs à Ispra du 11 au 13 avril. Les installations de traitement numérique ont fait l'objet d'un examen en avril. A la suite de celui-ci, il a été convenu de reprendre le traitement sur la base d'une nouvelle séquence de traitement utilisant les installations du RAE et du DFVLR.

ERS-1

L'examen final de phase B a eu lieu du 9 au 11 mai à Toulouse. Les efforts sont maintenant axés sur la préparation de la proposition de phase C/D.

Expériences de télédétection pour la FSLP

Depuis la réunion du groupe de travail des chercheurs (IWG) des 25 et 26 mars, où l'on a appris qu'un seul des deux satellites TDRSS serait disponible pour le soutien de la mission, un important travail de réaménagement du programme des expériences a été entrepris. Pendant ce temps, tous les essais ont été terminés pour le matériel des expériences, dont l'intégration en vue du vol est complète. La mission reste prévue pour le 30 septembre.



Spacelab

La NASA avait envisagé d'utiliser le modèle d'identification (EM) en soutien du premier vol du Spacelab mais y a finalement renoncé. Ce modèle continue d'être utilisé pour résoudre les problèmes de pannes. Une série complète d'essais sur la séquence de déroulement de la mission a été exécutée; on a notamment fait fonctionner l'unité de vol Spacelab dans des conditions analogues à celles que le véhicule spatial rencontrera au cours de son séjour en orbite. Un certain nombre de problèmes mineurs se sont posés mais les essais ont pu se terminer comme prévu. Du fait que ces essais présupposaient la disponibilité de deux satellites TDRSS, il faudra les reprendre

The Microwave Remote Sensing Experiment (MRSE) integrated on a Spacelab-1 pallet at Kennedy Space Center

L'expérience MRSE intégrée au porte-instruments du Spacelab-1 au Centre spatial Kennedy

Remote Sensing

SAR-580 campaign

An Experimenter Workshop organised by JRC was held at Ispra from 11 to 13 April.

A review of the digital-processing facilities took place in April. This resulted in an agreement to restart processing with a definition of a new processing sequence using RAE and DFVLR facilities.

ERS-1

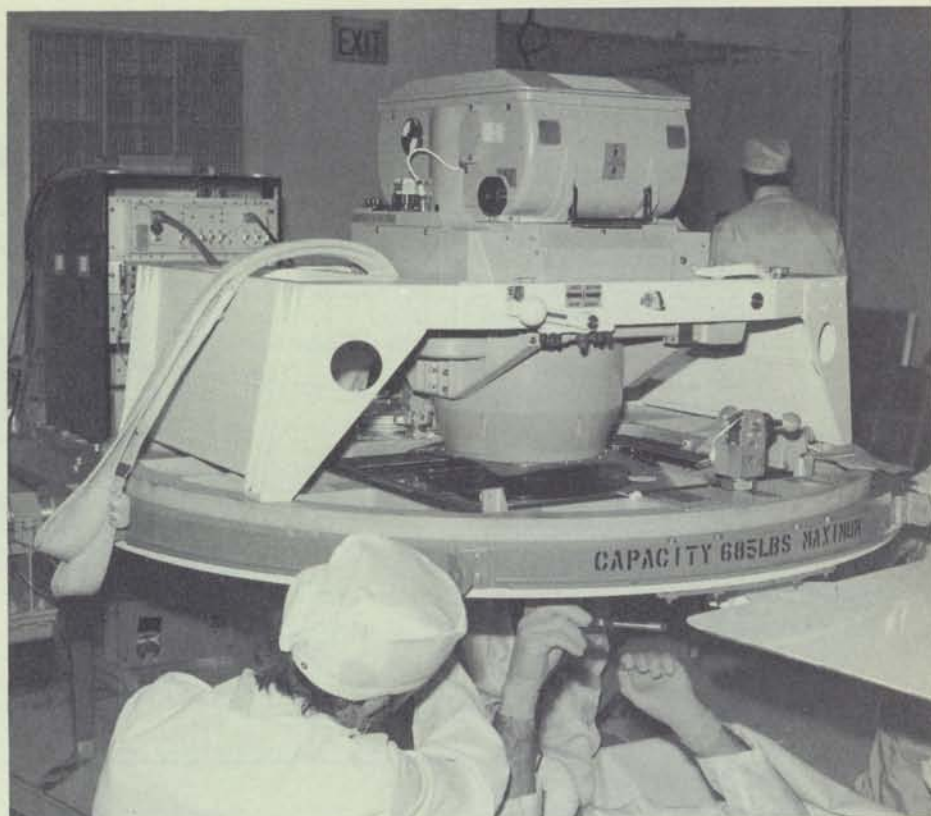
The Phase-B Final Review (FR) took place from 9 to 11 May in Toulouse. Effort is now directed towards preparation of the Phase-C/D proposal.

Remote sensing experiments for FSLP

Since the Investigators' Working Group (IWG) meeting in March (25 & 26), when it was announced that only one of the two TDRS satellites would be available to support the mission, a major effort has been undertaken to replan the experiments. Meanwhile the experiment hardware has finished all testing and is fully integrated for flight. The mission is still scheduled for 30 September.

Spacelab

Consideration was given by NASA to the use of the engineering model to support the first Spacelab flight, but this was finally not implemented. The engineering model continues to be useful for trouble-shooting. An extensive series of Mission Sequence Tests have been performed in which the Spacelab flight unit has been run under conditions representative of those that will be encountered on successive days in orbit. A number of small problems were encountered, but the tests were completed as scheduled. Since the test assumed that two TDRSs (Tracking and Data Relay Satellites) would be available, a repeat of some parts will be necessary, and a review of the time lines with one TDRS only is scheduled. Mating with the tunnel is now in progress; the CITE (Cargo Integration Test Equipment) test is scheduled in June, prior to the move to the Orbiter Processing Facility (OPF) in early August. The Flight-Readiness Review will be conducted in two parts, one in June and early July, the other in August and early September. FRR-1 will support the decision to move to the OPF, FRR-2 the decision to go ahead with the actual flight itself.



ESA staff are heavily involved in the FRRs and in the many other activities leading up to the flight.

The Spacelab-1 (SL-1) launch is still planned for 30 September, the only remaining doubt being the availability of the TDRS System (TDRSS). There are daily thruster firings, and it now appears that the first TDRS will achieve a successful orbit in late June, when the payload itself will be activated and its performance checked.

Follow-on Production

Four FOP pallets were delivered on-board a C5A aircraft on 16 March 1983 and nine FOP experiment racks were delivered on 30 March, for transport to Kennedy Space Center on-board a DC8 aircraft. Additionally, frequent deliveries of smaller items such as spares and mission-dependent hardware are being made as these pass customer acceptance. The Spacelab FOP contract is presently being amended to include further spares and three experiment racks ordered by NASA.

Work on IPS-FOP is continuing with only minor deviations from the plan, caused by the emphasis currently placed by the prime contractor on completion of IPS Phase-C/D.

Vérification et alignement de la Chambre photogrammétrique avec le hublot optique du Spacelab au Centre spatial Kennedy

Metric Camera alignment and fit check with Spacelab's optical window in progress at Kennedy Space Center

IPS

A number of design problems identified during qualification testing (drive unit, clamp unit, actuator) and design review (software) have led to a delay in IPS delivery from 31 December 1983 to early April 1984. In view of further NASA requests containing new requirements on the IPS, a rigorous freeze on the IPS requirements baseline has been instituted by ESA/IPS management, in order to protect the critical schedule situation. Review of the late design of the payload clamp assembly at MSFC has shown it to be adequate, but significantly more design verification effort is needed.

FSLP

Current information from NASA indicates that the TDRS-A tracking and data-relay satellite will be ready to support the STS-9 Shuttle/Spacelab mission on 30 September 1983.

The major elements of the Instrument Pointing System (IPS)

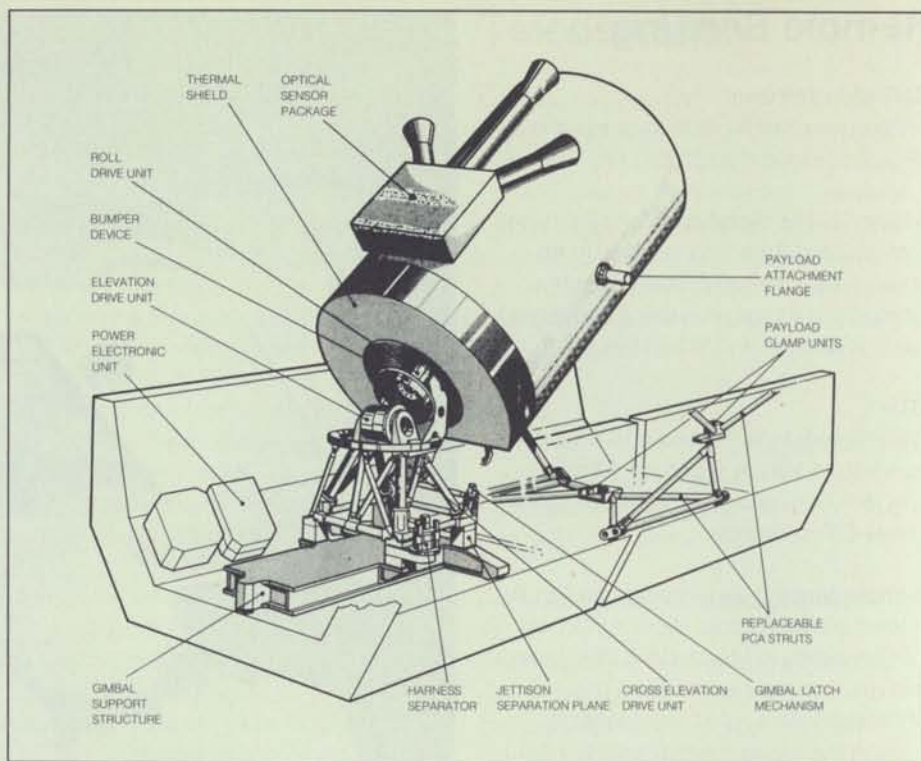
Les principaux éléments du Système de pointage d'instruments du Spacelab (IPS)

en partie et il est prévu de revoir la séquence des opérations en se basant sur un seul TDRSS. On procède actuellement au raccordement du tunnel. Les essais CITE (matériel d'essai d'intégration de la cargaison) sont prévus pour le mois de juin avant le transfert vers le hall d'assemblage et de vérification de l'Orbiteur (OPF) début août. La revue d'aptitude au vol (FRR) se déroulera en deux parties, l'une en juin/début juillet et l'autre en août/début septembre. La FRR 1 aboutit à la décision de transfert à l'OPF et la FRR 2 à la décision de vol. Le personnel de l'ESA participe très activement aux FRR et aux nombreuses autres activités précédant le vol.

Le lancement de Spacelab-1 (SL-1) est toujours prévu pour le 30 septembre, la seule incertitude portant sur la disponibilité du TDRSS. On procède actuellement chaque jour à des mises à feu des micropropulseurs et il semble maintenant que le TDRSS atteindra son orbite correcte à la fin du mois de juin; on activera alors sa charge utile et on vérifiera son fonctionnement.

Production ultérieure du Spacelab (FOP)
Quatre porte-instruments de type FOP ont été embarqués sur un C5A le 16 mars et neuf bâtis d'expériences FOP sur un DC8 le 30 mars pour être acheminés au Centre spatial Kennedy. De surcroît, des livraisons fréquentes d'articles moins importants, par exemple des rechanges ou des matériels propres à la mission, sont faites à mesure qu'elles sont réceptionnées par le client. Le programme FOP du Spacelab est en cours de modification afin d'y faire figurer de nouveaux rechanges et trois bâtis d'expériences commandés par la NASA.

Les travaux se poursuivent sur le modèle FOP de l'IPS; les seuls écarts mineurs par rapport au plan résultent de l'accent que le contractant principal a mis sur l'achèvement de la phase C/D de l'IPS.



IPS

A la suite d'un certain nombre de problèmes de définition, mis en lumière au cours des essais de qualification (ensemble d'entraînement, dispositif de fixation, actionneurs) et découlant de la revue de conception du logiciel, il est confirmé que la livraison sera reportée du 31 décembre 1983 au début d'avril 1984. Comme la NASA a encore présenté des demandes comportant de nouveaux impératifs de fonctionnement pour l'IPS, les responsables de l'IPS à l'Agence ont décidé d'arrêter de façon rigoureuse les impératifs de sa version de référence pour éviter que la situation du calendrier, déjà critique, soit mise en péril. L'examen de la dernière définition du système de fixation de la charge utile au MSFC a montré que celle-ci est adéquate, mais qu'il faudra encore procéder à des travaux de vérification importants.

FSLP

Des informations en provenance de la NASA indiquent que le satellite TDRSS-A sera prêt pour venir en soutien de la mission STS-9 qui commencera le 30 septembre 1983.

Le Groupe de travail des chercheurs s'est réuni à la NASA en mars et en avril et a conclu que l'on pouvait accepter le

30 septembre comme date de lancement avec un seul au lieu des deux satellites TDRSS prévus.

L'essai no 2 sur la séquence de déroulement de la mission concernant la charge utile intégrée a été mené à bien au Centre spatial Kennedy (KSC), conformément au calendrier. L'un des principaux résultats de l'essai est de rehausser la confiance dans la charge utile pour son exploitation dans l'environnement réel du Spacelab. Les prochaines grandes activités 'charge utile' au KSC seront les essais en boucle fermée et les essais de bout en bout.

Au Centre des vols spatiaux Marshall, les travaux se sont intensifiés dans les domaines suivants: simulation des expériences, préparation des chercheurs principaux aux activités du Centre de contrôle des opérations de charge utile (POCC) et entraînement de l'équipage.

Tous les éléments stockés pendant le lancement et l'atterrissage dans le Bâti double de science des matériaux (MSDR) ont été officiellement acceptés. En outre, au terme de l'examen des résultats de leur programme de qualification mené au Spice, tous les échantillons de matériaux, cartouches et dispositifs spéciaux ont été considérés comme qualifiés sous réserve d'achèvement de certaines actions.

Une session de formation de l'équipage

Investigator Working Group meetings were held at NASA in March and April. The conclusion of these meetings was that a 30 September 1983 launch with one, instead of two TDRS satellites on station, would be acceptable.

At NASA-KSC, Mission Sequence Test 2 on the integrated payload was successfully completed on schedule. A principal result of the test was enhanced confidence in the payload when operating in the real Spacelab environment. The next major payload activities at KSC will be the Closed-Loop and End-to-End Tests.

Work at NASA-MSFC has intensified on experiment simulations, training of Principal Investigators in Payload Operations Control Center (POCC) activities, and crew training.

All stowage items for the Material Sciences Double Rack (MSDR) have been formally accepted. In addition, a review was held at SPICE of the results of the qualification programme for the materials samples, cartridges and special devices. The conclusion was that all samples can be considered qualified, subject to the completion of certain actions.

A successful crew-training session was held at DFVLR, using the ground version of the MSDR and specially configured simulator facilities.

DFVLR, Porz-Wahn has been selected as the main European centre for information during the SL-1 mission and SPICE staff are participating in the associated planning and preparations.

The Preliminary Design Review for the Sled Payload Element on Spacelab D1 was successfully carried out at ERNO in April. The concept for the training-model programme has been finalised with ERNO and DFVLR. This will ensure a realistic set-up for the Sled Payload Element in the DFVLR crew training simulator at Porz-Wahn.

Microgravity

Biorack

An extensive series of end-Phase-B reviews have been completed during the period mid-February to mid-April. Their outcome can be summarised as follows:

- a. *Thermal-Conditioning Units Review*
Phase-B status was sufficiently satisfactory to start Phase-C/D work, subject to confirmation of the adequacy of a structural-design change involving extensive use of glass-fibre composite material. The material appears to be satisfactory for this application, but the detailed design implications have still to be worked out in parallel with the early Phase-C/D activities.
- b. *Glovebox Review*
A satisfactory overall design has been established. It is now clear that the air-circulation filters have to be specially developed and qualified for the combination of chemicals used by the experiments for Spacelab D-1. The design of the experiment-observation facility, including provision of a microscope and camera, is not yet frozen.
- c. *Experiment Reviews*
A number of review meetings have been held for the individual experiments. The progress of work and extent of definition has noticeably improved and is generally considered satisfactory for this stage of the programme. A consoling

observation is the trend that the more complex experiments have now become better defined in engineering and operational terms.

All industrial contractors for the ESA Biorack have been authorised to start with the early Phase-C/D work and long-lead-item procurements whilst the associated contracts are being agreed.

Long delivery times for critical components and changes that have to be implemented are causing delays. Investigations are underway with a view to reducing the predicted schedule delay.

Improved Fluid-Physics Module (IFPM)

The existing FPM, with some essential improvements, and not a completely new model, will be flown on the D-1 mission.

The development of the AFPM, an autonomous facility, will be commenced and continued in Phase-2 of the Microgravity Research Programme.

The Spacelab Programme Board has approved the selection of IFPM experiments proposed by the Agency for the Spacelab D-1 mission. The experiments selected are the following:

Floating-Zone Hydrodynamics	I. Da Riva ETSI Aeronauticos, Madrid
Marangoni Convection in Gas-Liquid Mass Transfer	A.A.M. Drinkenburg University of Groningen
Separation of Immiscible Liquids	D. Langbein, Battelle Institute, Frankfurt
Convection in Non-isothermal Binary Mixture Presenting a Surface Tension Minimum as a Function of Temperature	J.C. Legros, Free University, Brussels
Separation of Fluid Phases and Bubble Dynamics in a Temperature Gradient	R. Naehle, DFVLR, Cologne
Marangoni Flows	L. Napolitano, University of Naples
Capillary Experiments in Low Gravity Fields	J.F. Padday, Kodak Ltd., UK
Standby Experiment: Forced Liquid Motions	J.P.B. Vreeburg, NLR, Amsterdam

s'est déroulée avec succès au DFVLR où l'on a utilisé la version 'sol' du MSDR ainsi que des installations de simulation spécialement adaptées à cet effet.

Il a été décidé que pendant la mission SL-1, le principal bureau de presse européen serait installé au DFVLR, à Porz-Wahn. Le personnel Spice participe aux activités de planning et de préparation.

L'examen préliminaire de la conception de l'élément de charge utile Sled sur D1 s'est déroulé avec succès chez ERNO en avril. Le concept du programme de modèle de formation a été arrêté avec ERNO et le DFVLR. On sera ainsi assuré d'une mise en place réaliste de l'élément de charge utile Sled dans le simulateur d'entraînement de l'équipage à Porz-Wahn.

Microgravité

Biorack

Entre la mi-février et la mi-avril s'est déroulée une longue série d'examens de fin de phase B dont les résultats sont résumés ci-après:

- a. Examen des enceintes de conditionnement thermique
L'état d'avancement satisfaisant de la phase B a permis de commencer les travaux de la phase C/D sous réserve que soit confirmée l'adéquation d'une modification de la conception structurelle impliquant un large emploi d'un matériau composite à base de fibres de verre. Ce matériau semble convenir à cette application mais ses incidences sur la conception devront être déterminées en détail parallèlement aux premières activités de la phase C/D.
- b. Examen de la boîte à gants
La conception générale est satisfaisante. Il est clair, désormais, que les filtres à circulation d'air devront être spécialement mis au point et qualifiés en fonction de la combinaison de produits chimiques qui seront utilisés pour les expériences de la mission D-1. La conception de l'installation d'observation des expériences, y compris la mise en place d'un microscope et d'une chambre de

prise de vues, n'est pas encore définitivement arrêtée.

- c. Examen des expériences
Un certain nombre de réunions ont été tenues pour l'examen individuel des expériences. L'avancement des travaux et l'approfondissement de la définition ont considérablement progressé et sont en général considérés comme satisfaisants pour cette étape du programme. Il est encourageant de noter que les expériences les plus complexes tendent à être mieux définies tant sur le plan technique qu'opérationnel.

Tous les contractants industriels du Biorack ont été autorisés à engager les premiers travaux de phase C/D et à procéder à l'approvisionnement des éléments à long délai de livraison; les contrats correspondants sont en voie d'acceptation.

Les longs délais de livraison de certains éléments critiques ainsi que des modifications qui ont dû être prises en compte sont à l'origine de retards. On s'efforce actuellement de réduire le retard prévu sur le calendrier.

Module de physique des fluides amélioré (IFPM)

C'est le module de physique des fluides (FPM) actuel qui repartira avec la mission D-1, après avoir subi quelques améliorations essentielles, et non un modèle entièrement nouveau.

La réalisation d'un module de physique des fluides autonome (AFPM) sera entreprise et poursuivie dans le cadre de la phase-2 du programme de recherche en microgravité.

Le Conseil directeur du Programme Spacelab a approuvé le choix des expériences que l'Agence propose pour l'IFPM pour la mission D-1. Les expériences retenues sont mentionnées dans le tableau ci-dessous.

Fusées-sondes

Texus-7 et Texus-8 ont été lancées avec succès les 5 et 11 mai de l'Espace, à Kiruna. Les opérations de vol et de récupération ont été dans les deux cas nominales. Les conditions de microgravité ($10^{-4}g$) ont duré 5,5 minutes pour Texus-7 et 6,5 minutes pour Texus-8. D'après les premières indications, la plupart des installations expérimentales ont fonctionné normalement. Texus-7 et 8 avaient à leur bord 30 expériences, dont

Les expériences retenues sont les suivantes:

Hydrodynamique d'une zone flottante	I. Da Riva ETSI Aeronautics, Madrid
Effet de convection de Marangoni sur le transfert de masse liquide/gaz	A.A.M. Drinkenburg Université de Groningen, Pays-Bas
Séparation de liquides non miscibles	D. Langbein Institut Battelle de Francfort
Convection dans un mélange binaire non isotherme présentant une tension superficielle minimale en fonction de la température	J.C. Legros Université libre de Bruxelles
Séparation des phases fluides et dynamique des bulles sous gradient thermique	R. Naehle DFVLR, Cologne
Flux de Marangoni	L. Napolitano Université de Naples
Expériences sur la capillarité en conditions de faible pesanteur	J.F. Padday Kodak, Ltd., R-U
Expérience de réserve: Mouvements forcés de liquides	J.P.B. Vreeburg NLR Amsterdam

Sounding-Rockets Programme

Texus-7 and Texus-8 were launched successfully on 5 and 11 May 1983 from Esrange, Kiruna in Sweden. Flight operations and recovery were, in both cases, nominal. The microgravity times ($10^{-4}g$) were 5.5 min (Texus-7) and 6.5 min (Texus-8). First indications show that most of the experiment facilities functioned normally. Texus-7 and Texus-8 carried a total of 30 experiments, 14 of which were solicited and selected through the ESA Microgravity Programme.

In total (including Texus-6, which was launched in May 1982) 20 experiments have been conducted to date through the ESA Microgravity Programme, from the following Member States: Belgium (3), France (3), Germany (6), Italy (1), The Netherlands (1), Sweden (4) and the United Kingdom (2).

Preparation of the next round of rocket experiments for a launch in 1984 have started, after the selection by the Spacelab Programme Board of new experiments in the fields of metallurgy and fluid physics.

Eureca

Industry submitted the results of the Phase-A studies at the beginning of March 1983. They were presented to the members of the Eureca payload working group following a technical evaluation. Phase-A fulfilled all the major objectives for the definition of feasible technical concepts and the drawing up of a first cost estimate and probable time schedule.

From the technical point of view, the trade-off studies have been completed, except for those on the solar array and type of propellant for the main propulsion system and on certain improvements to the data-processing subsystem. Furthermore, and following competitive studies of the attitude command and control subsystem, a concept was selected and is to be refined in the course of the Phase-B study.

The type of propellant will be chosen prior to the start of Phase-B (definition phase) and a solar array will be selected during that phase.

A first evaluation of costs has been made. Further cost evaluation and reduction

studies will be made, relating in particular to power and propulsion systems.

As far as the time schedule is concerned, industry has drawn up a number of specific study assignments which, if included in Phase-B, would cause a delay in the overall schedule. The Phase-A studies contract has accordingly been broadened to enable additional study assignments that are considered crucial to be carried out.

The Phase-B Invitation to Tender was put out to industry on 15 March 1983 and replies were received towards the end of April. The technical aspects of the Phase-B proposal were studied and approved by the Spacelab Programme Board on 1 June 1983. The Phase-B proposal itself will be submitted for approval by the Industrial Policy Committee (IPC) on 22 and 23 June 1983. Phase-B is due to start on 4 July 1983. The study will last 9 months, with completion scheduled for early April 1984.

Although the conditions necessary for drawing up the Eureca Phase-B contract with ERNO/MBB are considered to have been met, it will be necessary to correct certain shortcomings in the industrial proposal which relate to the payload engineering and payload interface management and to the overall approach to cost-effective verification as regards testing and qualification.

Alongside the work of defining the Eureca reference concept, considerable effort has gone into studying the six experimental facilities to be flown on the first Eureca mission. Phase-B studies have begun for four of them and the Phase-A studies on the last two facilities [Multi-Furnace Assembly (MFA) and the Automatic Gradient Heating Facility (AGHF)] are currently drawing to a close.

The Call for Experiments for the first Eureca mission, issued in mid-January 1983, was extremely successful: 118 experiment proposals will be studied over the summer by six 'peer groups'. The results will be submitted to the Spacelab Programme Board in the Autumn of 1984 for selection of the experiments.

Finally, discussions with NASA have continued and some progress has been made in working out a more refined NASA policy on Eureca in-orbit rendezvous and retrieval strategy and the associated costs.

Ariane

For latest information, see page 8.

STS LTPP

Long-Term Space Transportation Systems Preparatory Programme

The Programme Committee set up by the Council met on 8 April 1983 to consider proposals for studies to be begun in 1983. The Committee having given its approval, the Executive has initiated the appropriate contract actions.

In line with the structure of the preparatory programme, the studies concern:

- future launchers
- space stations, in-orbit infrastructure.

The first studies started in 1982 in these areas were the subject of presentations – final ones in the case of the in-orbit infrastructure studies – made by Aerospatiale and Matra on 23 and 24 March 1983. Those relating to the study of the utilisation of manned space stations were presented by DFVLR on 12 April 1983 and the mid-term results of the space-station study (ERNO, Dornier, Aerospatiale, AEG) were presented on 12 and 13 April 1983.

For its part, NASA gave a presentation at ESA on 14 April 1983 of the results of its study activities relating to space stations.



14 proposées et sélectionnées dans le cadre du programme de recherche en microgravité de l'ESA.

A ce jour, ce programme a permis de réaliser un total de 20 expériences (en comptant Texus-6 lancée en mai 1982), provenant des Etats membres suivants: Allemagne (6), Belgique (3), France (3), Italie (1), Pays-Bas (1), Royaume-Uni (2), Suède (4).

La préparation des prochaines expériences à réaliser en fusée-sonde en 1984 a commencé, après le choix de nouvelles expériences par le Conseil directeur du programme Spacelab dans le domaine de la métallurgie et de la physique des fluides.

Eureca

L'industrie a présenté les résultats d'études de la phase A au début de mars. Ces résultats ont été présentés aux membres du groupe de travail charge utile d'Eureca, après évaluation technique des études. La phase A avait rempli tous les objectifs majeurs en ce qui concerne la définition des concepts techniques faisables et la préparation d'une première estimation du coût ainsi que du calendrier probable.

Techniquement, les études de compromis ont été achevées à l'exception de celles du réseau solaire et du type de propergol pour le système de propulsion principal, ainsi que pour certaines améliorations au sous-système de traitement des données. De plus, et à l'issue d'une étude en concurrence sur le sous-système de commande et contrôle d'attitude, un concept a été sélectionné et devra être affiné lors de l'étude de phase B.

Le type de propergol sera choisi avant le démarrage de la phase B et la sélection d'un réseau solaire sera effectuée pendant la phase B.

En ce qui concerne les coûts, une première évaluation a été faite. Des études ultérieures d'évaluation et de réduction des coûts seront entreprises tout particulièrement dans le domaine des systèmes d'énergie électrique et de propulsion.

Relativement au calendrier, l'industrie a déterminé un certain nombre de tâches d'études qui, si elles sont couvertes par la

phase B, provoqueraient un retard dans le calendrier général. Le contrat d'études de phase A a donc été complété pour entreprendre des tâches d'études complémentaires qui étaient jugées critiques.

L'appel d'offre pour la phase B a été soumis à l'industrie le 15 mars et les réponses ont été reçues vers la fin avril. La proposition de phase B a été examinée et approuvée sous ses aspects techniques par le Conseil directeur du Programme Spacelab (PB-SL) le 1er juin. La proposition de phase B sera soumise à l'approbation du Comité de la Politique Industrielle (IPC) les 22 et 23 juin. Le démarrage de cette phase B est prévu le 4 juillet. La durée de cette étude est de 9 mois (fin d'études en avril 1984).

Si les conditions requises pour stipuler le contrat de phase B avec ERNO/MBB ont été jugées remplies, il n'en demeure pas moins que certaines imperfections de la proposition industrielle — qui se situent dans le secteur de l'ingénierie de la charge utile et de la gestion d'interface de charge utile ainsi que dans la formule générale de vérification du rapport coût/résultat pour les essais et qualifications — devront être corrigées.

Parallèlement au travail de définition du concept de référence du véhicule spatial Eureca, un effort intensif a été porté sur les études des six installations expérimentales à embarquer sur la première mission. Les études de phase B ont démarré pour quatre d'entre elles, alors que les deux dernières installations [ensemble de fours (MFA) et le four automatique à gradient (AGHF)] terminent actuellement la phase A d'études.

L'appel aux expériences pour la première mission Eureca, lancé mi-janvier 1983, a connu un grand succès: 118 propositions d'expériences seront examinées dans le courant de l'été par six 'groupes des pairs'. Le résultat de cet examen sera soumis au Conseil directeur du Programme Spacelab à l'automne 1984 pour sélection des expériences.

Enfin, les discussions avec la NASA se sont poursuivies et un certain progrès a été réalisé pour établir une politique de la NASA plus affinée en ce qui concerne la stratégie de rendez-vous et de récupération en orbite d'Eureca, ainsi que les coûts afférents.

Ariane

Voir dernière information page 8.

STS - LTPP

Programme Préparatoire de Systèmes de Transport Spatiale à Long Terme

Le Comité de programme mis en place par le Conseil s'est réuni le 8 avril pour étudier la proposition d'études à démarrer en 1983. L'accord du Comité ayant été obtenu, l'Exécutif a procédé au démarrage des actions contractuelles correspondantes.

Conformément à la structure du programme préparatoire, ces études concernent:

- les lanceurs futurs
- les stations spatiales, l'infrastructure orbitale.

Les premières études engagées en 1982 sur ces thèmes ont fait l'objet de présentations, finales dans le cas des études d'infrastructure orbitale présentées les 23 et 24 mars par l'Aérospatiale et Matra, ainsi que de l'étude sur l'utilisation des stations spatiales habitées présentée par le DFVLR le 12 avril, ou à mi-parcours pour l'étude sur la station spatiale (ERNO, Dornier, Aérospatiale, AEG) les 12 et 13 avril.

La NASA, de son côté, est venue présenter à l'ESA (14 avril) les résultats de ses activités d'études sur les stations spatiales.



The New IRS Personal-Time-Series (PTS) Service

S. D'Elia, Software Division, ESA Information Retrieval Service, ESRIN, Frascati, Italy

The PTS (Personal Time Series) Service newly installed by ESA/IRS at its centre in Frascati, Italy, is available worldwide via private or public networks, direct phone call or telex. It allows time-series data to be easily tabulated, reproduced in graph form or plotted, for comparison or improved presentation purposes. The data can also be analysed using selectable statistical functions, for example to predict possible future values from past data.

Time-series management

Once logged onto the QUEST system, the user can call up the PTS service by typing:

```
BEGIN PTS
```

Time series tuples (combinations of values connected by a given relationship) can now be entered via the command:

```
NEW Series
```

The command allocates a time-series code to the password and prepares the system for accepting date/value tuples. Figure 1, an example of the dialogue, shows that the system first needs to know the frequency of the time series. This is used also to calculate and store related averages automatically, i.e.

- yearly average, for monthly data
- weekly, monthly and yearly averages, for daily data.

Note, that in all the figures, the user's input is behind the '?' character, while all other lines are generated by the system. Only in the case of the 'NEW' command does the user also enter the date/value tuples.

The string 'NNNN' (derived from the telex protocol) completes data transfer and is required from any terminal operating in scroll mode. Users on display terminals (e.g. TEL42), have not to issue this string, but can transmit only one screen of data, which is to be prepared before the 'NEW' command is entered.

The next step in generating a time series is to check whether any mistyping or transmission error has occurred. This is accomplished, as shown in Figure 2, by entering:

```
V IRSO TAB MONTHLY
```

Figure 1 — User/QUEST dialogue while entering a new time series

Figure 2 — Tabulation of the time series just entered

```
? BEGIN PTS
-----27Apr83 16:02:15 User0200---
      0.21 AU 0.32 Minutes in File32
      0.05 AU Telecomm charge
      0.26 AU approx Total
File 45: PTS SERVICE
SET ITEMS DESCRIPTION (+=OR;*=AND;-=NOT)
? NEW
Pls specify freq: YEARLY, MONTHLY, DAILY
? MONTH
IRSO: pls enter Date Value Tuples
JUL 85 15.3
AUG 5.7
SEP 6.5
OCT 6.9
NOV 5.2
DEC 0.9
JAN 86 1.4
FEB 2.0
MAR 2.3
NNNN
IRSO Time Series prepared
```

```
? V IRSO TAB MONTHLY
Table of the time series :
IRSO

MONTHLY AVERAGES
-----
MONTE      1985      1986
-----
JAN.        0.0      1.4000
FEB.        0.0      2.0000
MAR.        0.0      2.3000
APR.        0.0
MAY.        0.0
JUN.        0.0
JUL.       15.3
AUG.       5.7000
SEP.       6.5000
OCT.       6.9000
NOV.       5.2000
DEC.       0.9000
-----
```


Figure 3 — User/QUEST dialogue in updating a time series

Figure 4 — LIST command output

Error correction or future amendments are possible with the subfunctions replacement, deletion or addition of the command:

UPDATE (abbr. U)

Figure 3 shows, as an example, how the system tries to maintain data integrity, requesting confirmation before any permanent change is applied to the data. Up to six update functions can be chained in each update command.

To obtain an overall picture of the time-series codes allocated to the password at any time, it is sufficient to enter:

LIST

(or: LIST FREQ MONTH, to limit the display to one particular frequency). Figure 4 is an example. It also shows that one time series was released via the command:

RELEASE IRS6

Everybody can read the time series, knowing or guessing the code, but only the originating password holder can update it. Moreover, as neither the title nor the measuring unit are saved together with the time series, these series of numbers will have meaning only for those users knowing both the time-series code and the related application area. Moreover, they will not appear on another password holder's listing.

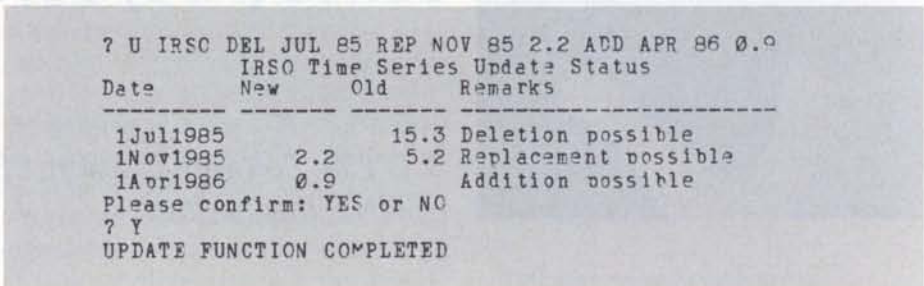
Time-series manipulation

The time series saved in the system can be manipulated via two main commands:

VALUE (abbr. V)

COMPUTE (abbr. COMP)

These can call the statistical routines listed in Table 1. The command VALUE produces only data to be displayed on the user's terminal. COMPUTE generates, instead, a new time series into the user's



set: this is the usual area of storage, reserved to the password for the duration of the session and normally used to save intermediate search results which can be retrieved via the sequential set number automatically assigned by system.

- The command syntax is:
- VALUE or COMPUTE
 - time series code or set number(s)
 - routine name
 - routine input parameters
 - frequency
 - range.

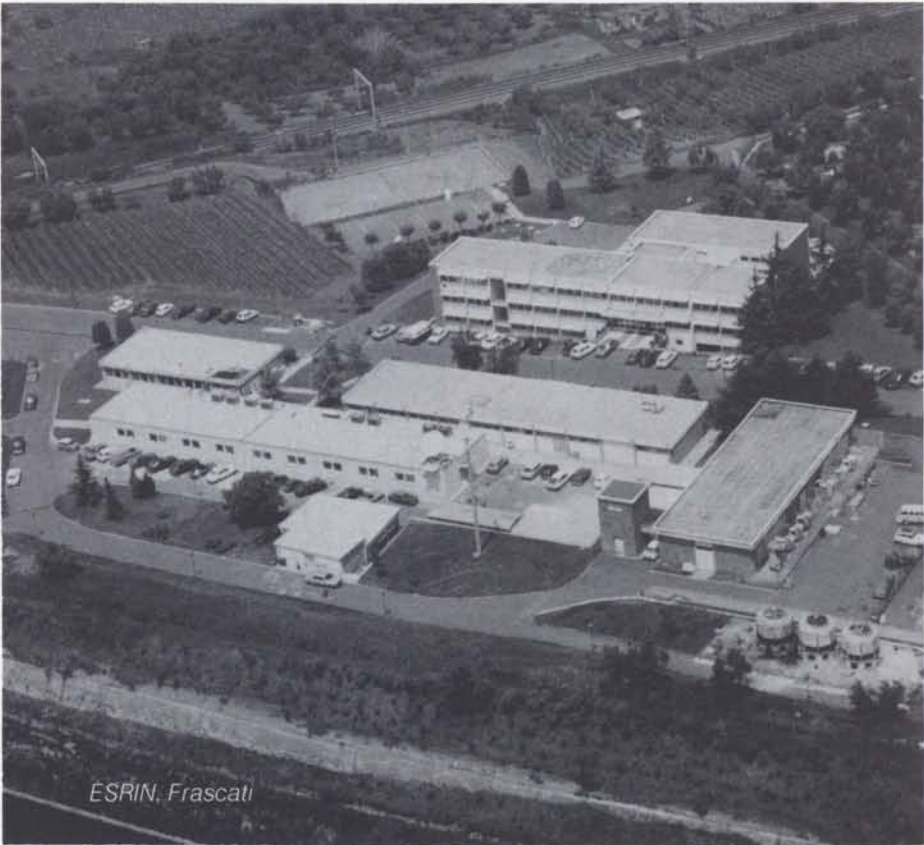


Table 1 — Statistical software package routines

COMMAND ROUTINE NAME		FUNCTION	INPUT PARAMETERS
V	(DEFAULT)	Calculates the statistics and tabulates the series	
V	TABLES	Prints the values of 1 to 5 series	
V	STATISTICS	Performs and prints elementary statistical functions (average min. and max., variance and standard deviation)	
V	GRAPH	Represents a single series graphically by points	
V	PLOT	Represents up to 8 series graphically by indexing to a common base	
V	SEASONAL ADJUSTMENT	Calculates seasonal coefficients, the ciclo-trend component and residuals	- applied solely to the weekly & monthly series - RANGE must be min. of 4 years
V	AUTOCORRELATION	Performs the simple autocorrelation function and autocovariance up to n-lags	- LAG < No. of observations - 1 < LAG < 104 - default: LAG=1
V	MOVING AVERAGE	Interpolates through non-centred moving averages to n terms	- 1 < No. of terms < No. of observations - default: no. of terms=2
V	GROWTH CURVES	Interpolates through linear, exponential and hyperbolic development curves	- default: linear interpolation - default: No. of forecasts=0
V	POLYNOMIAL INTERPOLATION	Interpolates through linear, parabolical and cubic polynomials	- default: Linear interpolation - default: No. of forecasts=0
V	MULTIPLE REGRESSION	Performs regression analysis (1-6 series)	- the 1 st set must be the dependent series
V	CORRELATION	Performs correlation analysis (1-6 series)	
V	CROSS CORRELATION	Performs cross correlation analysis (2 series)	- 1 < LAG < 104
V	EXPONENTIAL SMOOTHING	Performs the interpolation according to the exponential smoothing method	- No. of forecasts > 0 - 1 < α < 100
V	FORECAST	Performs forecasts from one to four weeks with minimums and maximums	
COMP	LOGARITHM	Performs logarithm operation	
COMP	EXPONENTIAL	Performs exponential operation	
COMP	SQUARE ROOT	Performs square root operation	
COMP	DIFEERENTIAL	Obtains the first differences in respect of any LAG	- 1 < LAG < No. of observations default: LAG=1
COMP	VARIATION	Obtains the % variations in respect of any delay (lag)	- 1 < LAG < No. of observations - default: LAG=1
COMP	INDEX	Indexes according to any base	- 1 < LAG < No. of observations - default: LAG=1
COMP	RIGHT SHIFT	Right Shift operations of n. periods	- 1 < LAG < No. of observations - default: LAG=1
COMP	LEFT SHIFT	Left Shift operations of n. periods	- 1 < LAG < No. of observations - default: LAG=1
COMP	ADDITION	Performs additions with constant	- default constant=0
COMP	SUBTRACTION	Performs subtractions with constant	- default constant=0
COMP	MULTIPLICATION	Performs multiplications by constant	- default constant=1
COMP	DIVISION	Performs divisions by constant	- default constant=1
COMP	(DEFAULT)	Performs the four operations among 2 to 6 series (COMP 3+5:6-2+1)	

Figure 5 — Graph of uncertainty in the position of the comet Halley nucleus (Mm)

Figure 7 — User/QUEST dialogue to pick up time series from PRICEDATA

Figure 6 — Plot of assumed incomes in Germany (1), France (2) and England (3)

Example:

V 3 6 9 PLOT MONTHLY 80 83

this means: plot the sets 3, 6 and 9 from 1980 to 1983 with monthly frequency. Range and frequency, once defined, are valid up to next change, which can also be given separately via the DELIMIT command:

DLM MONTHLY 1980 TO 1983

Entering the command

V IRSO GRAPH

results in the graph of Figure 5, which represents the uncertainty in the position of Halley's comet nucleus in Mm: the time series managed in the previous paragraph!

Another example of a typical application might be that of a German retailing firm which is also selling via branches in England and France. The firm and its overseas branches could each enter their income data into the PTS service, perhaps even daily. Head-office management could then analyse the yearly averages to assist their medium-term decision-making, regarding, for example, investments, publicity, personnel, etc. One might end up with the situation shown in Figure 6.

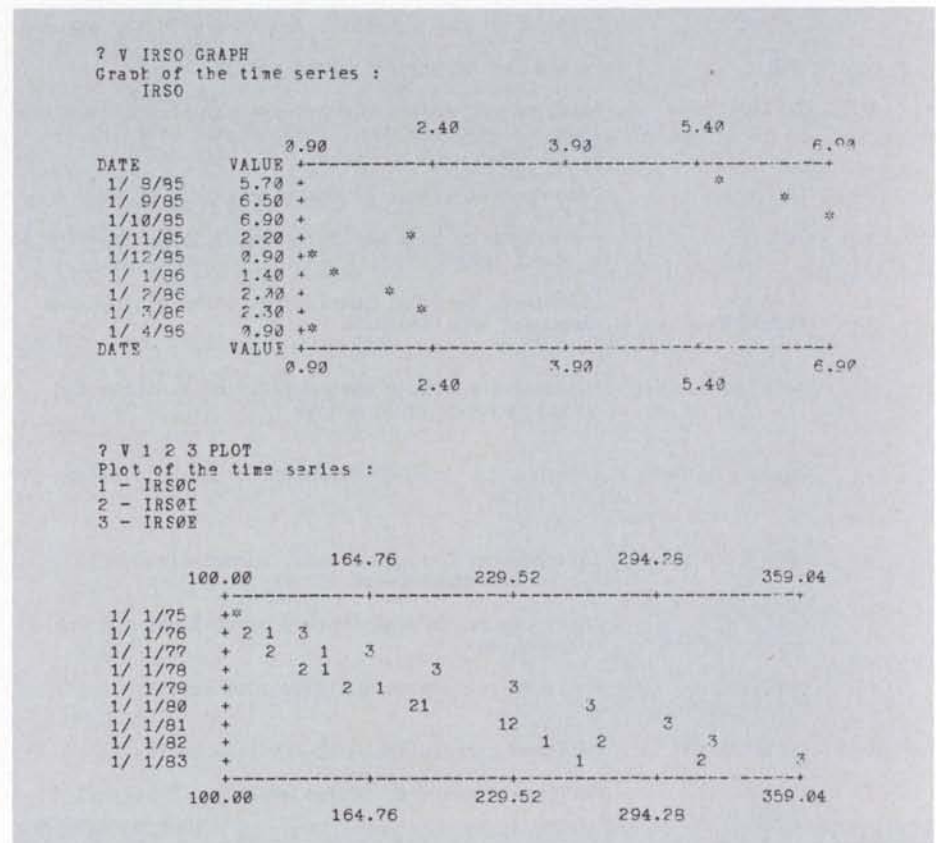
This shows the French market start to be difficult, whilst the English one looks most promising. However, inflation should be eliminated, and this is easily performed by switching into the PRICEDATA file with the command:

. FILE 46

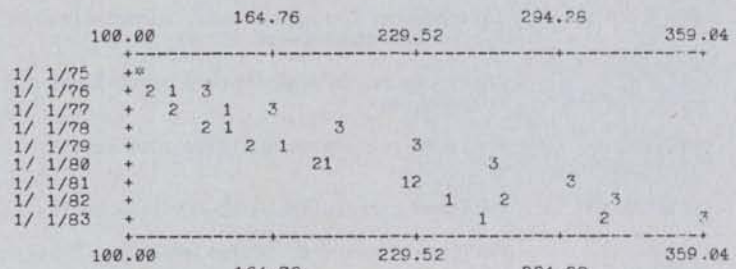
The time series of DM/POUND and FF/100DM can be collected and moved into the user's set via the command:

COMP set number

repeated for each series (Fig. 7), and returning to PTS:



? V 1 2 3 PLOT
Plot of the time series :
1 - IRS0C
2 - IRS0I
3 - IRS0E



. FILE 45

In multiplying or dividing English and French incomes with the related conversion factors, all the time series will be in DM. The real situation is now as shown in Figure 8, and the English market no longer looks so promising!

Computing and displaying the VARIATION for the English incomes could give better insight regarding the trend, shown in Figure 9. CORRELATIONS in the various markets could be checked for to see whether or not they are different. POLYNOMIAL INTERPOLATION and/or EXPONENTIAL SMOOTHING could be applied to each of the time series to forecast future values, which can be used as a basis for future planning.

Operational details

All the commands described above tolerate abbreviation or some

```
? .FILE 46
-----28Apr83 12:17:13 User0200-----
  0.90 AU 0.90 Minutes in File45
  0.15 AU Telecom charge
  1.05 AU approx Total
File 46: PRICEDATA
? FIND MARK IN LONDON
  4  8 MARK
  5  42 LONDON
  6  1 4*5
? FIND MARK IN PARIS
  7  8 MARK
  8  7 PARIS
  9  1 7*8
? COMP 6: COMP 9
 10  1 COMP 6
 11  1 COMP 9
? .FILE 45
-----28Apr83 12:18:14 User0200-----
  1.70 AU 1.02 Minutes in File46
  0.17 AU Telecom charge
  1.87 AU approx Total
File 45: PTS SERVICE
```

keyboarding errors in the parameters, provided no ambiguity arises. Moreover the commands NEW, UPDATE, LIST and RELEASE keep track of the user's input and show the system's understanding if immediately repeated and followed by a '?' (Fig. 10). Repeating this combination

Figure 8 — Plot of assumed incomes in Germany (1), France (2) and England (3), all expressed in DM

Figure 9 — Graph of variation in incomes in England, expressed in DM

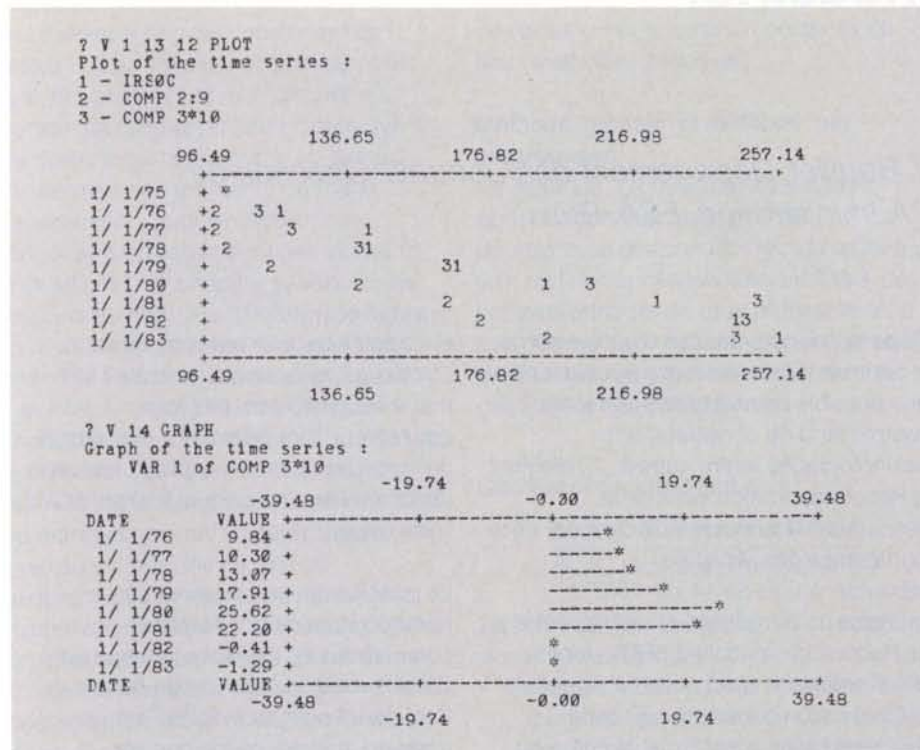
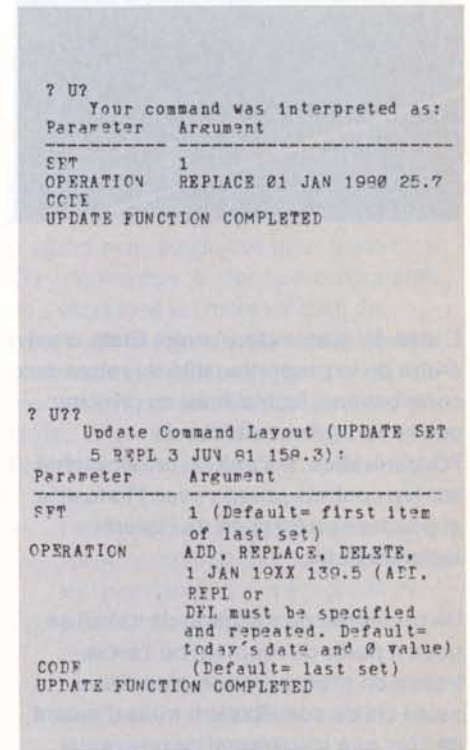


Figure 10 — Example of the computer's understanding of a command

Figure 11 — Example of the command layout provided by the system



again or entering the command code followed by '??' at any time will display the command layout, as in Figure 11.

When entering the tuples, that day's date is used as a default for the first one if no alternative is specified. The date of all other tuples will default to the date of the immediately preceding one.

The value in each tuple must not be confused with a day (1–31), a month (1–12) or a year (1935–1999 or 35–99), if these are not specified. Ambiguities may be solved by following data values with a decimal figure. For example, a value '82' should be written as '82.0'.

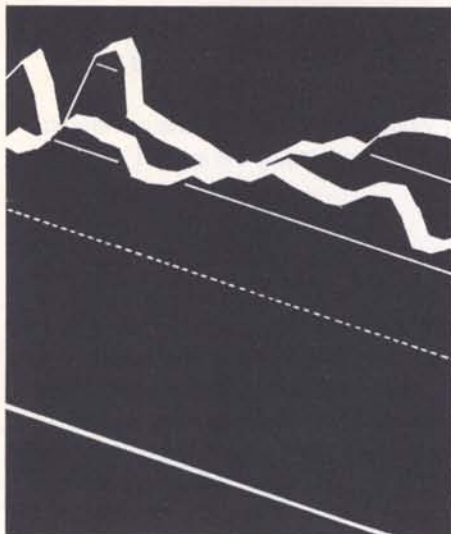
During the manipulation phase, the COMPUTE command will create into the user's set one time series without averages, having as frequency and range those values valid at the moment the COMPUTE command was entered. Changing the frequency and trying to use previously created sets may result in a 'NO DATA FOR THIS RANGE/FREQ.' message.

Conclusion

The new PTS services is a powerful tool for processing and displaying a wide variety of time-series data for a host of day-to-day applications in a commercial environment. The time-dependent data that can be manipulated with ease on the PTS system include:

- daily expenditures
- budget allocations
- manpower statistics
- reliability figures, etc.





Le principe de 'juste retour industriel'

J. Bouillet, Département des Contrats, Direction de l'Administration, ESA, Paris

L'idée de 'juste retour' entre Etats, c'est-à-dire de la proportionalité du retour aux contributions, fut instituée en principe dès le début des activités de l'Organisation. Il s'agit du retour global sur les contrats passés avec l'industrie et pondéré en fonction de l'intérêt technologique.

Un problème de méthode de calcul se posa à partir du moment où l'on se trouva en présence, non plus d'une seule clé de contribution, mais d'autant de clés que s'ouvraient de nouveaux programmes facultatifs aux côtés des activités de base obligatoires.

On explicite le problème, l'option formellement prise sur l'alternative ouverte, les effets et les modalités essentielles d'application de la méthode adoptée.

'Répartir ses commandes d'équipements et contrats industriels aussi équitablement que possible entre les Etats Membres, compte tenu de considérations... technologiques (entre autres)...', telle était la Recommandation objet de la Résolution VIII annexée à l'Acte Final de la Conférence des Ministres plénipotentiaires du 14 juin 1962, à l'adresse de l'Organisation européenne de Recherche spatiale (ESRO), dont la dite Conférence avait ouvert à signature la Convention constitutive. Et cette Recommandation est l'une de celles qui furent adoptées par le Conseil à sa première réunion tenue trois jours après l'entrée en vigueur de la Convention (le 20 mars 1964). En bref, le principe qu'exprime cette Recommandation, et que très tôt l'on nomma communément le 'juste retour' – retour 'industriel' s'entend puisqu'il devait s'agir du retour à partir des contrats passés avec l'Industrie – s'était trouvé institué d'emblée, il y a près de vingt ans.

Presqu'aussi ancienne est la quantification en intérêt technologique de ce 'juste retour'. Dès septembre 1965 en effet, une nomenclature de pondération des contrats et commandes en fonction de cet intérêt par référence aux Grands Titres et Titres du Budget était établie.

Ce principe du 'juste retour' fut repris dans la Convention de l'Agence spatiale européenne (à effet du 30 mai 1975) où il figure même en relative éminence. En effet, tandis que l'élaboration et la mise en oeuvre d'une politique industrielle appropriée... y est présentée comme l'un des quatre éléments de la 'mission' de l'Agence, c'est pour un des trois aspects

et objectifs de cette politique qu'est édictée la 'garantie que tous les Etats membres participent de façon équitable...'¹. Pareillement y était reprise, de façon parfaitement explicite, la notion de 'l'intérêt technologique' à attacher à ce 'juste retour'².

Le principe énoncé, muni de sa nomenclature de pondération, commandait en lui-même la tenue de statistiques et la conduite de calculs. Ceci devint obligation formelle à partir du moment où, de principe, le 'juste retour' fut institué en réelle référence de gestion. Ce fut le fait d'une Résolution du Conseil de fin 1967, laquelle fixait en contrepartie une tolérance numérique sur ce retour (il était toléré à 70% dans la limite d'une masse donnée de contrats). Cette institution fut consacrée sous la forme de la reprise de dispositions du même ordre, d'abord dans une Résolution de mise à jour en fin 1971 puis dans la Convention ESA elle-même (retour actuellement toléré à 80%)³.

La théorie de calcul

On n'en présentera ici que les grandes lignes. Certaines précisions et considérations de second ordre sont traitées dans le chapitre suivant, avec les modalités d'application.

La notion même de 'répartition équitable' dans la Recommandation d'origine conduisait normalement à faire, pour chaque Etat, le rapport du pourcentage des contrats reçus par lui – au sein du total en valeur pondérée⁴ des contrats attribués sur l'ensemble des Etats – à son propre pourcentage de contribution. C'est bien ce qui fut fait dès le départ.

Ce rapport de pourcentages fut habituellement appelé 'coefficient de retour'. Ce qu'il y a lieu de préciser, c'est que, dès le départ, le montant pris en compte par contrat en était, quelle que fût sa durée, le montant *total*, c'est-à-dire, initialement, son montant nominal à l'approbation, auquel viendront se substituer successivement des montants plus affinés (voir chapitre suivant), mais toujours du total. (La différence se marque ici d'avec le montant de l'engagement financier – a fortiori d'avec une situation instantanée des paiements effectués – engagement qui, selon les cas ou l'état de la procédure dans un contrat, peut en première instance se trouver bien en deçà du montant nominal à l'approbation, avec au surplus une répartition géographique différente elle aussi de la répartition nominale). Cette façon de faire devint et restera constante. Elle renferme en elle-même toute la nature du 'coefficient de retour': c'est un *indicateur de tendance* sur une projection à moyen terme en perpétuelle élaboration. L'essence de ce rôle écarte toute comparaison réellement valable avec un indice de retour de caractère financier.

Ceci précisé, l'exposé de la théorie de calcul s'arrêterait là si la situation avait été que l'on puisse perpétuellement et en toute rigueur parler du 'pourcentage de contribution' avec un article défini. Or la Convention ESRO prévoyait, en marge à son Programme, la possibilité de 'Projets spéciaux' entre certains Etats et au surplus, implicitement, à barèmes de contribution spécifiques. Pareillement et de façon plus nette dans la Convention ESA où de telles activités, nommées 'facultatifs', sont présentées dans le même article en complément naturel à celles dites 'obligatoires'. De fait, à partir de 1972, des contrats sur de telles activités se présentèrent. A la fin de 1973, leur somme (sur Télécom, Aérosat, Météosat, Marots et Spacelab) représentait 70% du total général. Il fallait désormais ajouter le qualificatif 'global' à l'expression 'coefficient de retour' – c'est cette expression ainsi complétée qui sera par la suite consacrée dans la Convention ESA⁵

– tandis que, du point de vue de la théorie de calcul, on se trouvait en présence de deux méthodes possibles.

Méthode 'globale' et méthode 'par programmes'

La méthode 'globale' consiste à faire, pour chaque Etat, le rapport du pourcentage des contrats reçus par lui au sein du total, sur l'ensemble des Etats, des contrats attribués en tous programmes, à son pourcentage de contribution, au sein du total des contributions de l'ensemble des Etats à tous programmes:

Coefficient de retour global =

$$\frac{\% \text{ reçu du total des contrats}}{\% \text{ du total des contributions}}$$

La méthode 'par programmes' consiste, pour chaque Etat, à:

- calculer, en chaque programme, le montant que, du total, sur l'ensemble des Etats, des contrats attribués en ce programme, il aurait idéalement dû recevoir compte tenu de son pourcentage de contribution au programme, montant dit 'montant idéal';
- faire ensuite le rapport du total des contrats reçus par lui en tous programmes au total des 'montants idéaux' qui précèdent:

Coefficient de retour global =

$$\frac{\text{Total des contrats reçus}}{\text{Total des montants idéaux}}$$

étant souligné:

- qu'à l'échelon d'un programme, la méthode produit un coefficient de retour qui, s'il est, à l'état brut, un rapport de montants, peut s'exprimer de façon arithmétiquement identique en rapport de pourcentages:

$$\frac{\% \text{ reçu des contrats dans le programme}}{\% \text{ de contribution au programme}}$$

- qu'à l'échelon global, il en est de même mais a condition de spécifier comme suit le dénominateur:

pourcentage sur l'ensemble des contributions qui seraient nécessaires à la couverture du total, sur l'ensemble des Etats, des contrats attribués en tous programmes.

L'exemple numérique qui suit, construit avec seulement deux Etats et deux programmes, illustre ces deux méthodes. On y notera que, si, dans un programme, on s'est donné un montant total de contributions égal au montant total des contrats, dans l'autre on s'est donné des montants largement différents. Dans la réalité, cette disparité est la règle. Brièvement rappelé, voici en quoi:

- Les contributions sont là pour couvrir les paiements de dépenses (toutes les dépenses), lesquelles d'ailleurs peuvent être disjointes en deux masses:
 - la masse des dépenses directes au titre des contrats pris en compte et sans la part qui en est neutralisée dans la statistique par la pondération ou le placement en dehors de l'ensemble des Etats, appelée communément masse des dépenses 'nobles' (du point de vue technologique);
 - la masse du reste, c'est-à-dire, outre la part neutralisée ci-dessus, les dépenses à d'autres titres, en particulier celles dites internes à l'Organisation;
 le rapport entre ces deux masses étant propre à chaque programme.

- De l'autre côté, dans le montant total des contrats, auquel le répondant en paiements est la première masse précitée, s'il n'y a certes que des contrats industriels, ils sont par contre tous à leur montant total, montant en règlement ou projeté (lequel peut même être, on l'a vu, supérieur au montant en engagement), le rapport entre le montant des contrats et celui qui y correspond au sein du montant de contributions étant, lui aussi, propre à chaque programme. La Figure 1

Figure 1

illustre, de façon schématique, cette disparité.

Le propos même de cet exemple était de montrer que, sur la base d'une répartition de contrats conférant à chaque Etat un coefficient de retour de 1 pour chaque Programme, la méthode 'par programmes' donne par définition un coefficient de retour global également de 1 pour chaque Etat, ce qui n'est pas le cas avec la méthode 'globale'. Et toute la différence provient de la disparité soulignée plus haut entre montant des contributions et montant des contrats. Plus concrètement, le fait qu'avec la méthode 'globale' l'Etat A par exemple a un coefficient plus fort qu'avec la méthode 'par programmes' tient à ceci: en correspondance à un montant projeté de contrats de 300 (auquel correspondrait, dans l'hypothèse d'une répartition 60% /40% des masses de dépenses évoquées précédemment, un montant total projeté de dépenses de: $320/60 \times 100 = 533$), la situation du programme était telle qu'elle n'exigeait que 100 en couverture de contributions (dont seulement d'ailleurs 60 pour la couverture des dépenses sur ledit montant de contrats), 100 sur lesquels cet Etat contribue pour 90 alors que virtuellement la seule couverture du montant projeté de contrats impliquait une contribution de sa part de $320 \times 90/100 = 288$. De façon abstraite, le rapport des coefficients selon chacune des deux méthodes est à raison inverse du rapport des pourcentages de contribution tels qu'établis respectivement en chacune d'elles.

Considération connexe: si l'on se place en la situation des programmes où la totalité des dépenses projetées devrait être couverte (fin des programmes) et supposant une répartition des masses précitées de dépenses: 60%/40% dans I (hypothèse ci-dessus) et 80%/20% dans II, les données de contribution ainsi que les coefficients de retour selon la méthode 'globale' deviendraient les suivants (on y a maintenu les montants de contrats à respectivement 320 et 110, comme si, avec ces montants, on avait couvert d'emblée

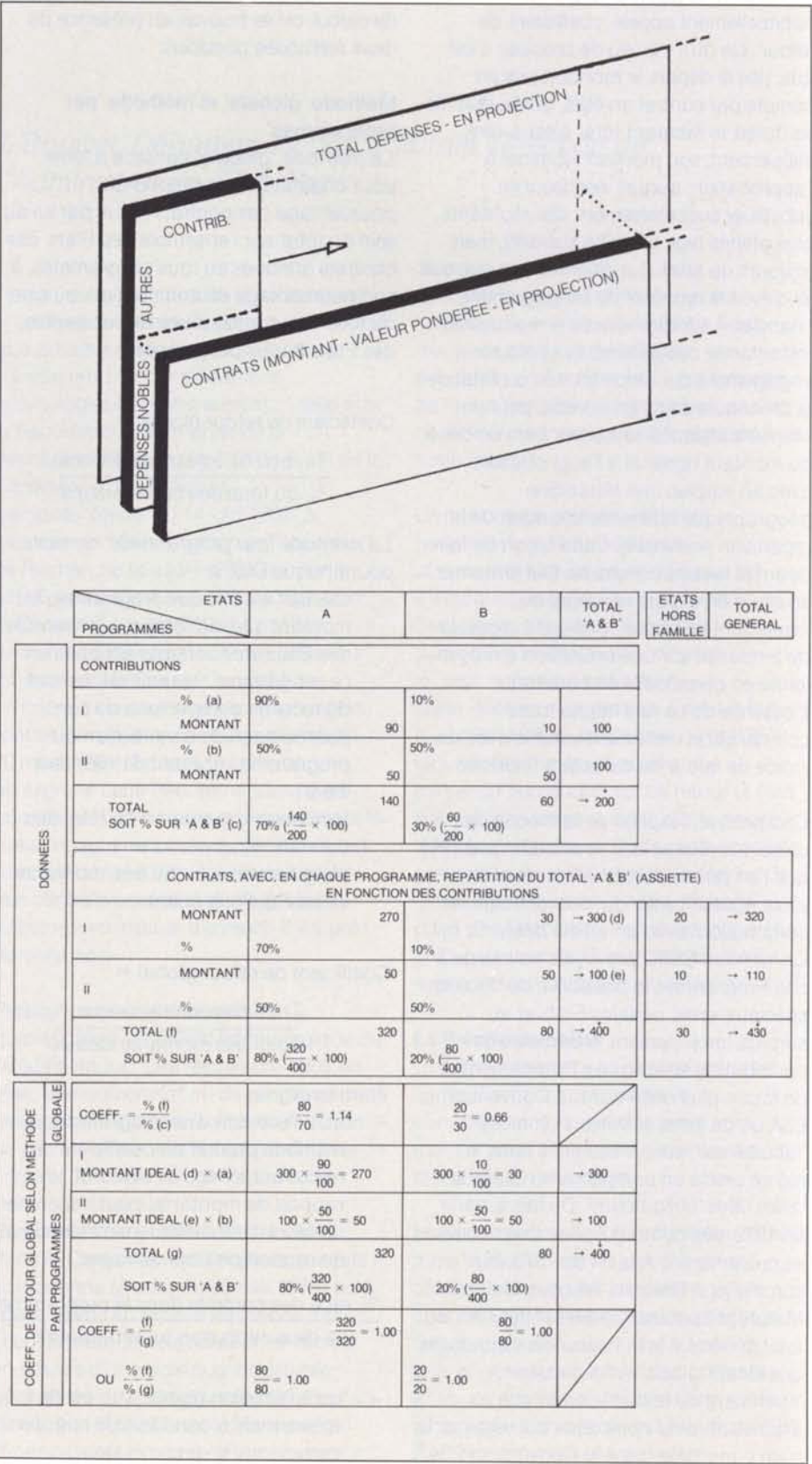


Figure 2

ETATS PROGRAMMES	A	B	TOTAL 'A & B'
CONTRIBUTIONS			
I %	90%	10%	$(320 \times \frac{100}{60})$
MONTANT	480	53	533
II %	50%	50%	$(110 \times \frac{100}{80})$
MONTANT	68.5	68.5	137
TOTAL SOIT % SUR 'A & B' (c)	548.5 81.9% $(\frac{548.5}{670} \times 100)$	121.5 18.1% $(\frac{121.5}{670} \times 100)$	↓ 670
COEFF. = $\frac{\% (f)}{\% (c)}$	$\frac{80}{81.9} = 0.98$	$\frac{20}{18.1} = 1.10$	

l'intégralité des programmes, ce qui est évidemment une simplification pour permettre la comparaison avec le calcul qui précède).

On y constate et l'on comprend que la double conjonction pour l'Etat A d'avoir la contribution relative la plus forte dans le programme à rendement relatif en dépenses 'nobles' le plus faible fait que cet Etat a un coefficient de retour global plus faible que celui selon la méthode 'par programmes', lequel reste par définition inchangé à 1. Et vice versa à l'égard de l'Etat B.

L'option pour la méthode 'par programmes'

Prise après de longs débats au Comité Administratif et Financier, cette option fut mise en oeuvre dans la situation de fin décembre 1973. Par la suite, le texte même de la Convention ESA, assorti d'une Résolution interprétative complémentaire du Conseil, consacra officiellement la méthode⁶. Il était essentiel que cette Résolution comporte entre autres une mise à jour de la définition littérale de l'ensemble des Etats sur lesquels on doit établir le montant des contrats à répartir, ce qui constitue proprement l'"assiette de calcul". Cet ensemble y est ainsi défini: 'ensemble des Etats participant à au moins un des programmes de l'Agence',

actualisant ce que la Convention entend par 'ensemble des Etats membres'. Ici trois remarques s'imposent:

- Aux onze Etats membres de l'Agence (Allemagne, Belgique, Danemark, Espagne, France, Irlande, Italie, Pays-Bas, Suède, Suisse et Royaume-Uni) sont venus se joindre deux Etats associés (Autriche et Norvège) et un Etat coopérant (Canada). Total: 14 Etats.
- Vu le nombre actuel de programmes (35), le cas n'existe plus d'un Etat membre participant à tous.
- La situation se présente actuellement d'un Etat non-membre qui participe à autant de programmes qu'un Etat proprement membre.

Les modalités essentielles d'application Contrats reçus par un Etat

Sous cette expression volontairement elliptique employée dans l'exposé de la théorie, se place en premier lieu la question de savoir à quel niveau nécessaire et suffisant de sous-traitance doit se situer l'établissement, dans un contrat, de la répartition géographique des travaux. Tout normalement, on s'en tient à la charte industrielle de répartition de lots homogènes, laquelle descend en principe jusqu'au niveau 'sous-systèmes'

telle que tout contrat en est, quand il y a lieu, généralement assorti. A moins même que n'y figurent des dispositions spécifiques, en termes de seuils de montants monétaires, pour l'identification de sous-contractants additionnels.

A partir de là, il peut arriver, en la complexité actuelle du monde industriel, que le placement par nationalité pose problème. La Convention ESA a traité ce point: 'l'appartenance d'une entreprise à l'un des Etats... est jugée à la lumière des critères suivants: localisation de son siège social, de ses centres de décision et de ses centres de recherche, et territoire sur lequel les travaux doivent être exécutés'⁷ avec, dans les cas douteux, recours au Comité de la Politique industrielle, par délégation du Conseil.

En d'autres termes, c'est la réalité des choses que l'on doit chercher à dégager pour l'établissement du 'retour'. Il faut regarder derrière l'apparence juridico-commercial. Il faut regarder derrière l'apparence monétaire pareillement, au nom de la même philosophie. En effet, il peut se trouver que, dans un contrat, un poste monétaire en une monnaie nationale donnée soit destiné à couvrir, outre les dépenses du contractant principal et de l'industrie sous-contractante de même appartenance, les dépenses d'une industrie sous-contractante d'appartenance différente, les autres ayant par contre leurs postes monétaires propres. Il peut même advenir que, pour des raisons particulières, un contrat ait été libellé pour le tout en la seule monnaie de l'Etat d'appartenance du contractant principal, le soin revenant dans les deux cas à ce dernier d'assurer les opérations de change et la distribution. Dans les grands contrats, l'identification, sous la ligne, de sous-contractants additionnels' révélera généralement des situations de même nature, qui sont parfois loin d'être négligeables. On tient donc compte de toutes ces situations, en correctif, dans l'établissement de la répartition géographique.

Montant des contrats

On a dit plus haut qu'au montant nominal à l'approbation viennent se substituer successivement des montants plus affinés. La première phase d'affinement est naturellement la survenance du contrat qui, lui, comporte les réelles données d'obligation. A partir de quoi va jouer l'effet d'inflation. En termes concrets, on va atteindre successivement des phases où intervient l'application de la formule de révision des prix, ou 'des' formules s'il y a plusieurs firmes en jeu, chacune pouvant avoir la sienne propre. Il n'y aura donc aucun parallélisme entre firmes dans cette évolution, d'autant plus que la gamme des travaux évolue elle-même de façon propre à chaque firme. A cet effet d'inflation vient se combiner celui de la *variation annuelle des taux de conversion* des monnaies nationales en unités de compte dans lesquelles on va exprimer, pour en faire la somme, les paiements effectués et ceux, en projection, restant à effectuer. Or, non seulement les variations des taux de conversion ne présentent aucun parallélisme entre monnaies, mais en plus, la répartition des paiements entre les différentes monnaies est également variable dans le temps. Au total, partant d'un montant nominal donné en unités de compte assorti d'une répartition géographique donnée, on arrive fatalement après être passé par des états successifs de dossier, à un montant différent avec une répartition géographique différente. Dans les grands contrats, la mesure de cette double divergence peut être importante en valeurs absolues, et non négligeable en valeurs relatives. C'est la façon de faire décrite qui a été officiellement consacrée par le Conseil au terme d'un long débat sur la question de la prise en compte ou non des deux effets précités dans le calcul du retour industriel⁸.

Autre point: la pondération. Bien entendu, depuis septembre 1965, le barème fit l'objet de révisions mais dans le maintien de la règle 'pondération contrat par contrat' – règle qui fut explicitement

reprise dans la Convention ESA⁹ – et du système de référence au sous-titre budgétaire d'imputation. Dans le barème actuellement en vigueur, trois facteurs de pondération seulement entrent en jeu, distribués sur 50 sous-titres: 0,00 (facteur totalement absorbant), 0,25 (partiellement absorbant) et 1,00 (conservation du contrat à sa valeur entière).

En corollaire à la règle 'pondération contrat par contrat' s'était instituée celle 'un seul facteur de pondération par contrat' qui, elle aussi, fut implicitement reprise dans la Convention ESA, la possibilité d'exception y étant toutefois prévue dans le cas des contrats dont le 'montant est important'. La seule règle arrêtée à ce jour se rattachant à cette disposition est, au sein des grands contrats de réalisation de satellites, la pondération à 0,50 du système 'Equipement mécanique de soutien au sol'.

Un point particulier: celui de la pondération des lanceurs. Lors de la révision de 1972, la règle avait été arrêtée d'une pondération à 0,00. C'était une virtualité puisque, jusqu'alors, tous les lanceurs utilisés étant américains, les contrats s'y rapportant tombaient en dehors de l'assiette de calcul du retour, c'est-à-dire se trouvaient de toutes façons neutralisés. Mais par le fait de la reconduction des règles de 1972 pour tous sous-titres budgétaires non nouveaux, le 0,00 subsista pour les lanceurs tandis qu'entretemps le lanceur européen (Ariane) apparaissait. Pour ce qui est des quatre premiers lanceurs Ariane, s'agissant de 'développement', les règles de droit commun jouèrent normalement, à savoir 'pondération contrat par contrat' (plusieurs centaines sur le total desquels l'effet global de la pondération atteint 0,90). Pour ce qui a trait aux six lanceurs de la série de promotion, la question se trouva écartée du fait d'une décision prise par le Conseil¹⁰ de tenir ce programme hors du champ de calcul des coefficients de retour global, ce qui, aux termes de la

Convention, est toujours possible à l'égard des activités 'facultatives' dès lors que les 'Etats participants initiaux y donnent leur accord à l'unanimité'¹¹. On le précise ici, à cette occasion, car ce fut jusqu'alors le seul cas. Mais voilà que la question a récemment resurgi dans la perspective des premiers projets de contrats de production entre l'Agence et Arianespace, et est donc actuellement à l'ordre du jour.

Montants idéaux

Parler des montants idéaux, c'est en fait parler des contributions. Dans l'enregistrement de celles-ci, on va naturellement suivre le même principe de projection que pour les montants de contrats (les coefficients de retour sont des indicateurs de tendance), ce qui conduit à compléter les montants des *comptes annuels* officiels des données officielles de *budget*, en leur dernier état de *révision* et d'*ajustements* au fur et à mesure. C'est ainsi que, normalement, dans le calcul des coefficients de retour au dernier trimestre de l'année N, les montants de contributions qui y interviendront comprendront le cumul des comptes annuels depuis l'origine du programme, à l'intérieur de la série statistique considérée, jusqu'à l'année N-1 (dont les comptes officiels auront été officiellement arrêtés à la mi-année N), les données du budget de l'année N encore en cours, en l'état de sa dernière *révision*, ainsi que celles de l'année N+1 à venir. Situation qui sera reconduite dans le premier trimestre de l'année N+1 (les comptes de l'année N, à inscrire en substitution aux données du budget, n'interviendront en effet à leur tour qu'à la mi-N+1), mais à compléter, dès qu'ils se présenteront, des *ajustements* des contributions de l'année N. Ces ajustements sont normalement de trois types:

- ajustements pour tenir compte des différences entre estimations budgétaires initiales et dépenses réelles;
- ajustements dus aux modifications éventuellement apportées au cours

de l'exercice aux barèmes mêmes de contributions;

- ajustements pour tenir compte des différences – avec toutefois seuil de franchise – entre les expressions des contributions en unités de compte aux taux respectivement annuels de l'ESA et journaliers au jour de versement; c'est là une disposition du Règlement financier.

Si, dans un programme, la clé de contribution n'est nullement affectée par le premier type d'ajustements, puisqu'ils sont répartis au prorata de cette clé, il en va différemment avec les deux autres. Dans l'un des cas, c'est la raison même des ajustements; dans le dernier, c'est parce que, pour le calcul des coefficients de retour, ces ajustements, qui sont globaux par Etats, sont répartis entre les programmes au prorata des données nominales du Budget auxquelles rétroactivement ils se rapportent alors que, du point de vue financier, ils sont intégrés dans les comptes plus larges des gains et pertes de change. L'effet est loin d'être insignifiant dans ledit calcul à l'époque de grandes distorsions monétaires qui est la nôtre, de sorte que, même dans un programme à clé de contribution invariante (et il y en a quelques-uns), cette clé en réalité varie.

Dernier point essentiel à préciser: en certains programmes, les contributions sont différentes (clé ou loi) selon qu'elles se rapportent aux dépenses dites 'internes' ou à celles dites 'externes'. Il est clair que, dans l'optique du 'retour industriel', on ne prendra en compte que les secondes.

A la réflexion, on pourra se dire, à juste titre, qu'en faisant ainsi continuellement la somme, pour chaque programme et au compte de chaque Etat, des contributions pour en tirer des états successifs de clé de contribution moyenne pondérée dont le dernier est celui qui détermine les montants 'idéaux', on pratique en fait, à l'intérieur de chaque programme, la méthode 'globale'.

Remarque: Ainsi que souligné au début dans l'exposé de théorie, la méthode 'par programmes' produit des coefficients de retour par programme. Mais il faut bien voir que, pour un programme donné, ces coefficients peuvent, toutes choses étant égales par ailleurs, être différents de ceux résultant du texte (Accord, Arrangement ou Déclaration) gouvernant ledit programme. Exemple typique: l'ajustement des contributions sur le retour au sein du total sur l'ensemble des Etats participants, mais de ces Etats seulement.

Montant des contrats sur l'ensemble des Etats de l'Agence (les 14 Etats) ou 'assiette de calcul' pour le calcul des coefficients de retour global: 250 dont 200 sur l'ensemble des seuls Etats participants.

Soit 50 le montant reçu par tel de ces Etats, ce qui, rapporté à 200, représente 25%, pourcentage qui sera donc celui de contribution.

En d'autres termes, son coefficient de retour au regard de la disposition spécifique du programme sera 1 tandis que, dans le cadre de calcul des coefficients de retour global, il sera de $50/250 \times 100 \times 1/25 = 20/25 = 0,80$ (coefficient réduit dans le rapport des deux assiettes 200/250).

Il peut y avoir dans les textes du programme des dispositions spécifiques d'autre nature qui peuvent être également source de pareille différence.

★

Telles sont la théorie et les modalités essentielles de calcul des coefficients de retour global.

Les séries officielles d'édition de ces coefficients, à périodicité triennale ainsi que le requiert la Convention ESA¹², sont actuellement au nombre de deux:

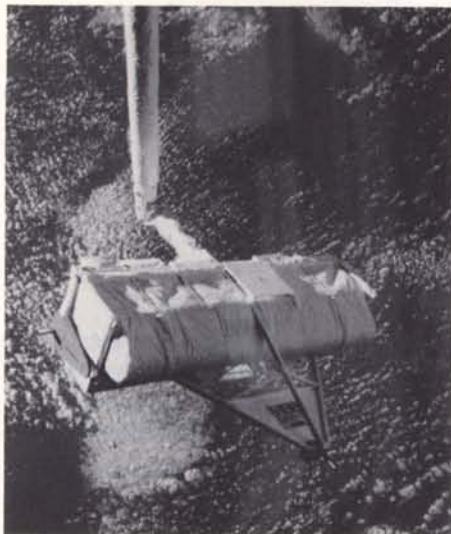
- une série 'depuis 1963', c'est-à-dire depuis l'origine
- une série 'depuis janvier 1972'.

C'est à cette dernière série qu'il est

d'usage d'attacher le seuil de tolérance de 0,80, évoqué dans le premier chapitre, tel que fixé dans la Convention³ et resté jusqu'ici inchangé. En d'autres termes, c'est avec cette série que l'on regarde la situation.

Mais son étendue dans le temps atteint à présent une mesure telle – plus de 11 ans – que l'on est nécessairement conduit à s'interroger. Interrogation centrée moins sur l'aspect purement technique de la variation de sensibilité de l'instrument dans sa production de valeurs relatives – les coefficients, ce qui est un sujet en soi – que sur l'importance, en valeur absolue, des capitalisations sur une telle étendue. Cette interrogation est à l'ordre du jour. ☛

1. Convention, art. II (d) et art. VII, 1 (c).
2. Convention, Annexe V, art. IV, 2.
3. Convention, Annexe V, art. IV, 6: pour les trois premières années, retour toléré à 80%, les révisions triennales à intervenir par la suite ne pouvant que jouer en hausse par rapport à cette valeur donnée pour plancher de référence, et au-dessous duquel il y a déclenchement de mesures de redressement.
4. Dans le reste de ce texte, lorsque l'on parlera de montants de contrats, ce sera toujours, sous-entendu, en 'valeur pondérée'.
5. Convention, Annexe V, art. IV, 1.
6. Convention, Annexe V, art. IV, 1: '...le coefficient de retour global d'un Etat... est défini comme le rapport entre le pourcentage des contrats qu'il a reçu calculé par rapport au montant total des contrats passés dans l'ensemble des Etats..., et son pourcentage de contribution'. Voir aussi, la Résolution du Conseil du 26 juin 1980 (ESA/C/XLII, res. 4): 'L'expression 'montant total des contrats passés' s'entend du montant total de l'ensemble des contrats relatifs à l'ensemble des programmes de l'Agence placés auprès des Etats membres ou des Etats participant à au moins un de ces programmes' et 'L'expression 'pourcentage total de contribution' s'entend du pourcentage total de l'ensemble des contributions nécessaires pour financer le montant pondéré des dépenses encourues au titre des contrats précités'.
7. Convention, Annexe V, art. II, 3.
8. Résolution ESA/C/V, res. 1, adoptée par le Conseil le 17 décembre 1975.
9. Convention, Annexe V, art. IV, 2.
10. Résolution ESA/C/XXII/res. 11 du 15 décembre 1977.
11. Convention, Annexe V, art. IV, 1 (a) et (b).
12. Convention, Annexe V, art. IV, 4.



A European Heat-Pipe Experiment on the Second Flight of Space-Shuttle 'Challenger'

C.J. Savage, Thermal/Environmental Control Section, Spacecraft Technology Department, ESTEC, Noordwijk, The Netherlands

The second flight of 'Challenger' carried a European heat-pipe experiment designed to measure the performance of constant-conductance heat pipes, variable-conductance heat pipes and diodes over a 24 h period. The experiment, sponsored jointly by ESA and the German Ministry of Science and Technology (BMFT), formed part of the first payload for the German Shuttle Pallet Satellite (SPAS-01).

By the time this is published, SPAS-01 (Fig. 1) should already have completed its first mission and been returned to Earth for post-flight testing and, hopefully, refurbishment for the next flight. SPAS, the Shuttle Pallet Satellite, is a German national development and constitutes the first of Europe's retrievable spacecraft, the forerunner of systems such as ESA's European Retrievable Carrier (Eureca).

The first flight of SPAS-01, which at the time of writing is scheduled for June this year, carries a payload which consists of a 'core' of experiments sponsored directly by the German government, together with a number of additional experiments provided by outside sponsors for flight on a commercial basis. ESA has two experiments in the latter category, namely an infrared yaw sensor experiment and a solar-cell calibration experiment. The heat-pipe experiment, however, is a joint venture, co-sponsored by ESA and the Germany Ministry of Science and Technology (BMFT), and as such is included within the core payload.

The SPAS-01 heat-pipe experiment is the latest in a series of experiments aimed at measuring heat-pipe performance under zero-gravity conditions. Past experiments have made use of sounding rockets, but the short (<8 min) zero-g time available has restricted tests to only constant-conductance heat pipes. The SPAS-01 flight provides 24 h of heat-pipe experiment time in zero-g, enabling more complex heat-pipe devices to be tested. In addition, the active test phase is preceded by some 50 h during which low-g conditions exist, eliminating the

uncertainties that have arisen with nearly every sounding-rocket test concerning the priming status at the start of testing.

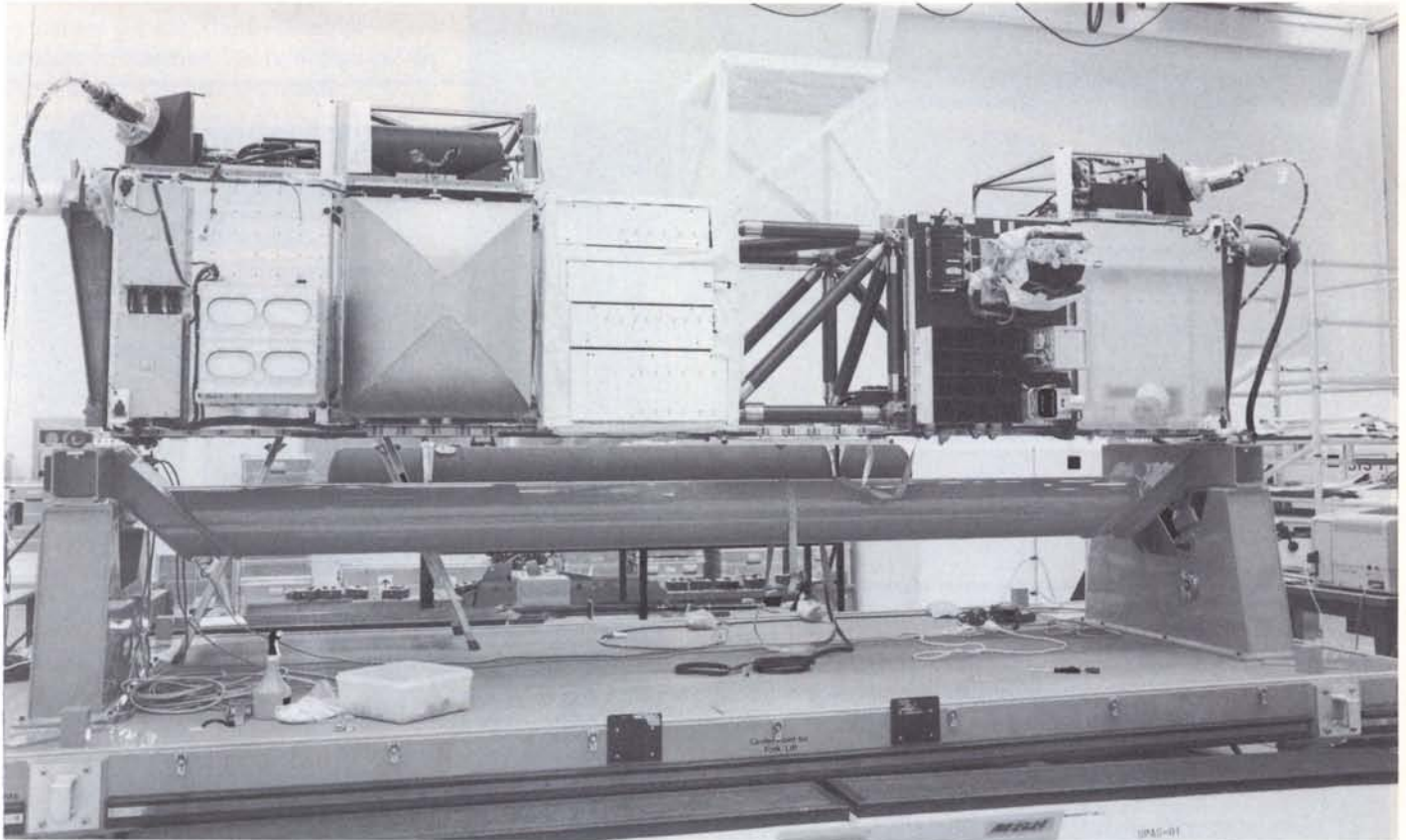
Constant-conductance heat pipes developed in Europe are already flying in the Marecs maritime communications satellite, and will form an important thermal-control element on the Franco-German TV-Sat and ESA's L-Sat and ERS-1 spacecraft.

Why test in zero-g?

All heat-pipe devices operate by transferring heat as latent heat in the vapour phase of a volatile working fluid. The working fluid evaporates at the heat-source end, in the evaporator section, and recondenses at the heat-sink, or condenser, end. Return of the condensate to the evaporator is usually, and in current space heat pipes exclusively, achieved by capillary action in a porous wick material. For most practical purposes the heat-transport capacity of a heat pipe is determined by the effectiveness of the wick, and this is affected by gravity. For instance, the heat-transport capacity of most heat pipes falls to zero if the wick is asked to work against a hydrostatic head of more than a few centimetres. Although gravity is not a problem in space, testing must be performed on the ground and it is important to confirm that these tests can be extrapolated to zero-g conditions.

On the ground, excess liquid – liquid in excess of that needed to saturate the wick – will form a pool in the bottom of the pipe. In space it will be somewhere else, and may affect the heat-pipe conductance value, temperature-control

Figure 1 – SPAS-01 undergoing final integration and preflight checks at Kennedy Space Center in February 1983



characteristics of VCHPs*, shut-down characteristics of diodes**, etc.

The flight also allows zero-g priming to be observed, uncomplicated by gravity-dominated liquid pools, etc. and in the case of VCHPs enables the behaviour of the gas/vapour interface (the gas front) to be observed in the absence of convective effects.

* VCHP – Variable-Conductance Heat Pipe – basically a heat pipe in which a noncondensing gas, occupying a reservoir attached to the condenser end and a part of the condenser, modifies the condenser active length (and hence its conductance) as a function of the evaporator temperature (see ESA Bulletin No. 10, August 1977, pp. 49-55).

** Heat-pipe diodes – one-way heat pipes – either blockage devices, using noncondensable gas or excess liquid to block the vapour space, or liquid-trap devices in which the working fluid condenses into a trap, when in the 'shutdown' or reverse mode (see ESA Bulletin No. 10, August 1977, pp 49-55).

Finally, it provides an unarguable demonstration that the technology works in a space environment; the value of this in convincing potential users is sometimes underestimated.

The experimental payload

The complete heat-pipe experiment contains nine individual experiment units involving experimenters from Dornier System, Institut für Kernenergetik und Energiesysteme der Universität Stuttgart (IKE), and ESTEC. The units are mounted, together with the supporting electronic control and data system, on both sides of a standard SPAS experiment-support plate (ESP), 820 mm long and 690 mm wide. The five units requiring a view to space are mounted on the top surface, whilst the underside carries the electronics boxes and three of the remaining units (Figs. 2a & b). The ninth unit, a diode experiment, although not requiring a view to space, is too large to be

accommodated on the underside of the ESP and has instead been located on the top surface, beneath the largest radiator. Figures 2a and b show the experiment during interface-verification testing at ESTEC. Once installed on SPAS-01, much of the detail is shrouded under thermal-insulation blankets (Fig. 1).

The individual instruments are listed in Table 1 and are briefly described in the following paragraphs. All the heat-pipe devices use anhydrous ammonia as working fluid. Where a noncondensable gas is used, in the VCHPs and gas diode, the gas employed is nitrogen.

Constant-conductance heat-pipe experiments IA1 and IA2

IA1 and IA2 are similar experiments differing only in the length of their evaporator sections. The higher radial heat-flux density associated with the shorter evaporator on IA2 might reduce

Figure 2a – The SPAS-01 heat-pipe experiment (top view)

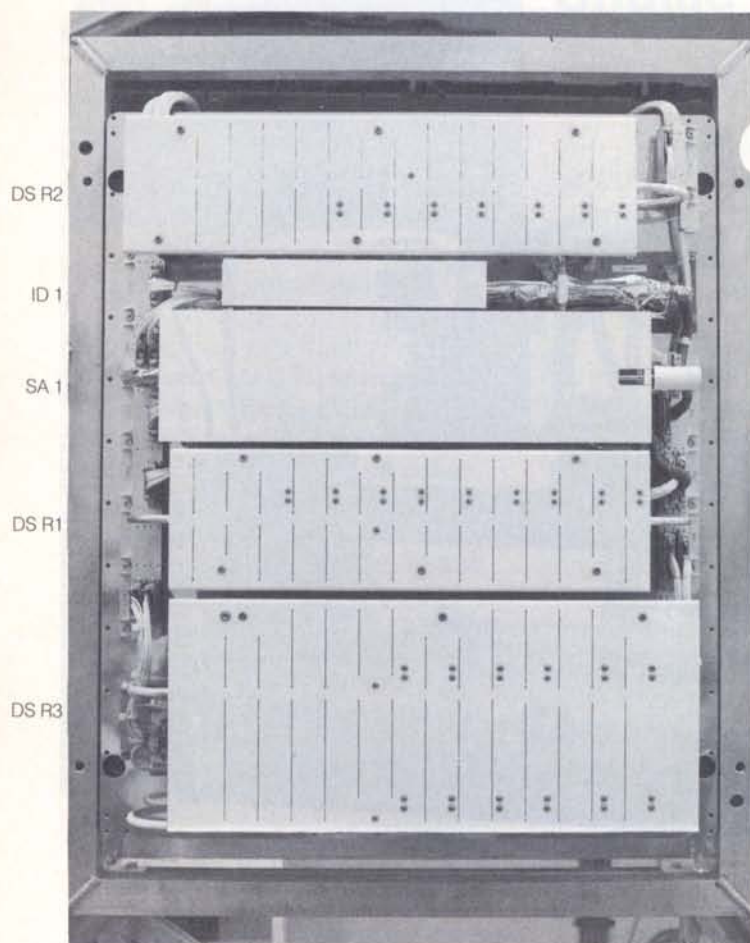


Figure 2b – The SPAS-01 heat-pipe experiment (bottom view)

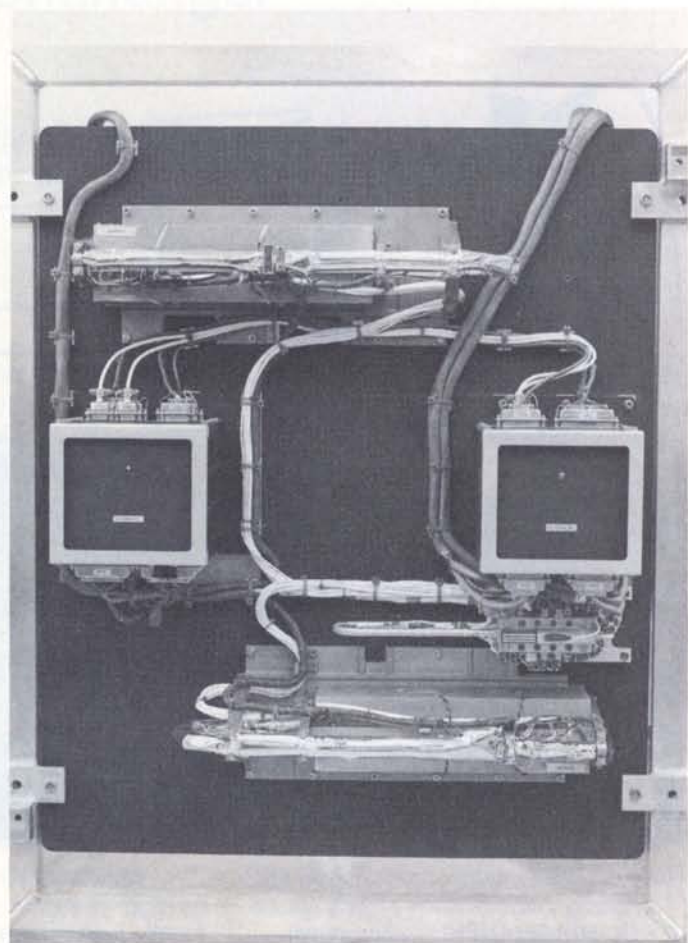


Table 1 – Individual units making up the SPAS-01 heat-pipe experiment

Unit	Nature	Source
IA1	Constant-conductance artery heat pipe	IKE/ESTEC
IA2	Constant-conductance artery heat pipe	IKE/ESTEC
DS R1	Gas-controlled VCHP radiator	Dornier System
SA 1	Gas-controlled VCHP radiator	ESTEC
DS R2	Gas-controlled VCHP radiator	Dornier System
DS R3	Gas-controlled VCHP radiator	Dornier System
ID1	Liquid-trap diode	IKE/ESTEC
DS D1	Liquid-trap diode	Dornier System
DS D2	Gas diode	Dornier System

the heat-transport capacity of that pipe somewhat due to the onset of nucleate boiling in the wick and consequent disruption of liquid flow. The heat pipes are stainless-steel artery designs similar to those flying on Marecs, and each is capable of transporting about 150 W

when horizontal. Heat is supplied electrically to the evaporators according to a pre-programmed power profile, allowing the load to be increased progressively from zero to 150 W. Should the heat-transport limit of the pipe be lower than 150 W, the resulting dry-out

and rapid rise in evaporator temperature is detected by the experiment control and data system and the unit is switched off. The heat transported by the pipes is absorbed by phase-change-material thermal capacitors (PCM cells) containing eicosane wax and attached to the condenser sections. A cooling time of several hours is provided for the wax to refreeze between experiment cycles. The experiments are each instrumented with eight thermistors to provide temperature data for control and for transmission to the ground.

VCHP radiators DS R1 and SA1

DS R1 and SA1 are in many respects similar experiments. Each contains a gas-controlled VCHP with electrically heated evaporator section, and makes use of a space-viewing radiator to cool the

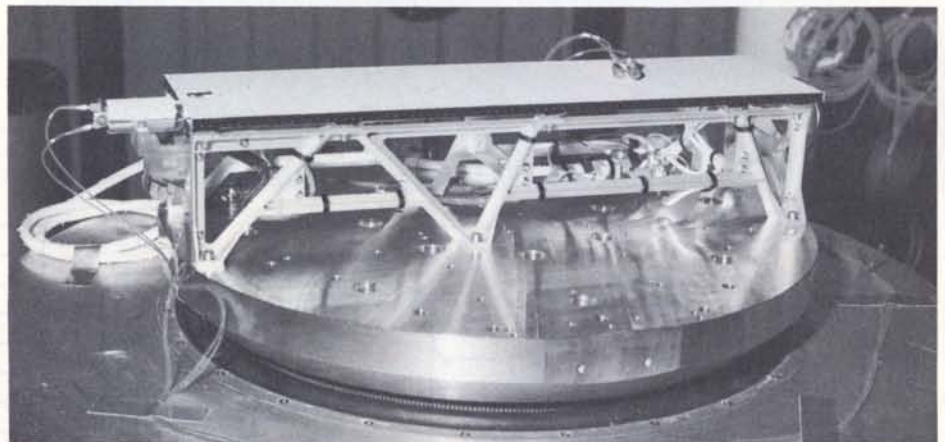
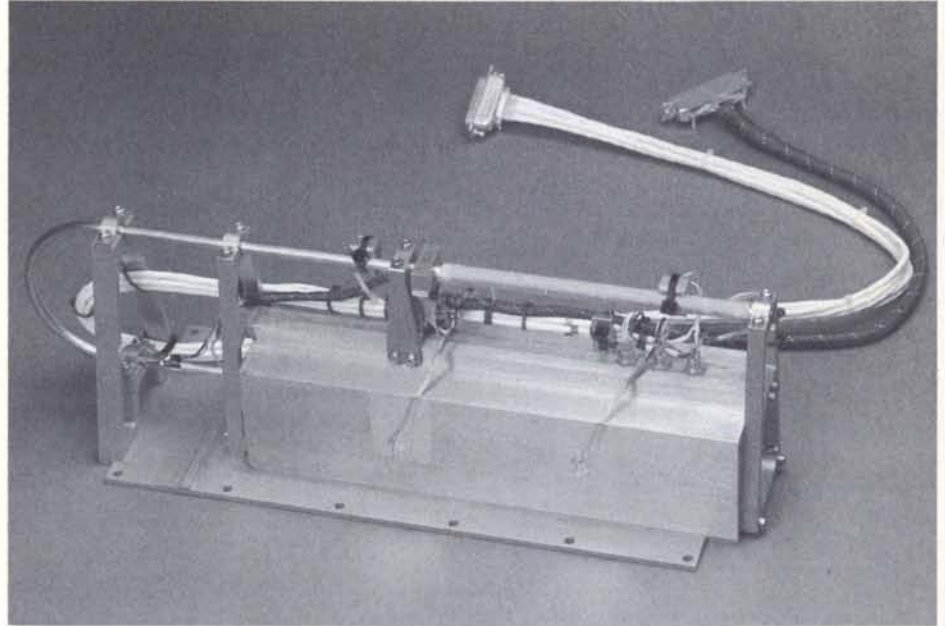
Figure 3 — The constant-conductance heat-pipe experiment IA1

Figure 4 — SA1 during vibration testing

condenser section. There are some differences, however. The heat pipe in DS R1 is a Dornier System extruded-aluminium design using an axial-groove wick structure, and is attached to a slotted radiator (Fig. 2a) to improve the temperature-control characteristic. The gas reservoir is mounted behind the radiator and so is not visible in the photographs. The SA1 heat pipe is stainless steel with a simple artery wick structure, and was supplied by Société Anonyme Belge de Constructions Aéronautiques (SABCA), Brussels. The gas reservoir is cooled by direct radiation to space and is clearly visible in Figure 2a. In addition to the hardware differences, there are significant differences in the experimental procedures adopted. The heat load on DS R1 is stepped progressively up to 20 W and then down again. Each step lasts several hours, which will enable the effects of the varying external environment as 'Challenger' orbits the Earth to be identified and allowed for in assessing radiator and VCHP performance. The SA1 procedure, on the other hand, contains a larger number of far shorter steps, and is aimed at exploring the heat-transport capacity as well as the VCHP control function. The heat load on SA1 is increased progressively until evaporator dry-out is detected (expected around 22 W) or 25 W is attained. The response to step changes in heat load of 10, 15 and 20 W will also be observed. DS R1 is equipped with eleven control and monitoring thermistors, and SA1 with twelve.

Housekeeping VCHP radiators, DS R2 and DS R3

The main task of these radiators is to prevent the ESP from overheating. During experiment operation the ESP acts as a heat sink for the diodes DS D1 and DS D2, the control and data system, and the PCM cells of IA1 and IA2. The amount of heat actually received by the ESP is somewhat uncertain (particularly that received from IA1 and IA2), since it depends on the heat-pipe performance in orbit. An earlier-than-expected dry-out of



these pipes significantly reduces the total dissipation, since it is the higher power steps which are lost. DS R2 is equipped with one gas-controlled VCHP and DS R3 with two, all three being similar in design to that in DS R1. Instead of being heated electrically, however, the evaporator sections are attached directly to the top surface of the ESP. At low ESP temperatures, for instance at the start of experiment operations, the radiators are inactive. As the ESP warms up they start to reject heat and are designed to control ESP temperatures to within a few degrees of 30°C. If the temperatures were to be

allowed to rise significantly above this figure the PCM cells would not re-freeze in the time available and the relevant experiments would be inhibited by the control and data system.

Diodes DS D1, DS D2 and ID1

DS D1 is a liquid-trap diode experiment. Two identical diodes are mounted, at their evaporator (trap) ends, to a common plate equipped with a heater (the 'forward-mode' heater). The free ends of the diodes are attached to a PCM cell and heater block (the 'reverse-mode' heater), respectively. Basically, one diode

Figure 5 — Block diagram of the control and data system

demonstrates forward-mode operation, the heat transported being absorbed by the PCM cell, and the other demonstrates the shutdown or reverse mode. Ten thermistors are used for monitoring and control purposes.

ID1 is also a liquid-trap diode experiment, aimed specifically at investigating the shutdown transient. The diode is a stainless-steel design based on the heat pipes in IA1 and IA2. Separate trap and evaporator heaters are provided which are sequenced to establish a forward mode of operation. These heaters are then switched off and a heater at the other end (condenser) powered to initiate the shutdown. The evaporator and trap are attached to a small radiator and cool by radiation to space. The experiment examines the transient response of the diode to different condenser heat loads. As with DS DI, the diode is instrumented with ten thermistors.

DS D2 is a gas-diode experiment, consisting essentially of a VCHP with a heater at each end. In forward-mode operation, the gas is contained in a reservoir at the condenser end; in the reverse mode, the gas is swept to the evaporator end where it blocks the vapour space. The performance is monitored by eight thermistors.

Control and data system

SPAS-01 provides the heat-pipe experiment with power at 28 ± 4 V DC, a data interface allowing experiment-generated data to be transferred via the Shuttle to the ground, and three basic commands: power on, experiment start, and power off. The experiment control and data system performs the tasks of sequencing the individual experiments according to a pre-programmed 'time-lining', controlling each experiment to ensure that required temperatures or heater power levels are maintained,

checking safety-related parameters and taking the necessary actions when these are outside preset limits, and finally collating, formatting and transmitting the experiment data to the SPAS-01 data-handling system.

A block diagram of the system, the heart of which is a 16-bit Texas Instruments microprocessor, is shown in Figure 5. It will be noted that the heater design (right-hand side of Fig. 5) is somewhat more complex than might have been expected. This is because it is important to dissipate the heater power in the heater windings and not in the drive electronics. The heater design is based on the use of four parallel windings with resistances in the ratio of 1:2:4:4, each in series with its own control transistor. The three highest-power (lowest-resistance) windings are switched either fully on or fully off; only the lowest power winding is controlled in a linear fashion. Since a transistor which is

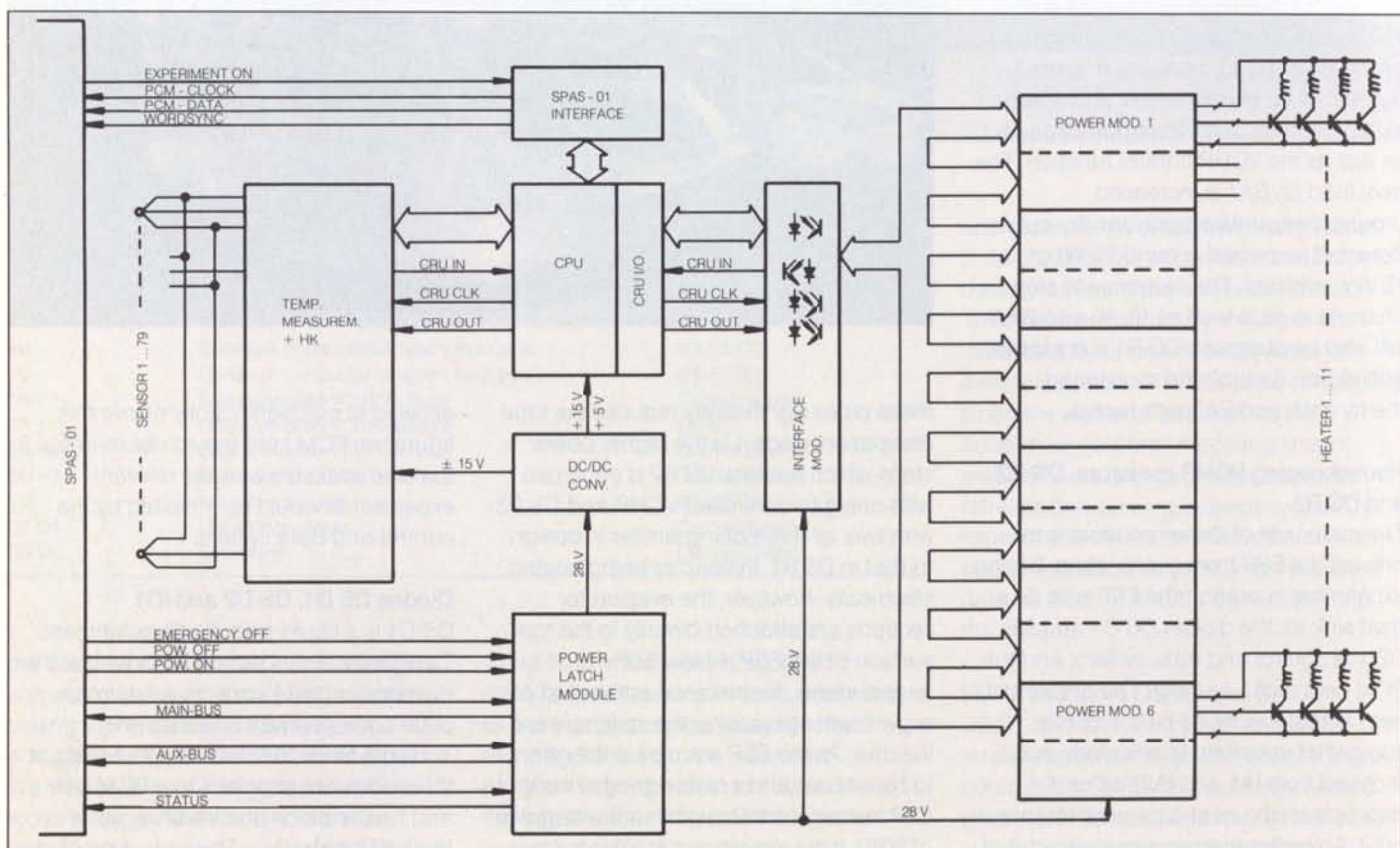


Figure 6 — Underside of heat-pipe experiment, showing the control and data system

switched fully on or fully off dissipates little heat, the losses in the heater drive electronics are largely limited to one transistor, and that the one handling least current. In a number of the experiments the control transistors are mounted on the evaporator sections of the heat pipes, immediately adjacent to the heater itself. In operation the heater is powered directly from the SPAS-01 28 ± 4 V DC supply. The experiment control and data system measures the total dissipation in a given heater and compares it with the required value stored in the computer. Any difference is used to adjust the status of the transistors controlling the windings.

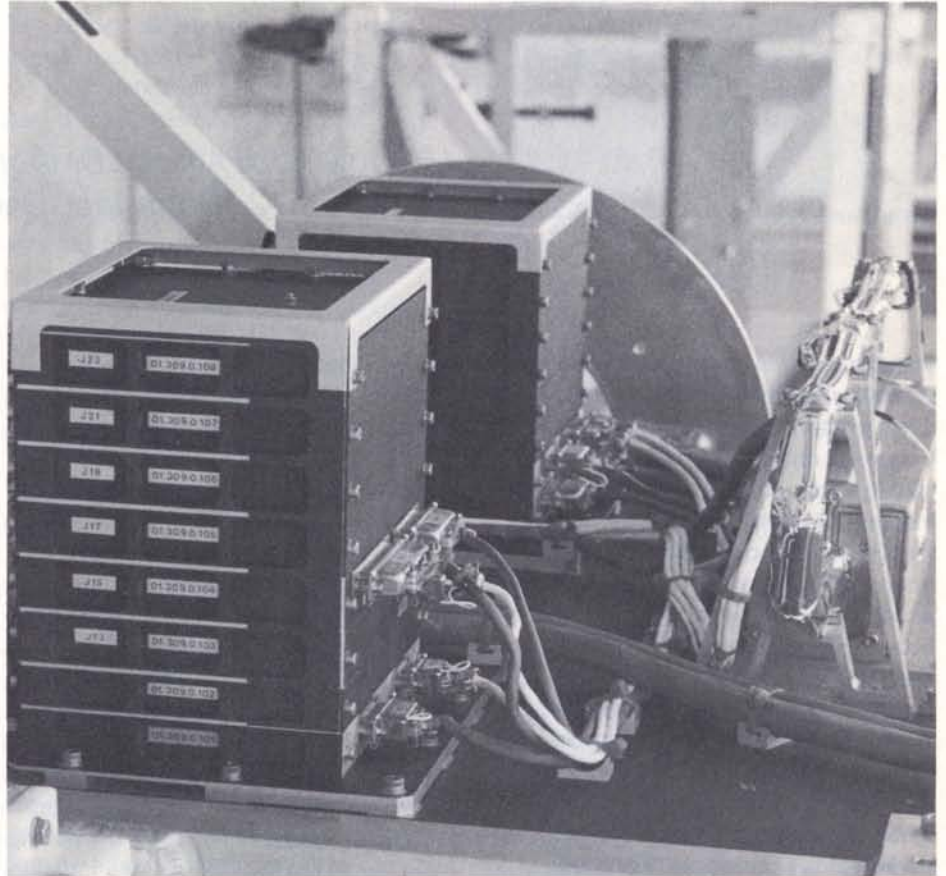
The hardware for the control and data system is accommodated in two separate packages, a power box and a data box (Fig. 6).

Experiment integration and verification

Experiment development started in 1980, following agreement and an exchange of letters between ESA and the German Ministry of Science and Technology (BMFT). Some ground work had been done prior to this, however, via a study performed for ESTEC by Dornier System on the possibility of adapting a heat-pipe sounding-rocket experiment [Astro-8(ii)] for inclusion in a Spacelab payload.

The experimenters listed in Table 1 were each responsible for designing, manufacturing and testing their own experiments. In addition Dornier System served as the integration authority and primary interface with the flight authority (MBB). Kayser-Threde developed the experiment control and data system.

The ESP was procured from MBB as a fully qualified, flight-accepted component. Each experiment and electronics box was individually qualified, at box level, to confirm its flightworthiness. These tests, carried out at Dornier System for their experiments and at ESTEC for the remaining units, included acceleration and vibration tests, supplemented by mechanical-redundancy analyses (to



confirm that the units were structurally 'fail-safe'), thermal-vacuum, and performance tests. As a result, mechanical testing at experiment level was limited to exposure to acoustic noise only.

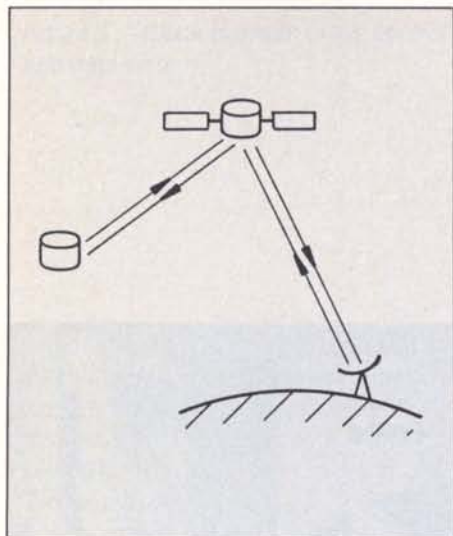
The experiment first came together as an integrated whole in 1981 at ESTEC, where it was subjected to a comprehensive series of performance, interface-verification (mass properties, electrical, EMC), and environmental (acoustic noise, thermal-vacuum, launch depressurisation simulation) tests. Delivery to MBB for integration into SPAS-01 took place in July 1982.

Conclusion

A heat-pipe experiment has been developed under the joint sponsorship of ESA and the German Ministry of Science and Technology, for flight on the SPAS-01

mission. The experiment consists of nine individual experiments to test constant-conductance heat pipes, VCHP radiators and diodes, and is equipped with a control and data system to support a 24 h in-orbit test programme. At the time of writing, the experiment has successfully completed its pre-flight checkout at Kennedy Space Center, and SPAS-01 is being integrated into the STS-7 payload awaiting availability of the Space-Shuttle 'Challenger'.





High-Accuracy Orbit Determination for Spacecraft in Low Earth Orbits

J.M. Dow, Orbit Attitude Division, European Space Operations Centre (ESOC), Darmstadt, Germany

With the continuing development of high-precision tracking techniques for near-Earth orbiters (lasers, improved two-frequency microwave range and range-rate systems, satellite-to-satellite tracking, altimetry, plus water-vapour radiometers for correction of tropospheric delays), new standards of accuracy for orbit determination are becoming possible, at the level of decimetres or better. From global tracking of such orbiters many other parameters of geophysical interest in addition to the orbital parameters can be extracted from the tracking data, some examples being gravity coefficients, coordinates of networks of ground points, polar motion, Earth rotation, and tidal parameters.

Although between 1968 and 1976 operational support for some six spacecraft in low Earth orbits was provided by ESOC, these missions all had rather weak requirements in terms of orbit-determination accuracy (kilometres in position), and sufficient tracking data could be obtained from two or three ground-based interferometers measuring the direction of the spacecraft when it was close to the east-west or north-south axis of the ground stations. A new generation of low-orbiting satellites for observation of the Earth – the earlier spacecraft were normally looking away from the Earth – is beginning to present requirements on the accuracy of the reconstituted orbit which are not only orders of magnitude better than for those missions, but are also pushing beyond the high accuracy levels that have been achieved in recent years on a number of missions specially designed for satellite geodesy and oceanography.

Table 1 lists some characteristics of the GEOS-3, Seasat, Lageos and Starlette spacecraft. The first two of these were designed for oceanographic research and carried radar altimeters as part of their payloads. The second two are small passive spheres covered with laser retro-reflectors, and are used for geodynamics research (crustal dynamics, Earth orientation, tidal studies, etc.). Together with the satellites of the Transit System (polar orbiters at around 1000–1100 km altitude, used for precise determination of ground points and Earth-orientation parameters), the tracking of these spacecraft has provided a rich database for the improvement of orbit models and has resulted in a remarkable increase in the precision with which near-Earth orbits can be reconstituted.

Table 1 also gives the same characteristics for the ERS-1 (ESA Remote Sensing Satellite 1), Popsat (Precise Orbit

Table 1 – Some characteristics of satellites requiring precise orbit determination

<i>Past/current missions</i>	GEOS-3	Seasat	Lageos	Starlette
Launch year	1975	1978	1976	1975
Agency	NASA	NASA	NASA	CNES
Orbit height (km)	840	790	5900	810/1105
Inclination (deg)	115	108	110	50
Mass <i>M</i> (kg)	346	2217	408	47
Cross-section <i>A</i> (m ²)	1.44	~ 30	0.283	0.045
<i>A/M</i> (m ² /kg)	4.2×10^{-3}	1.4×10^{-2}	6.9×10^{-4}	9.6×10^{-4}
<i>Future missions</i>	ERS-1	Popsat	Topex	
Launch year	1988	?	?	
Agency	ESA	ESA	NASA	
Orbit height (km)	780	5900	1334	
Inclination (deg)	98.5	98	63	
Mass <i>M</i> (kg)	2000	700	1330	
Cross-section <i>A</i> (m ²)	~ 30	3.1	12	
<i>A/M</i> (m ² /kg)	1.5×10^{-2}	4.4×10^{-3}	9.0×10^{-3}	

Positioning Satellite) and Topex (Ocean Topography Experiment) missions currently in various stages of planning by ESA and NASA. The ERS-1 mission* is mainly concerned with observation of the World's oceans and will carry a payload that includes an altimeter with similar performance to that of Seasat (10 cm accuracy over 1 s at the 1σ level). The aim of NASA's proposed Topex mission is to map the topography of the oceans and provide data on their circulation: the principal payload elements will be an altimeter accurate to 2 cm and a tracking system allowing the radial position component of the spacecraft to be determined with better than 10 cm accuracy. Popsat, on the other hand, is being designed by ESA for the study of the solid Earth, and would lead to new standards of accuracy and time resolution in determining positions of points on the Earth (absolute or relative) and the parameters defining the orientation of the Earth's principal axes, and ultimately to an operational system for earthquake prediction and monitoring.**

Tracking systems

Figure 1 illustrates some of the types of measurements that may be used as inputs for orbit determination for a low Earth orbiter. Angular measurements are normally not of comparable accuracy to the distance or range-rate types shown.

The two-way range measurement between spacecraft and ground point may be based on measuring the transit time of a very narrow pulse of electromagnetic radiation, or alternatively on measuring the difference in phase between a transmitted and received signal at the measurement point, which could be on the ground or on the spacecraft. The first method has proved to be extremely successful at optical

frequencies: lasers with pulse widths of the order of 200 ps* are now giving ranging accuracies of 2 to 3 cm. Ground-based laser systems have the advantage of simplicity on the spacecraft (no active systems), but are expensive to construct and to operate and depend on the absence of cloud cover. A spaceborne laser would allow ranging to a large number of ground points equipped only with a small retro-reflector array, but would require a complex pointing and stabilisation system on the spacecraft to control the laser.

The second method of ranging may be based on a tone-ranging technique. This uses pure sine waves at various frequencies to remove the ambiguity due to the fact that the phase measurement only gives a two-way distance containing an unknown integral number of tone wavelengths. Another possibility is to modulate a carrier with a pseudo-random noise code and to correlate the return signal with the same code sequence. In all cases it is preferable to avoid one-way ranging measurements, which require separate oscillators at both ends of the signal path, and give a 'pseudo-range' measurement which includes a contribution due to the relative drift of the two oscillator frequencies.

A one-way system measuring the Doppler shift on a signal transmitted by a beacon on the spacecraft (Fig. 1b) has been successfully used on the Transit satellites for many years. Oscillator drift is largely eliminated by assuming that the frequency remains constant over the length of a pass and by solving for a frequency bias for each pass when processing the data. The Doppler measurement gives the change in range r of the spacecraft during the time of counting cycles representing the Doppler shift, and for short time intervals this is equivalent to the range rate $\dot{r}$.

Satellite-to-satellite tracking techniques (SST, Fig. 1c) may be based on one- or two-way range and/or Doppler measurements. A variant (Fig. 1d) is to use a four-way measurement from a ground station via a geostationary satellite, a technique that was successfully tested with GEOS-3 using the geostationary ATS-6 satellite.

Figure 1e illustrates the principle of a tracking system known as Series-X, which is being studied at NASA/Jet Propulsion Laboratory (JPL) for the Topex mission. It is based on the Global Positioning System (GPS), which will include a system of 18 satellites in three orbital planes at 60° inclination and 20 000 km altitude. In the basic GPS system, one-way pseudo-range and Doppler measurements are made at a ground point, and by measuring (for example) the range to four GPS spacecraft a nearly instantaneous positional fix can be obtained for the station (the fourth measurement is necessary to remove the frequency offset in the ground receiver). By differencing the range (or range-rate) measurement from two GPS spacecraft, a new measurement containing no bias due to the user receiver oscillator frequency is obtained (e.g. $r_1 - r_2$ in the figure, where the user receiver is onboard a satellite). By further differencing this measurement with a similar measurement to a reference ground station ($r_{10} - r_{20}$), a double-differenced range measurement ($r_1 - r_2$) - ($r_{10} - r_{20}$) is obtained, which in addition is not biased by relative frequency offsets in the different GPS spacecraft, and partially eliminates errors in GPS spacecraft ephemerides. There is no requirement for the low orbiter to be visible from any ground station and global coverage of the latter with respect to this measurement type is possible with as few as seven ground points.

The most important errors in all these measurements are often those due to the interaction of the signal with the transmission medium. The charged particles of the ionosphere, at altitudes

* See ESA Journal, Vol. 7, No. 1 (1983)

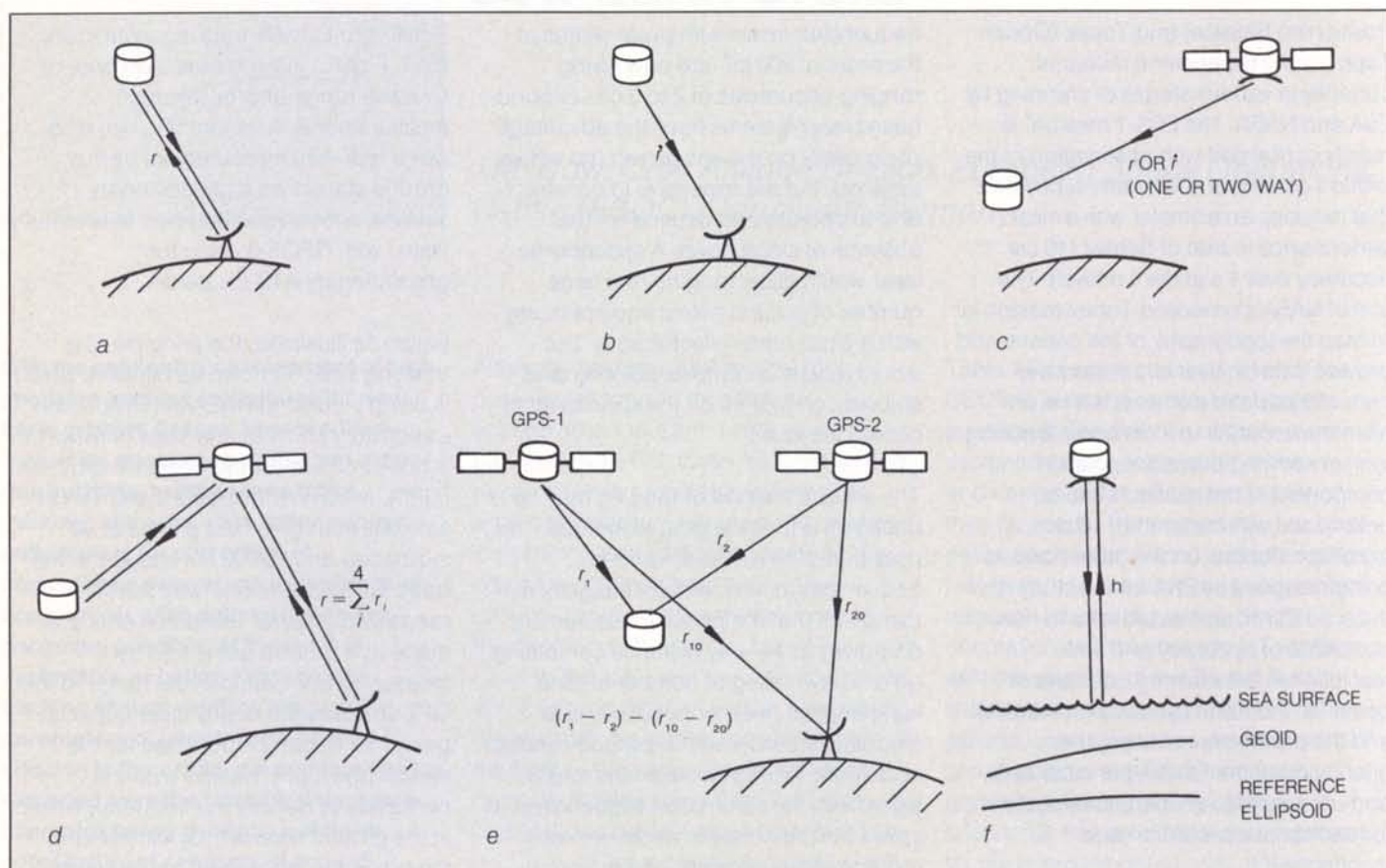
** See ESA Bulletins, No. 31 August 1982 & No. 28 November 1981

* 100 ps = 10^{-10} s is equivalent to 3 cm in distance (two-way)

Figure 1 — Tracking measurement techniques

- (a) Two-way ranging
(b) One-way Doppler
(c) Satellite-to-satellite tracking (SST)

- (d) SST, four-way via geostationary satellite
(e) GPS double-differenced range (Series-X)
(f) Satellite altimetry



from 80 to about 1000 km and with a peak density around 300 km, cause a bias in range measurements that is, to a first approximation, inversely proportional to the square of the carrier frequency, and directly proportional to the integrated electron content along the ray path. At the optical frequencies used by lasers, this effect is negligible in practice, but at microwave frequencies it will normally dominate the error budget unless corrected by using two widely spaced frequencies to eliminate the first-order effect. By a suitable choice of frequencies, the error can be reduced to the centimetre level.

Unfortunately, the neutral atmosphere or troposphere (the lowest 10 km of the atmosphere) is not significantly dispersive with respect to frequency, and correcting precise tracking measurements for tropospheric propagation effects is much

more troublesome. The delay on a range measurement at the station zenith amounts to about 2.5 m (15 m at 10° elevation), of which 80–90% can be modelled using values for local pressure at the station (the 'dry component'), and 0–40 cm depends on temperature and water-vapour content along the line of sight (the 'wet component'). Since the latter is difficult to model using only measurements of water vapour at the ground point, the wet component limits the accuracy of the correction. Studies have indicated that for the zenith 5 cm accuracy for the total correction can be achieved using monthly mean weather data, and 2 cm using measurements of temperature, pressure and relative humidity at the ground point. Since even the latter can imply 6 cm errors at 20° elevation, further improvements are being sought using dual-frequency radiometers. By measuring the brightness temperature

in the line-of-sight direction at a frequency close to the water-vapour absorption line at 22 GHz and at a second frequency (e.g. 31 GHz), two linear relations containing the water-vapour content and the liquid-water content can be obtained, and the water-vapour content can be computed. Accuracies of 1 cm along the line of sight are claimed for the total tropospheric correction using such a radiometer.

Although laser systems cannot range through clouds, due to absorption, the wet component of the troposphere is not so important for laser ranging measurements, and 1 cm zenith accuracy is possible for the tropospheric correction using only local temperature and pressure measurements.

Forces acting on the spacecraft

Table 2 lists the main forces acting on an Earth orbiter. The gravitational

Figure 2 — Tidal distortion of the Earth by Moon or Sun, showing phase lag in the Earth's response

perturbations due to Sun and Moon are important, but can be accurately modelled using available ephemerides. The orbital motion is determined mainly by the Earth's gravity field, which can be conveniently described by a fixed field due to the mean mass distribution and a variable field due to tidal distortion of the non-rigid Earth.

The fixed part is normally described by a harmonic expansion in Legendre functions. A gravity model is described by the set of coefficients of this expansion. Current gravity models run to at least degree and order 36, giving a total of 1368 coefficients. Using realistic models for the behaviour of the coefficients with increasing degree, it can be shown that for an orbit of the ERS-1 type a model valid to at least degree and order 50 is necessary for 10 cm radial position accuracy.

For the recent GRIM-3 gravity model, some 200 000 optical, laser and Doppler measurements spanning 1028 days for 22 satellites were processed, together with some 25 000 $1^\circ \times 1^\circ$ gravity anomalies (mainly measured or predicted over land) and a similar number of gravity anomalies derived from GEOS-3 altimetry over the oceans.

A large amount of older, angular data from optical tracking is still included in recent gravity models: this data, although not very accurate, considerably

strengthens the solution because of the wide range of the corresponding satellite inclinations and heights. Some special relationships are introduced between the zonal harmonic coefficients (those describing the rotational symmetry), based on the analysis of secular and long-period effects on the elements of suitable orbits. Similarly orbits with near-commensurability with the Earth's rotation period exhibit resonances characterised by limited subsets of gravity coefficients (e.g. of order 13, 14, 15; 27, 28, ..., 31 the orbits concerned having between 13 and 15 revs./day), and the resulting linear relationships between these coefficients help considerably in decorrelating them in the general solution. Only coefficients up to about degree and order 15 can be separated by satellite data. More detailed solutions rely on measurements of surface gravity averaged for example over $1^\circ \times 1^\circ$ blocks in latitude and longitude. These data are mainly available over land, and the accuracy variation is considerable. Over the sea, altimeter measurements (from GEOS-3 and Seasat) have provided good global coverage of the fine structure of the gravity field, but a more extensive data set of 10 cm altimetry would give a valuable input for gravity-model improvement.

Anelastic deformation of the Earth under the influence of the gravitational attractions of the Moon and the Sun (Fig. 2) slightly modifies the gravitational acceleration experienced by an Earth satellite. The main effect is due to the solid

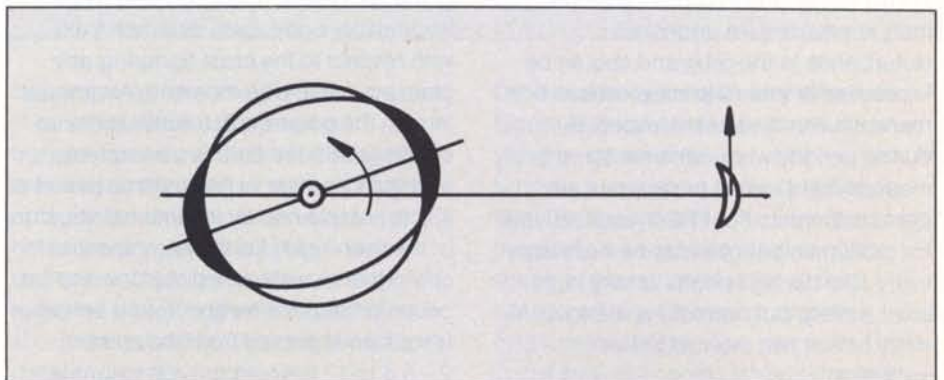
Earth, but ocean tides also cause measurable perturbations on satellite orbits, while atmospheric tides are responsible for small changes in the Earth's rotation rate and axis. The main tides are semi-diurnal, but a rich spectrum of tidal components occurs, with periods defined by combinations of parameters of the Earth—Moon—Sun system (Earth rotation period, lunar month, periods of lunar node and perigee precession, etc.). Tidal perturbations mainly affect the orbital plane of a satellite and may amount to a few tens of metres with a period of 10 d or longer.

Unlike the gravitational perturbations, the surface forces (air drag, radiation pressure, and photonic thrust) depend strongly on the specific geometric and reflectivity characteristics of the spacecraft structure, and models will normally contain some empirical parameters that have to be solved for in the orbit-determination process. Complex air density models taking into account the diurnal bulge, influences of solar and geomagnetic activity, seasonal effects, etc. may still only be accurate to 20%, and a daily drag parameter (and possibly its rate of change) may have to be estimated, in which the effects of various unknown errors are lumped together. Fortunately, air drag has a very clear signature on the orbit (a secular decay in the altitude), which makes it easy to separate from other perturbations.

Uncertainties in the reflectivity properties

Table 2 — Forces perturbing the orbit of a low-orbiting Earth satellite

Gravity	
—	Earth's mean mass distribution
—	Sun, Moon, planets
—	Luni-solar tides (solid-Earth, ocean)
Surface forces	
—	air drag
—	radiation pressure (direct solar pressure, Earth albedo and infrared)
—	photonic thrust
Others	
—	orbit/attitude manoeuvres



of the surfaces (a fraction of the incoming radiation being absorbed, the remainder reflected partly specularly, partly diffusely), variations in the spacecraft attitude, relative motion of solar panels and antennas, and shadowing effects (by the Earth, or by part of the structure on another) make precise modelling of radiation pressure rather complex in some cases (e.g. ERS-1), though – intentionally – very simple in others (Lageos, Starlette). The main effect is due to the direct radiation from the Sun, but visible (albedo) radiation reflected from the Earth amounts to about 10% of the direct effect at heights around 800 km, while radiation re-emitted by the Earth at infrared frequencies contributes a further 5%. Modelling of the albedo perturbation is troublesome due to the variability in albedo coefficient with location and time, and the need to integrate over the illuminated part of the Earth as seen from the satellite, leading to a significant along-track acceleration. Models of varying degrees of complexity have been developed.

Photonic thrust is a small perturbation due to the nonuniform temperature distribution on the spacecraft surface. The surface radiates in proportion to the fourth power of the local temperature (Stefan-Boltzmann law), and any temperature gradient (e.g. between Sun-facing and back faces of spacecraft) implies an unbalanced force. This may be a significant effect when designing a spacecraft for the Popsat mission.

Thrust forces due to orbit or attitude manoeuvres are an undesired disturbance to the orbit and should be kept to a minimum if precise orbit reconstitution is required, especially during periods when sensitive force or measurement model parameters are being estimated. For ERS-1, manoeuvres for orbit maintenance may be necessary every 10 d during periods of very high solar activity, but normally a manoeuvre every one or two months will be sufficient.

Figures 3a–e illustrate the most important perturbation effects on the ERS-1 orbit, including the lower zonal harmonics J_2 , J_3 , J_4 of the Earth's gravity field, luni-solar gravity, air drag and radiation pressure.

Modelling of station positions

The orbit-determination problem is solved by adjusting the orbital and other uncertain parameters of the orbit and measurement models in such a way that a suitable function of the measurement residuals (the difference between the observed tracking measurements and those computed from the adopted models) is minimised. Having numerically integrated the equations of motion in an appropriate inertial coordinate system, such as the rectangular equatorial system defined by the mean equinox and equator at 1950.0, it is necessary to compute the positions of the tracking stations in the same system. (The equations of motion can also be integrated in a noninertial system, by taking Coriolis forces into account.)

The main factors influencing this transformation of the station positions are:

- polar motion
- Earth rotation
- nutation, precession
- solid-Earth tides
- tectonic plate motion.

Polar motion refers to the irregular motion of the spin axis of the Earth with respect to its principal body axes, assumed fixed with respect to the crust (ignoring any plate motion for the moment). An annual term in the polar-motion series is due to coupling with the Earth's atmosphere, and the Chandler wobble, with a period of 435 d, is explained by the internal structure of the (non-rigid) Earth. Many spectral components, with periodicity down to 1 d, occur in the polar motion, and a temporal resolution improved from the current 2–5 d to 12 h would provide valuable

inputs to theories of the Earth's structure. The amplitude of the polar motion is of the order of 10 m at the Earth's surface, and the two components are determined routinely as a byproduct of the orbit-determination solutions for the Transit satellites and for Lageos, with an accuracy of about 20 cm.

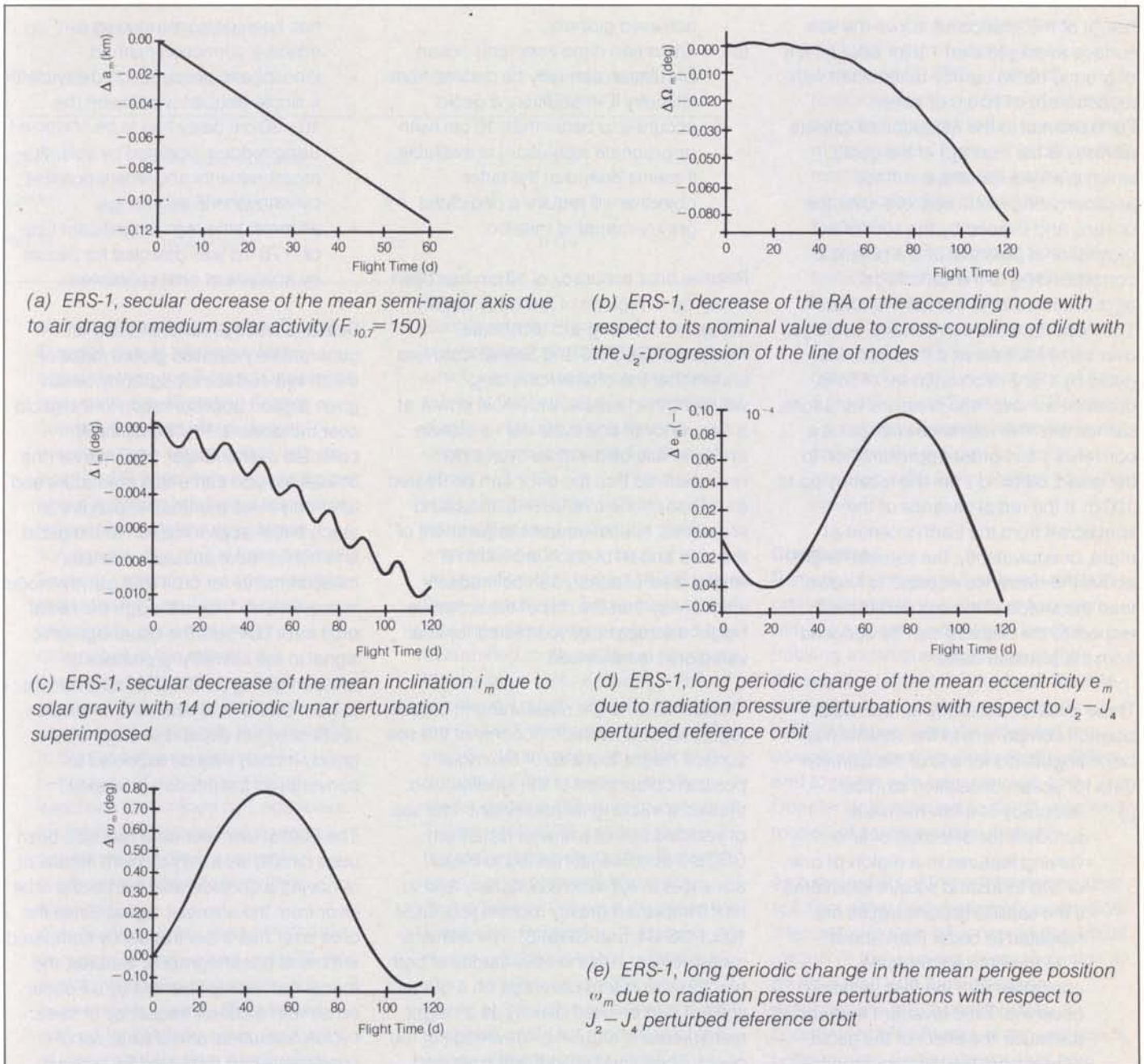
Closely associated with polar motion is the rotation rate of the Earth about its axis. The rotation angle of the Greenwich meridian with respect to a fixed inertial direction (the first point of Aries) defines the UT1 time scale, which can be related to the more uniform atomic time scale UTC (Coordinated Universal Time) by several means, including observing variations of the ascending node of a very stable orbit, such as that of Lageos.

The principal polar axis of the Earth precesses about the pole of the ecliptic with a period of 26 000 y, and nutates (wobbles) about this mean path with smaller amplitudes with periods of between 1 d and 18.6 y (the period of revolution of the lunar node). New theories of precession and nutation have recently been adopted by the International Astronomical Union, and the nutation theory now takes account of the liquid core, which in turn influences the determined values of the polar motion coordinates.

Solid-Earth tides not only perturb the satellite motion, but directly cause motions of the stations of about 30 cm with a principal component that is semidiurnal. Recent models of this effect give frequency-dependent vertical and horizontal displacements for many different tidal components and for various models of the Earth's internal structure.

Finally, tectonic-plate motion ('continental drift') can cause relative station movements of up to 10 cm/y. Some of these motions have been detected using multiyear datasets, but at present estimates for a particular location are generally based on theoretical models.

Figure 3 — Perturbations on the mean elements of ERS-1



A conventional terrestrial reference system is defined implicitly by the coordinates of a network of well-distributed primary stations. Such a set of coordinates is one of the elements of the type of global gravity solution discussed above. A certain arbitrariness is involved, for example, by the need to fix the longitude of one station. Different coordinate solutions having a subset of common stations can

be compared by making a least-squares fit for a suitable set of common transformation parameters. It is essential that a compatible set of station positions and gravity coefficients be used for orbit determination, and if feasible any new stations whose coordinates are not available from the gravity-model solution should be solved for from the tracking data.

Orbit accuracy for altimetry missions

Figure 1f illustrates the principle of radar-altimetry measurements, which consists of sending a very short pulse of radiation from the spacecraft to the Earth's surface (normally the sea) and recovering the shape of the returned pulse at the spacecraft together with a precise measurement of the two-way transit time. In this way, after some corrections, the

height of the spacecraft above the sea surface averaged over 1 s (or about 7 km of ground track) can be determined with an accuracy of 10 cm or better. Fundamental to the utilisation of satellite altimetry is the concept of the geoid, which is an equipotential surface approximating mean sea level over the oceans and defined by the sum of the gravitational potential and a potential corresponding to the centrifugal acceleration due to the Earth's rotation. The instantaneous sea surface, averaged over some kilometres, differs from the geoid by 1 or 2 m on account of tides, currents, atmospheric pressure variations, salinity, etc. The reference ellipsoid is a convenient first-order approximation to the geoid, differing from the latter by up to 100 m. If the radial distance of the spacecraft from the Earth's centre of mass, or equivalently, the satellite height above the reference ellipsoid, is known, then the shape of the sea surface with respect to the ellipsoid can be deduced from the altimeter data.

Three levels of accuracy for the radial position component of the satellite may be distinguished for use of the altimeter data for ocean-circulation studies:

- (i) Accuracy of a few metres is sufficient for detection of time-varying features in a region of one or two thousand square kilometres, if the satellite ground tracks are repeated to better than about ± 1 km within a time scale consistent with the feature being observed. Time-invariant features, in particular the effect of the geoid, cancel from the differences in the height measurement along a few thousand kilometres of repeated track, and orbit errors can be largely removed by making best fits of the altimeter profiles to each other. The development of mesoscale eddy systems has been clearly observed in Seasat altimetry.
- (ii) The variable ocean circulation can be studied on a global scale if 10 cm radial orbit accuracy can be

achieved globally.

- (iii) The mean (time-invariant) ocean circulation can only be derived from altimetry if, in addition, a geoid accurate to better than 10 cm (with appropriate resolution) is available. It seems likely that the latter objective will require a dedicated gravity-mapping mission.

Relative orbit accuracy of 10 cm has been achieved in regions of low eddy activity using the 'crossing-arc technique'. Analysis of GEOS-3 and Seasat data has shown that the orbit error is long-wavelength in nature, with most power at a frequency of one cycle per revolution and very little below three cycles per revolution, so that the error can be treated as a linear trend over several thousand kilometres. A least-squares adjustment of the bias and tilt of each arc within a limited area of ocean can be made in such a way that the rms of the crossover height discrepancies (corrected for tidal variations) is minimised.

The altimeter height measurement can be regarded as a function not only of the sea-surface height, but also of the radial position component of the satellite, and thus as a tracking measurement. The use of selected sets of altimeter data from GEOS-3 and Seasat has led to major advances in ephemeris accuracy and to much improved gravity models (e.g. GEM 10B, PGS-S4, and GRIM-3). The altimeter measurement has the advantages of both high precision and coverage on a global scale. It can be used directly as a height measurement, requiring knowledge of the geoid, ocean and solid-Earth tides and currents (as far as these are known), and/or as crossover differences whereby the geoid and other time-invariant features are eliminated. Other corrections required include:

- instrument bias, found to be -5.6 m for GEOS-3 and 0 ± 7 cm for Seasat
- sea-state bias (a function of significant wave height)
- tropospheric delays: use of the Seasat microwave radiometer data

has been demonstrated as an effective correction method

- ionospheric-propagation delays: with a single-frequency altimeter the 10–30 cm delay has to be corrected using models, updated by solar flux measurements and where possible by ionospheric soundings.
- altimeter time-tag: a significant bias of -78 ms was detected for Seasat by analysis of orbit crossovers.

Seasat altimetry has been used to generate very detailed global maps of mean sea-surface topography, which gives a good approximation to the geoid over the oceans. Precise altimetry collected over a longer time interval (the Seasat mission came to a premature end after only three months) would give a much better approximation to the geoid, and hence more accurate altimeter measurements for orbit and gravity-model improvement. Thus although the radial orbit error corrupts the oceanographic signal in the altimetry, a process of iteration giving successive improvements to both orbital and sea-surface models (both of which depend strongly on the gravity model) may be expected to converge as the mission proceeds.

The Seasat altimeter data has also been used directly as a very efficient means of removing a considerable part of the orbit error from the altimeter signal. Since the orbit error has a low frequency compared with most oceanographic features, the former can be represented by a Fourier series with a cut-off frequency of three cycles/revolution, and a small set of coefficients can be solved for by least squares. Residual radial errors of about 50 cm have been found by this method.

Results

Some recent results can be briefly reviewed as follows:

- Table 3 summarises accuracies obtained at Goddard Space Flight Center for Seasat. The PGS-S4 gravity model differs from PGS-S3 in the inclusion of an 18 d arc of Seasat

Table 3 – Seasat orbit accuracy

Gravity model	Tracking data	Arc length	Estimated radial orbit error
PGS-S3	laser, S-band Doppler	6 d	1.2 m
PGS-S4	laser, S-band Doppler	6 d	0.7 m
PGS-S4	Tranet Doppler	3 d	0.4 m

altimeter data. Although the Tranet Doppler data is inherently less accurate than the S-band Doppler or laser data, the 45-station Tranet network provided much denser coverage than was possible with the laser and S-band networks, and gave about a 40 cm radial orbit accuracy.

- Independent station coordinate solutions for the global laser network tracking Lageos show agreement to better than 10 cm (rms) in each coordinate, once systematic differences in the reference coordinate systems have been removed. Solution for the same coordinates using only laser ranging to Starlette shows agreement to better than 20 cm (rms). Global baselines determined by Lageos are, for the better-determined stations, consistent to 3 cm for annual solutions and 8 cm for monthly solutions.
- A dedicated gravity model PGS-1331 complete to degree and order 36 plus additional zonals and resonance harmonics to degree 48 has been derived for Starlette, using four years of laser ranging data. Amplitudes and phases for 20 ocean-tide parameters have been estimated from a subsequent year of data. Radial orbit accuracy (deduced from overlapping arcs of tracking data) is about 20 cm (rms) in the cross-track and 50–100 cm in the along-track components.
- Determination of the line of nodes of the Lageos orbit over a six-year span using an independent record of the

Earth's rotation (lunar laser ranging) shows an acceleration in the node which cannot easily be explained in terms of tidal effects and seems to be due to a change in the second-degree harmonic of the Earth J_2 of about $-3 \times 10^{-11} \text{ y}^{-1}$. This value would be consistent with viscous rebound of the Laurentide shield area of Canada as a result of the deglaciation that began 18 000 y ago.

- Error analyses for Topex have shown that the radial component could be determined to about 15 cm accuracy (1σ) using a laser network or the improved Tranet network, whereas the Series-X method (1 rev. fit) could yield 5–10 cm accuracy. The dominant error source is gravity-model errors in the case of laser and Tranet, while GPS ephemeris error is the main contributor to the Series-X error. Longer arc solutions with Series-X over 10 d have indicated the feasibility of improving the gravity model in addition to the orbital and other dynamic parameters, which would at the same time give a more accurate geoid for modelling of the Topex altimeter measurements.
- For two- or three-day arcs of the ERS-1 orbit tracked by laser and/or two-frequency microwave systems, it is expected that gravity-model errors will give errors of 50–70 cm in the radial position component, while radiation pressure and air drag may contribute a further 10–15 cm. These results are hardly affected by the size of the ground network (5 stations or 50 stations). To improve this

accuracy, it is imperative that a dedicated gravity model be developed for ERS-1 using all available tracking data and altimetry collected during the first few months of the mission. During this period the most extensive ground-tracking network possible should be mobilised.

- Analysis of the proposed Popsat system has shown that baselines between stations covering a seismically active zone such as the Friuli region of NE Italy could be determined with an accuracy of 3 to 5 cm in 1 d and 2 cm in 5 d. Baselines up to intercontinental distances could be determined to 2 to 3 cm accuracy with 2 d of Popsat tracking data.

Conclusion

Remarkable progress has been made in orbit determination in the last few years with the extensive use of very precise tracking techniques, accurate to the decimetre or subdecimetre level. Satellite-to-satellite tracking and altimetry in particular have radically extended the coverage regions for close-Earth orbiters and together with laser ranging and Doppler data have led to much improved models of satellite orbital motion.

As a byproduct of the orbit determination solution, other parameters of geophysical interest having an influence on the orbital motion or the tracking measurements can be estimated with high precision: examples are gravity coefficients, coordinates of networks of ground points, polar motion, Earth rotation, and tidal parameters.



In brief

Prof. Reimar Lüst to be next Director General of ESA

At its session of 8 June 1983 the ESA Council appointed Prof. Reimar Lüst as the next Director General of the Agency, with effect from 15 May 1984, when the contract of the present Director General, Mr. E. Quistgaard, comes to an end.

Prof. Lüst is currently President of Germany's Max-Planck-Gesellschaft. A physicist by profession, he was Scientific Director of ESRO from 1962 to 1964, and has served on numerous ESRO/ESA committees. From 1965 to 1970 he was Vice Chairman of the ESRO Council.



EUMETSAT Convention Signed

Following the second session of the Intergovernmental Conference on an operational European Meteorological Programme, held at ESA Headquarters in Paris from 21 to 23 March 1983 (see ESA Bulletin No. 34, p. 69), twelve countries – Belgium, France, Germany, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom – signed the EUMETSAT Convention at the Conference of Plenipotentiaries held in Geneva on 24 May 1983. Finland, Greece

and the Republic of Ireland also attended this Conference as observers and they may decide subsequently to participate in the programme.

The Delegations to the Conference also accepted the legal texts related to the conducting of the Meteosat Operational Programme as an optional ESA programme during the period preceding the entry into force of the EUMETSAT Convention. This step will allow the programme to get underway without delay.

ESA will now initiate procurement of three improved versions of the Meteosat spacecraft, procurement of the Ariane launchers needed, and the other necessary activities associated with the launches of the three Meteosat flight units, in May 1987, August 1988 and November 1990.



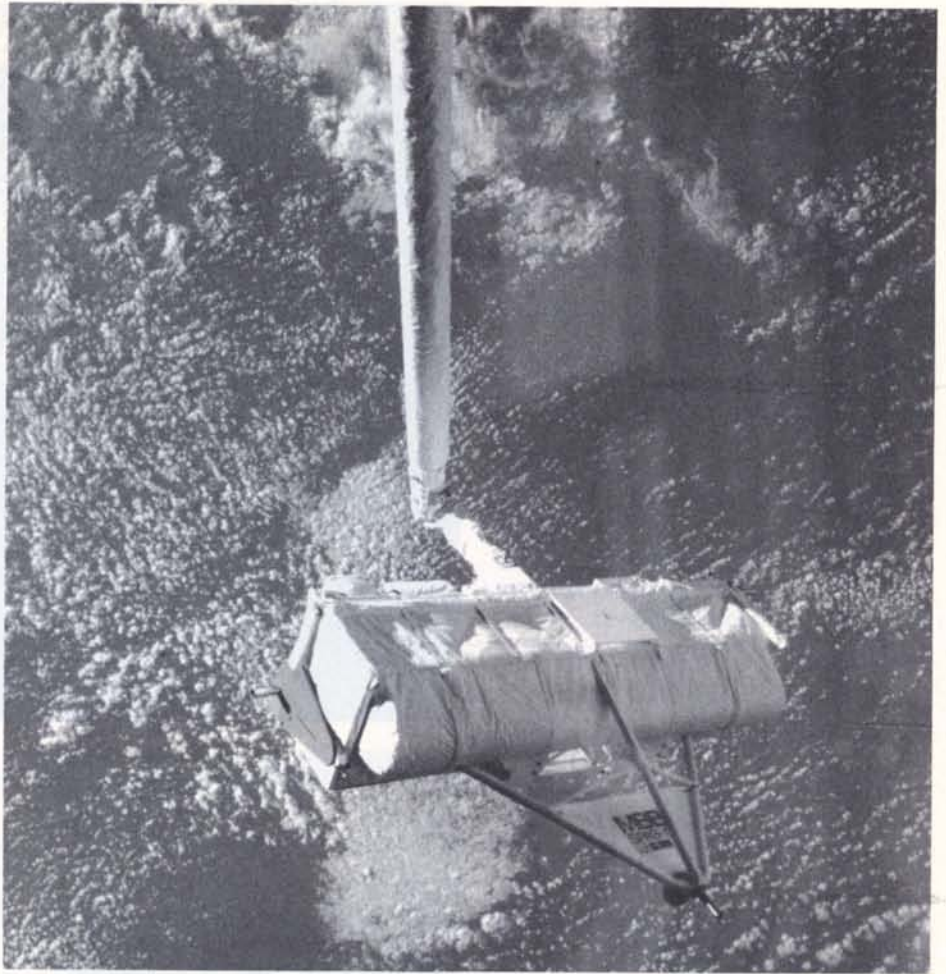
Signature of the EUMETSAT Convention for Switzerland by Dr. A. Dunod, Director of the Swiss Meteorological Institute

ESA Experiments on Latest Shuttle Flight

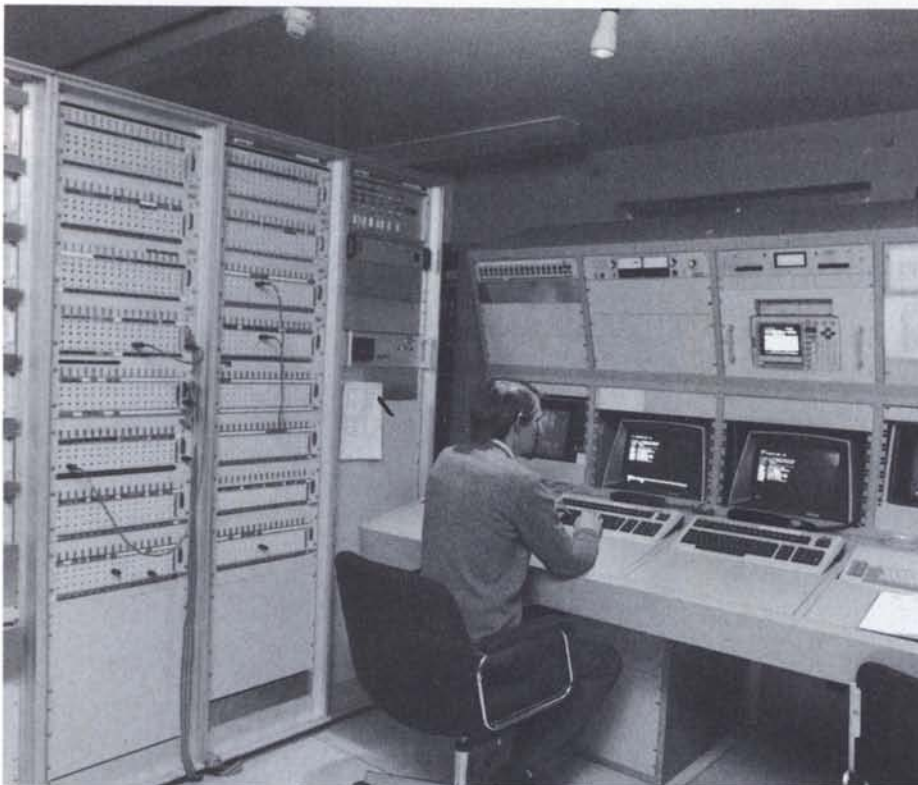
Space Shuttle 'Challenger', launched on 18 June, carried in its cargo bay the German Shuttle Pallet Satellite, SPAS-01, which has recently been selected by ESA as the basic structure for its future European Retrievable Carrier Eureka. During the six-day mission, SPAS-01 was released and allowed to fly free of Challenger for about 10 h, before being recovered ready for re-entry.

The SPAS-01 multi-disciplinary payload included three technological experiments developed by the Agency within the framework of its Technology Programme: a solar-cell calibration experiment and a yaw Earth sensor package, as well as a joint ESA/German (BMFT) experiment designed to validate theoretical performance predictions for gravity-sensitive heat pipes. All three experiments were operated during the 24 h 'attached operations' period on 20/21 June whilst SPAS-01 was still in the Shuttle cargo bay.

The heat-pipe experiment that was conducted is described in more detail in the article on page 76 of this issue.



Release of SPAS-01 from the Space Shuttle



Control Room of the IRS telecommunications network

Two New Aerospace Databanks from IRS

Two new ESA Databanks – SATELDATA and SPACECOMPS – compiled by ESTEC and the Agency's Information Retrieval Service (IRS) in Frascati, have recently been put on line by IRS. SATELDATA is a technical databank on mechanical and electronic satellite equipment of European manufacture, while SPACECOMPS contains information on spacecraft components, i.e. procurement specifications, quality control, contractor test reports, etc., and their use and reliability.

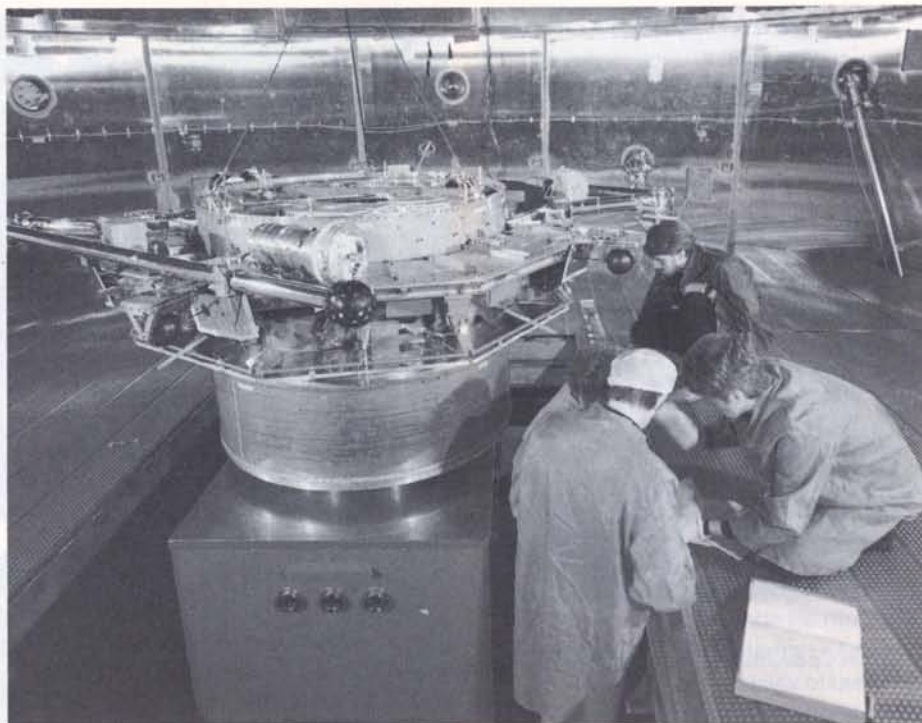
These two new ESA-IRS databanks are the fruits of experience accumulated from twenty years of European space activities and should prove of substantial benefit to European aerospace industry.

Further information can be obtained from ESA-IRS in Frascati, Italy (telephone 39.6.9401329).

Sweden's Viking Satellite tested at ESTEC

The Swedish Viking satellite, developed by Saab-Scania's Aerospace Division (prime contractor) under contract to the Swedish Space Corporation, recently underwent electromagnetic-cleanliness, vibration- and thermal-vacuum testing (thermal balancing with solar simulation and thermal cycling) and mass-property measurement at ESTEC, Noordwijk, in the period mid-April to late July.

The Viking satellite, destined for scientific research into magnetospheric and auroral phenomena, will be launched into an elliptical orbit (apogee 15 000 km, perigee 822 km, orbit inclination 98.7°, and period 4.5 h) in January 1985, together with the French Spot earth-observation satellite, on an Ariane launcher, from the ESA launch site at Kourou in French Guiana.



The Viking satellite in the Dynamic Test Chamber at ESTEC

ESA Exhibition 'Europa in de Ruimte' in Ghent

The opening of the Agency's recent exhibition of spacecraft, space technology and space products (Meteosat imagery, etc.) at the Rijksuniversiteit in Ghent, Belgium, was attended by the Belgian Prime Minister, Mr. W. Martens. The

exhibition, which lasted from 21 April to 8 May drew more than 25 000 visitors, notable among them being Belgian television's well-known 'weatherman', Mr. Armand Pien.

The accompanying photographs show Prime Minister Martens during his tour of the Exhibition (below left) and

engrossed in the study of Meteosat images with Mr. Armand Pien (below right).

The exhibition attracted a great deal of interest from the education sector, many of the visitors being on trips organised by schools, colleges and universities.



World Comet Expert lectures at ESTEC

Prof. Fred Whipple, one of the world's foremost experts on comets and cometary phenomena, visited the Space Science Department of ESA, at ESTEC, on 10 and 11 March 1983.

On the first day of his visit, Prof. Whipple made a summary presentation to ESTEC staff of the major findings that have resulted from his many years of research into comets. He concentrated particularly on those aspects that will be of particular relevance when comet Halley returns in 1986, to be observed by the Agency's Giotto spacecraft (for latest status of Giotto, see page 55).



Le Bourget – 35th International Aerospace Exhibition

Centrepiece of ESA's stand at the Le Bourget Salon this year (26 May - 5 June), the year of the Agency's first venture into manned spaceflight, was a full-scale model of the first flight configuration of Spacelab.

An additional attraction was the presence of ESA's Payload Specialists, Ulf Merbold and Wubbo Ockels, who greeted visitors to the ESA pavilion.

With the Space Shuttle 'Enterprise' parked opposite the ESA pavilion on trade days and on Press Day, the media were able to examine Spacelab and its carrier together, at close quarters, for the first time.

Other Agency programmes featured this year at Le Bourget were Ariane, Exosat and Olympus. The Exosat satellite was in fact launched on the Exhibition's Press Day, 26 May, from Vandenberg Airforce Base, in California (details can be found on page 18 of this issue). Olympus, previously known as L-Sat, will weigh 2400 kg at launch and its long solar arrays will have a tip-to-tip span of 27 m when deployed in orbit.



ESA Spacelab Payload Specialists Wubbo Ockels (left) and Ulf Merbold (right) at Le Bourget with NASA Deputy Administrator Hans Mark





Space Shuttle Pays Flying Visit to ESTEC

The sistership 'Enterprise' of the Shuttle 'Columbia' which will carry Spacelab aloft at the end of September, paid a flying visit to ESTEC on Sunday 5 June, atop its Boeing-747 transport aircraft.

The Boeing 747 flew north along the Dutch coast to pass over ESTEC on its way back to the United States via Great Britain and Canada, from the Paris airshow at Le Bourget.



ESA and Arianespace Sign Contracts for Launch of Four Satellites

Representatives of ESA and Arianespace have recently signed two separate contracts for the launch of four satellites. The first covers the launch in the second half of 1986 of the European Large Telecommunications Satellite (L-Sat), recently re-christened Olympus, on an Ariane-3 launcher. The second contract is a direct follow on to the recent signature of the EUMETSAT Convention and to the decision by participating countries to entrust ESA with the conduct of the Meteosat Operational Programme

Signature of ESA/Arianespace Contracts by (left) Mr. E. Mallett, ESA's Director of Application Programmes, and (right) Mr. Charles Bigot, Director General of Arianespace

pending the entry into force of the Convention. This contract covers the launch of the three improved versions of Meteosat, in mid-1987, mid-1988 and at the end of 1990, respectively. It is planned to launch all three Meteosats on the Ariane-4 launcher now under development.

The two contracts are worth over

130 million accounting units (or 1 thousand million French francs). They bring the Arianespace order book to 4.7 thousand million French francs, more than 40% of which relates to exports outside Europe. With these new orders, Ariane launcher production is already guaranteed up to launch L24.

Comet 1983D-IRAS-Araki-Alcock observed by IUE

Astronomers working with the IUE satellite reacted promptly to the announcement of the new comet 1983D-IRAS-Araki-Alcock and began observations of it on 6 May. These observations were carried out by a team of European experts from ESA's ground-based observatory at Villafranca (Madrid). The ultraviolet spectra obtained so far indicate that the comet's gas content predominates over the dust and its chemical composition is similar to that of previously observed comets.

The observations were repeated on 8 and 12 May and will hopefully provide astrophysicists with a better understanding of the physical processes leading to the formation of the different types of molecules in comets. The information derived should prove extremely useful in the Agency's preparations for the Giotto mission to rendezvous with comet Halley in 1986.

Ariane Launch Manifest 1983 – 85 (firm orders only)

	Launch	Vehicle	Payload(s) Spacecraft	Mission	Authority	Launcher orbit
1983						
September	L7	AR 1	Intelsat-V F7	Communications	Intelsat	GTO*
November	L8	AR 1	Intelsat-V F8	Communications	Intelsat	GTO
1984						
February	L9	AR 1	Intelsat-V F9	Communications	Intelsat	GTO
May	L10	AR-3	ECS-2	Communications	ESA	GTO
			Spacenet-1	Communications	Southern Pacific CC (USA)	GTO
July	L11	AR 3	Telecom-1A	Communications	France	GTO
			(or Marecs-B2)	Communications	ESA	GTO
			GSTAR-1	Communications	GTE (USA)	GTO
October	L12	AR 3	Arabsat	Communications	Arabsat	GTO
			(or Marecs-B2)	Maritime communications	ESA	GTO
December	L13	AR 3	Spacenet-2	Communications	Southern Pacific CC (USA)	GTO
			GSTAR-2 (or Telecom-1B)	Communications	GTE (USA)	GTO
				Communications	France	GTO
1985						
February	L14	AR 3	Marecs-B2	Communications	ESA	GTO
			(or Arabsat)	Communications	Arabsat	GTO
			Telecom-1B	Communications	France	GTO
			(or GSTAR-2)	Communications	GTE (USA)	GTO
January	L15	AR 1	SPOT	Remote sensing	CNES	Sun-sync.
			Viking	Plasma studies	Swedish Space Corp.	Sun-sync.
March	L16	AR 3	SBTS-1 + ...	Communications	Brazil	GTO
April	L17	AR 2	Intelsat-V F14	Communications	Intelsat	GTO
			(or TV-Sat)	Direct TV	Germany	GTO
May	L18	AR 2	TV-Sat	Direct TV	Germany	GTO
			(or Intelsat-V F14)	Communications	Intelsat	GTO
Jun/Jul	L19	AR 2	Intelsat-V F15	Communications	Intelsat	GTO
			(or TDF-1)	Direct TV	France	GTO
Jul/Aug	L20	AR 1	Giotto	Scientific	ESA	GTO
Aug/Sep	L21	AR 3	SBTS-2	Communications	Brazil	GTO
			ECS-3	Communications	ESA	GTO
October	L22	AR 2	TDF-1	Direct TV	France	GTO
			(or Intelsat-V F15)	Communications	Intelsat	GTO
December	L23	AR 4	Ariane 4-01	Test flight	ESA-CNES	

* GTO = Geostationary Transfer Orbit

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table on page 105 and using the Order-Form on page 106.

ESA Journal

The following papers have been published in ESA Journal Vol. 7, No. 2 (June 1982):

THE ISPM MISSION: SCIENCE OBJECTIVES AND MISSION OVERVIEW
WENZEL K-P, MARSDEN R G & SMITH E J

TOWARDS AN ARTIFICIAL COMET
HAERENDEL G

HIGH-THROUGHPUT DIGITAL SAR PROCESSING
JONES M, DEGAVRE J-C I & GUIGNARD J P

AMPLITUDE CALIBRATION OF SPACEBORNE SYNTHETIC APERTURE RADARS
HELD D N

THE GROUP AGROMET MONITORING PROJECT (GAMP): APPLICATION OF METEOSAT DATA FOR RAINFALL, EVAPORATION, SOIL-MOISTURE AND PLANT-GROWTH MONITORING IN AFRICA
ENGLAND C E ET AL

NODAL PERIOD OF A SATELLITE PERTURBED BY THE EARTH'S OBLATENESS
ROTH E A

MATHEMATICAL MODELLING OF A FLEXIBLE BEAM UNDER GRAVITY
JANSSENS F

Special Publications

ESA SP-183 // 479 PAGES
PROC SIXTH ESA SYMPOSIUM ON EUROPEAN ROCKET & BALLOON PROGRAMMES AND RELATED RESEARCH, INTERLAKEN, SWITZERLAND 11-15 APRIL 1983 (JUN 1983)
BURKE W R (ED)

ESA SP-191 // 440 PAGES
PROC 4TH EUROPEAN SYMPOSIUM ON MATERIALS SCIENCES UNDER MICROGRAVITY, MADRID, SPAIN, 5-8 APRIL 1983 (JUN 1983)
GUYENNE T D & HUNT J (EDS)

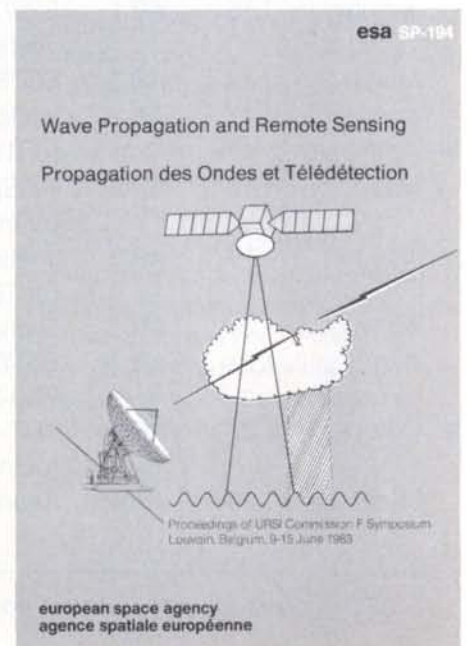
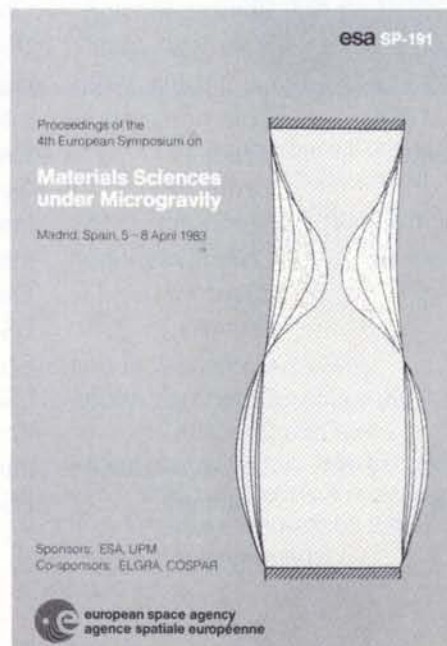


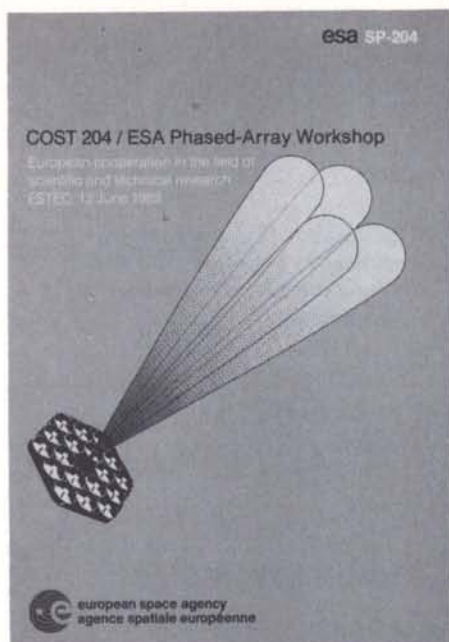
ESA SP-193 // 180 PAGES
RADAR CALIBRATION – PROCEEDINGS OF AN EARSSEL WORKSHOP, ALPBACH, AUSTRIA, 6-10 DECEMBER 1982 (FEB 1983)
ROLFE E J & BATTRICK B (EDS)

ESA SP-194 // 495 PAGES
WAVE PROPAGATION AND REMOTE SENSING – PROC URSI COMMISSION F SYMPOSIUM, LOUVAIN, BELGIUM, 9-15 JUNE (APR 1983)
BATTRICK B & ROLFE E J

ESA SP-204 // 66 PAGES
COST 204/ESA PHASED-ARRAY WORKSHOP, ESTEC, NOORDWIJK, THE NETHERLANDS, 13 JUNE 1983 (JUN 1983)
ROEDERER A & GUYENNE T D (EDS)

ESA SP-206 // 123 PAGES
SPACE BIOLOGY – PROC WORKSHOP HELD AT DFLVR INST OF AEROSPACE MEDICINE, COLOGNE, GERMANY, 9-11 MARCH 1983 (MAR 1983)
LONGDON N & MELITA O



**ESA SP-1048 // 112 PAGES**

THE APOLLO CONCEPT – ELECTRONIC DOCUMENT DELIVERY BY SATELLITE (APR 1983)
 APOLLO WORKING GROUP (CEC, ESA, EUTELSAT & PERMANENT NUCLEUS OF CSTD/GTD)

ESA SP-1051 // 70 PAGES

APPLICATIONS DE LA TELEDETECTION A L'AGRO-METEOROLOGIE OPERATIONNELLE DANS LES PAYS SEMI-ARIDES (JUL 1983)
 GUYENNE T D (ED)

Procedures, Standards & Specifications**ESA PSS-01-703 ISSUE 1 // 28 PAGES**

THE BLACK-ANODISING OF ALUMINIUM WITH INORGANIC DYES (OCT 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-705 ISSUE 1 // 22 PAGES

THE DETECTION OF ORGANIC CONTAMINATION OF SURFACES BY INFRARED SPECTROSCOPY (OCT 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-713 ISSUE 1 // 26 PAGES

MEASUREMENT OF THE PEEL AND PULL-OFF STRENGTH OF COATINGS AND FINISHES WITH PRESSURE-SENSITIVE TAPES (OCT 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-716 ISSUE 1 // 34 PAGES

THE LISTING AND APPROVAL PROCEDURE FOR MATERIALS AND PROCESSES (OCT 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-721 ISSUE 1 // 39 PAGES

FLAMMABILITY TESTING FOR THE SCREENING OF SPACE MATERIALS (OCT 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-727 ISSUE 1 // 17 PAGES

THE CLEANING OF ECCOSORB AN FOAM (OCT 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-732 ISSUE 1 // 17 PAGES

THE CLEANING OF GUDE-SPACE D96 TAPE (DEC 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

ESA PSS-01-733 ISSUE 1 // 36 PAGES

THE APPLICATION OF THE THERMAL-CONTROL PAINT PYROLAC PSG 120 FD (OCT 1982)
 PRODUCT ASSURANCE DIVISION, ESTEC

Scientific & Technical Memoranda**ESA STM-227 // 16 PAGES**

DETERMINATION OF RE-EVAPORATION DURING VBQC OUTGASSING TESTS (MAR 1983)
 DAUPHIN J & PREMAT G

ESA STM-228 // 21 PAGES

FURTHER COMMENTS ON THE INTERPRETATION OF THE VBQC OUTGASSING TEST (MAR 1983)
 DAUPHIN J

ESA STM-230 // 50 PAGES

EVALUATION OF THE TEMPERATURES ATTAINED BY ELECTRONIC COMPONENTS DURING VARIOUS MANUAL SOLDERING OPERATIONS (MAR 1983)
 DUNN B D

Contractor Reports**ESA CR(P)-1674 // 32 PAGES**

SURVEY OF THE STATE OF THE ART IN ROBOTICS AND ARTIFICIAL INTELLIGENCE – EXECUTIVE SUMMARY (JUL 1981)
 DORNIER SYSTEM, GERMANY

ESA CR(P)-1675 PART 1 // 120 PAGES

ADAPTATION OF THE PFM FOR THE ERS MISSION – FINAL REPORT – PART 1: PFM MISSION LIFETIME EXTENSIONS TO 3 YEARS (APR 1982)
 MATRA, FRANCE

ESA CR(P)-1675 PART 2 // 123 PAGES

ADAPTATION OF THE PFM FOR THE ERS MISSION – FINAL REPORT – PART 2: POWER SUBSYSTEM ADEQUACY (AUG 1982)
 MATRA, FRANCE

ESA CR(P)-1675 PART 3 // 171 PAGES

ADAPTATION OF THE PFM FOR THE ERS MISSION – FINAL REPORT – PART 3: EFFECTS OF THE SAR AND SCATTEROMETER ANTENNAS (APR 1982)
 MATRA, FRANCE

ESA CR(P)-1675 PART 4 // 99 PAGES

ADAPTATION OF THE PFM FOR THE ERS MISSION – FINAL REPORT – PART 4: FEASIBILITY OF SATELLITE ROLL TILTING (APR 1982)
 MATRA, FRANCE

ESA CR(P)-1676 // 54 PAGES

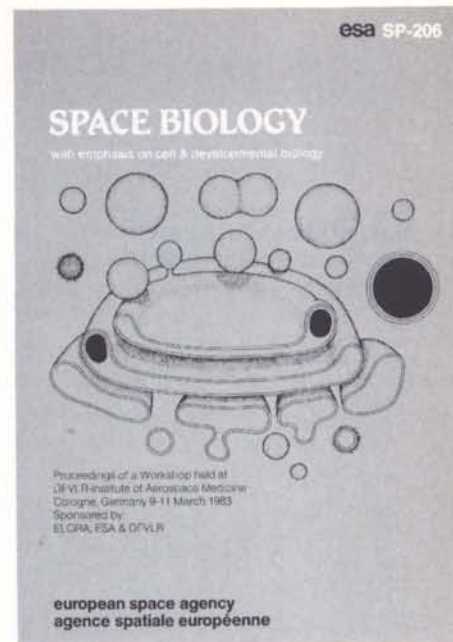
SPACELAB FOLLOW-ON DEVELOPMENT MEDIUM-TERM STUDY – PART A: UNMANNED PLATFORMS – VOLUME 1: EXECUTIVE SUMMARY (APR 1982)
 ERNO, GERMANY

ESA CR(P)-1677 // 110 PAGES

SPACELAB FOLLOW-ON DEVELOPMENT MEDIUM-TERM STUDY – PART B: MANNED PLATFORMS – VOLUME 1: EXECUTIVE SUMMARY (MAR 1982)
 AERITALIA, ITALY

ESA CR(P)-1678 // 116 PAGES

SYSTEMES DE LANCEMENT FUTURS – SECONDE PHASE PROSPECTIVE – RAPPORT FINAL (JUN 1982)
 AEROSPATIALE, FRANCE

**ESA CR(X)-1679 // 121 PAGES**

STUDY OF ERS-1 ON-BOARD RECORDING SYSTEM – FINAL REPORT (FEB 1982)
 LABEN, ITALY

ESA CR(P)-1680 // 52 PAGES

DESIGN STUDY AND DEVELOPMENT OF A MAGNETIC BEARING SCANNING MECHANISM (MBSM) FOR OPTICAL SENSOR APPLICATION (MAY 1981)
 BADG, UK

ESA CR(P)-1681 // 143 PAGES

INDUSTRIAL DEVELOPMENT OF EMITTER MODULES – PHASE 1 – FINAL REPORT: VOLUMES 1 AND 2 (OCT 1980)
 SEP, FRANCE

ESA CR(X)-1682 // 183 PAGES

HIGH-SPEED ADC MODULE – FINAL REPORT (JUN 1982)
 SAAB-SCANIA, SWEDEN

ESA CR(X)-1683 // 119 PAGES / 129 PAGES / 54 PAGES

SAR DATA-CONVERSION AND TIME-EXPANSION UNIT – FINAL REPORT (APR 1982)
 SELENIA, ITALY

ESA CR(X)-1684 // 121 PAGES

PERFORMANCE EVALUATION OF A DUAL GATE FET WHEN USED AS A SWITCHING ELEMENT IN A QPSK MODULATOR – PHASE 1 FINAL REPORT (DEC 1981)
 PLESSEY RESEARCH (CADWELL) LTD, UK

ESA CR(P)-1685 // 362 PAGES

RADAR ALTIMETRY TEST AND CALIBRATION STUDY – FINAL REPORT (JULY 1982)
 BADG, UK

ESA CR(P)-1686 // 151 PAGES

MACS – CHARACTERISTICS AND DESIGN RULES – HANDBOOK (SEP 1982)
 MBB, GERMANY

ESA CR(X)-1687 // 143 PAGES

SSMA OVER A TELEVISION BROADCAST SATELLITE (FEB 1982)
 MILLER COMMUNICATIONS SYSTEMS LTD, CANADA

esa SP-1048
EUR-6589 EN

The APOLLO concept Electronic Document Delivery by Satellite

A joint report by
the APOLLO Working Group

Commission of the
European Communities

European Space
Agency

EUTELSAT

Permanent Nucleus
of CSD/GTD

ESA CR(P)-1688 // 25 PAGES

RECENSEMENT DES PROBLEMES LIES A UNE
DETERMINATION PRECISE DE LA
CONCENTRATION EN CHLOROPHYLLE A PARTIR
D'UN SATELLITE (APR 1982)
UNIV DES SCIENCES ET TECHNIQUES LILLE,
FRANCE

ESA CR(P)-1689 // 51 PAGES

SPECTRAL QUALITY FOR AMI WAVE MODE –
FINAL REPORT (JUL 1982)
MARCONI, UK

ESA CR(X)-1690 // 351 PAGES

AEROMARITIME NAVIGATION RECEIVER STUDY –
FINAL REPORT (NOV 1982)
MILLER COMMUNICATIONS SYSTEMS LTD,
CANADA

ESA CR(P)-1691 // 189 PAGES

STUDY OF A THREE-BEAM SCATTEROMETER –
FINAL REPORT (SEP 1982)
MARCONI, UK

esa SP-1051

Applications de la Télédétection à l'Agro-météorologie opérationnelle dans les pays semi-arides

1er Séminaire international de formation
organisé par l'ONERA, l'ORMM, l'ESA & la FAO

Centre AGROHYMET, Nancy (France)
11 - 29 juillet 1983



ESA CR(P)-1692 // 146 PAGES

STUDY OF A THREE-BEAM SCATTEROMETER –
FINAL REPORT (SEP 1982)
DORNIER SYSTEM, GERMANY

ESA CR(P)-1693 // 317 PAGES

SYSTEM AND GROUND SEGMENT DEFINITION
AND FEASIBILITY STUDY OF AN EARTH
KINEMATICS SATELLITE SYSTEM FOR PRECISE
ORBIT POSITIONING (POP) – FINAL REPORT (JUL
1982)
DEUTSCHES GEODAETISCHES
FORSCHUNGSINSTITUT, GERMANY

ESA CR(P)-1694 // 68 PAGES / 443 PAGES

POPSAT INDUSTRIAL FEASIBILITY STUDY – FINAL
REPORT (JUN 1982)
AERITALIA, ITALY

ESA CR(P)-1695 // 29 PAGES

INVESTIGATION OF TORQUE ANOMALY IN
OSCILLATING PDM BEARINGS (MAY 1981)
ESTL/UKAEA

ESA CR(P)-1696 // 48 PAGES

STUDY OF INTERNAL STRESSES OF THIN SOLAR-
CELL MODULES – FINAL REPORT (JUN 1982)
AEROSPACE ENGINEERING OFFICE,
SWITZERLAND

ESA CR(X)-1697 // 183 PAGES

REPORT ON THE ADVANCED POWER SYSTEM
STUDY (APSS) – STEP 2 (AUG 1982)
BADG, UK

ESA CR(P)-1698 // 57 PAGES

A STUDY OF ROCKET EXHAUST PLUMES AND
IMPINGEMENT EFFECTS ON SPACECRAFT
SURFACES – EXECUTIVE SUMMARY (MAR 1982)
DFVLR, GERMANY

ESA CR(P)-1699 // 113 PAGES

ELECTRICAL MOTORS AND ACTUATORS AT
CRYOGENIC TEMPERATURES – FINAL REPORT
(UNDATED)
SEP, FRANCE

ESA CR(P)-1700 // 148 PAGES

DEVELOPMENT OF SMALL CRYOGENIC HEAT
PIPES – PHASE 3 REPORT (SEP 1982)
SABCA, BELGIUM

ESA CR(P)-1701 VOLUME 1 // 91 PAGES

LIQUID MOTION EFFECTS ON SPIN-STABILISED
SPACECRAFT – SLOSH TESTS AND SCALING (JAN
1982)
ONERA, FRANCE

ESA CR(P)-1701 VOLUME 2 // 43 PAGES

INFLUENCE DES LIQUIDES SUR LA STABILITE
D'UN SATELLITE TOURNANT – COMPARAISON
THEORIE/EXPERIENCE RELATIVE AU SATELLITE
EXOSAT (FEB 1982)
ONERA, FRANCE

ESA CR(P)-1701 VOLUME 3 // 65 PAGES

LIQUID MOTION EFFECTS ON SPIN-STABILISED
SPACECRAFT – ANALYTICAL AND EMPIRICAL
DETERMINATION (OCT 1982)
ONERA, FRANCE

ESA CR(X)-1702 // 23 PAGES

STUDY OF OTS DEMONSTRATIONS 1980/1981
(AUG 1979)
EUROSAT, SWITZERLAND

ESA STM-230
March 1983

Evaluation of the temperatures attained by electronic components during various manual soldering operations

B.D. Dunn
European Space Research & Technology Centre
Noordwijk, The Netherlands
G. Hilbrands & P.J. Nielsen
Christian Rosing A/S
Ballerup, Denmark

European Space Agency
agence spatiale européenne

ESA CR(P)-1703 // 16 PAGES

STUDY OF DISTRIBUTED SYSTEMS SUPPORTING
PARALLEL PROCESSING – FINAL REPORT (DEC
1982)
MATRA, FRANCE

ESA CR(P)-1704 // 54 PAGES / 184 PAGES

PROPAGATION STUDIES FOR FEEDER LINK
DESIGN – FINAL REPORT – VOLUME 1: SUMMARY
– VOLUME 2: MAIN REPORT (AUG 1982)
BRADFORD UNIVERSITY RESEARCH LTD, UK

ESA CR(X)-1705 // 100 PAGES

OSCILLATEUR A QUARTZ HG DE HAUTES
PERFORMANCES – RAPPORT FIN DE PHASE III B
(SEP 1982)
OSCILLOQUARTZ ZA, SWITZERLAND

ESA CR(P)-1706 // 219 PAGES / 126 PAGES

IMAGE CODING ON BOARD SCIENTIFIC
SATELLITES – REPORT 1: SYSTEM STUDY –
REPORT 2: PERFORMANCE DEMONSTRATION
(SEP 1982)
SELENIA, ITALY

ESA CR(P)-1707 // 155 PAGES

DEVELOPMENT OF A CLIMATIC MAP OF
RAINFALL ATTENUATION FOR EUROPE (JUN
1982)
UNIVERSITY OF BRADFORD, UK

ESA CR(X)-1708 // 132 PAGES

HOMODYNE DETECTION OF CO₂ LASER
RADIATION – FINAL REPORT (JUL 1982)
TECHNISCHE UNIVERSITAT WIEN, AUSTRIA

ESA CR(X)-1709 // 218 PAGES

RF SENSING FOR HIGH GAIN REFLECTOR
ANTENNAS – PHASE I AND II – FINAL REPORT
(SEP 1982)
BADG, UK

ESA CR(X)-1710 // 196 PAGES

CHARACTERISATION AND EVALUATION OF GAAS
POWER MESFETS IN THE FREQUENCY RANGE 1.5
TO 12 GIGAHERTZ (OCT 1982)
MARCONI, UK

ESA CR(P)-1711 // 72 PAGES / 278 PAGES
TRAFFIC ROUTING IN A SWITCHED
REGENERATIVE SATELLITE – TASK 1: TRAFFIC
REQUIREMENTS; TASK 2: REPEATER
CONFIGURATIONS (SEP 1982)
TELESPAZIO, ITALY

ESA TT-756 // 30 PAGES
BACKSCATTERING OF LASER MIRRORS
BENTLAGE H, DFVLR, GERMANY

ESA TT-760 // 70 PAGES
SYNTHESIS OF NON-INTERACTING CONTROLS
FOR LINEAR AND NONLINEAR SYSTEMS
MERCIER O, ONERA, FRANCE

Technical Translations

ESA TT-738 // 164 PAGES
AN OBSERVER APPROACH TO THE
IDENTIFICATION AND ISOLATION OF SENSOR
FAILURES IN FLIGHT CONTROL SYSTEMS
STUCKENBERG N, DFVLR, GERMANY

ESA TT-762 // 260 PAGES
ON THE COMPUTATION OF WEAK SOLUTIONS OF
HYPERBOLIC SYSTEMS OF CONSERVATION LAWS
BY DIFFERENCE SCHEMES
LERAT A, ONERA, FRANCE

ESA TT-750 // 61 PAGES
PLANNING OF A C-BAND PULSE DOPPLER
RADAR WITH POLARIZATION DIVERSITY FOR
ATMOSPHERIC RESEARCH IN THE MESO-SCALE
RANGE
SCHUSTER H, DFVLR, GERMANY

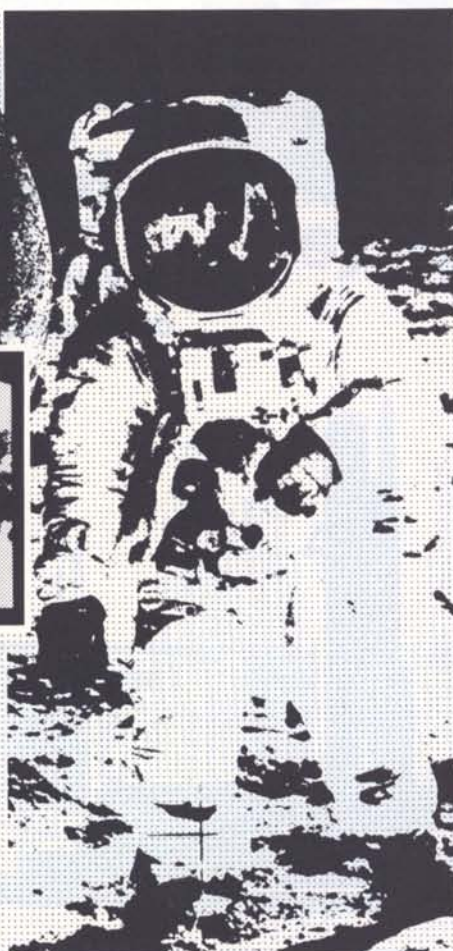
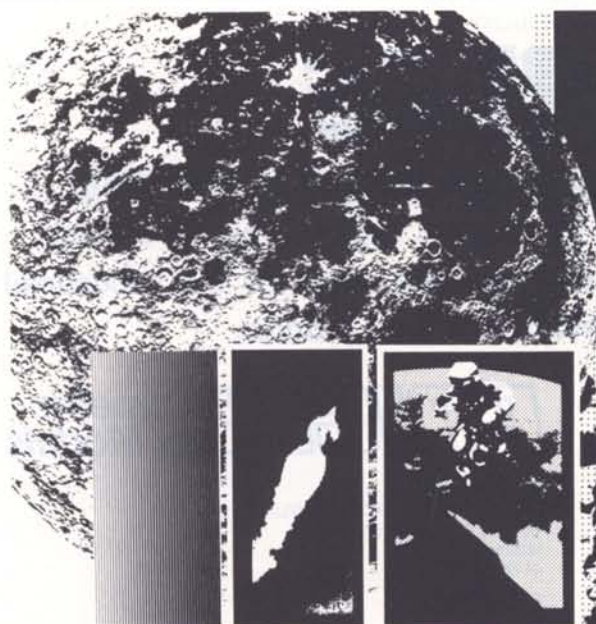
ESA TT-770 // 77 PAGES
OFFSET-REFLECTOR ANTENNAS. DESIGN,
COMPUTATION, CONSTRUCTION AND PATTERN
MEASUREMENTS
KLEMENT D, STEINER H-J & STEIN V, DFVLR,
GERMANY

ESA TT-751 // 257 PAGES
TIME AND TIME DETERMINATION AT THE CNES
CNES, FRANCE

ESA TT-771 // 82 PAGES
LA RECHERCHE AEROSPATIALE – BIMONTHLY
BULLETIN, 1982-3
ONERA, FRANCE

ESA TT-752 // 194 PAGES
LAMINAR BOUNDARY LAYERS IN THE VICINITY OF
THE ATTACHMENT LINE ON WINGS AND
WINGLIKE BODIES AT INCIDENCE
SCHWAMBORN D, DFVLR, GERMANY

ESA TT-781 // 66 PAGES
LA RECHERCHE AEROSPATIALE – BIMONTHLY
BULLETIN, 1982-4
ONERA, FRANCE



In addition
to manufacturing molds,
HAWO

are the suppliers of products for use in the
aviation, radar, space, and
nuclear industries. This is your guarantee
for buying high precision tools.



metaalbewerking hawo bv
gruttostraat 51
7471 er goor / holland
p.o. box 42
7470 aa goor
telephone 05470 - 27 39



TELDIX

Momentum & Reaction Wheels

It's our experience that counts in space

TELDIX
HEIDELBERG

P.O. Box 10 56 08 · Grenzhöfer Weg 36
D-6900 Heidelberg · W.-Germany
Phone (0 62 21) 51 22 31 · Telex 04 61 735

RCA



PRICE

means more cost effective engineering
... five parametric cost estimating models
provide the essential tools for the successful
development of a new product

PRICE Parametric Cost Models

For more information, contact
RCA PRICE Systems/RCA Limited/Lincoln Way
Windmill Rd/Sunbury on Thames/
Middlesex, England
44-(9327)-85511

Elintech GmbH
Kuckucksblumenstr 1
8000 München 50
West Germany
(089) 1503488

Sofragem - Ordisor
6, Place du Colonel-Bourgoin
75012 Paris, France
33(1)3416666

SIMC
Via Lucrezio Caro, No. 12
00193 Rome, Italy
39(6) 3575177

Why CTL...

The ancient Chinese were on the right track when they observed "a journey of a thousand miles must begin with a single step".

The implication being that this step must be taken – and the rest of the journey will be easier if it's taken in the right direction.

Which brings us to CTL.

CTL stands for Computer Technology Limited. Over the past 9 years, we have provided computers for satellite checkout systems using the European Space Agency's specially developed checkout software, on METEOSAT I and II ... GEOS I and II ... EXOSAT ... FOC ... ISPM ... ECS Series ... MARECS A and B ... FTEL ... IRAS ... L-SAT ... and the GIOTTO scientific satellite that will intercept Halley's Comet in 1986.

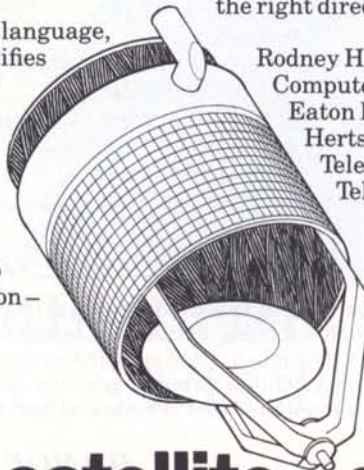
Why CTL? Several Reasons ...

- CTL's unmatched flexibility for interfacing which allows every onboard instrument and system to be checked out using the same OCOE (overall check out equipment) – at every stage of development. For any contract or subcontractor. Anywhere.
- CTL's ability to provide high speed decommutation of packet telemetry through intelligent, programmable I/O interfaces.
- CTL's unique CLASS language, which speeds and simplifies development of special communications protocols.
- CTL's unique MOMENTUM feature which provides the amount of system resilience required – up to full non-stop operation – at a sensible cost.

- CTL's high-response, multi-terminal hardware.
- CTL's high-speed CAMAC interface controller.
- CTL's experience with broadband local area networks.
- CTL's willingness to tackle specials – and serve as consultants if required.

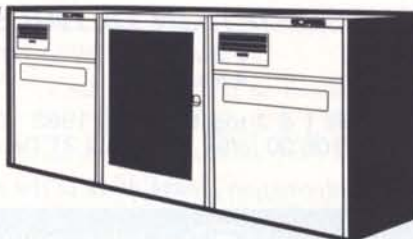
Next time you're ready to embark upon a journey from decision to launch, check out CTL. It will be a step in the right direction.

Rodney Howlett,
Computer Technology Ltd.,
Eaton Road, Hemel Hempstead,
Herts. HP2 7LB, England.
Telephone: (0442) 3272
Telex: 825052



...for computerised satellite checkout systems?

The Computers with MOMENTUM



CTL Computer Technology Limited

an **ITL** Information Technology Company

Wiley JOURNALS

A New Journal from Wiley ■ Announcement and Call for Papers

INTERNATIONAL JOURNAL OF *Satellite Communications*

CHIEF EDITORS

PROFESSOR B.G. EVANS

Department of Electronic & Electrical Engineering,
University of Surrey, Guildford, Surrey GU2 5XH, U.K.

DR. R. COLBY

INTELSAT, Box 32, 490 L'enfant Plaza, South West,
Washington DC 20024, U.S.A.

EDITORIAL ADVISORY BOARD

P.L. BARGELLINI *USA*

S.K. BARTON *UK*

P.J. COTT *UK*

J.H. COWAN *UK*

G. DAWSON *UK*

J. DICKS *USA*

F.M. GALANTE *France*

R. GOUGH *UK*

F.B. JAMES *UK*

A.K. JEFFERIS *UK*

P. KALE *India*

W. KRIEGL *West Germany*

O. LUNDBERG *UK*

H. MAHNER *West Germany*

E.F. MALLETT *France*

A. MILLER *Canada*

B.J. MILLER *UK*

P. NORRIS *UK*

R.M. OWEN *UK*

R. PARTHASARATHY *USA*

C. ROSETTI *France*

C.P. SANDBANK *UK*

J.O. SCANLAN *Ireland*

D. SACHDEV *USA*

P. SARGEAUNT *UK*

H. TACHIZAWA *Japan*

P.T. THOMPSON *UK*

C. TURNER *France*

P. ACKERMAN *USA*

R.G. GOULD *USA*

B.A. PONTANO *USA*

Further names are being added to the Editorial Advisory Board

AIMS

To produce initially a quarterly technical journal to act as a focus for workers, as well as other parties interested in satellite communications. The journal will span the various disciplines applicable in the field of satellite systems and will provide rapid communication of new results and trends

in this expanding area. As well as new research and development results and applications, the journal will also contain general interest articles of a review or tutorial nature.

RANGE OF TOPICS

The journal will cover all aspects of the theory and practice of satellite systems and networks, e.g. telecommunications, remote sensing, data collection and broadcasting. Topics will include:

- NETWORK PHILOSOPHY AND PLANNING
- COMMUNICATION SYSTEMS AND EQUIPMENT
- ANTENNAS: EARTH STATION AND SATELLITE

- SPACE CRAFT TECHNOLOGY AND CONTROL
- EARTH STATION EQUIPMENT AND PLANNING
- PROPAGATION ASPECTS INCLUDING INTERFERENCE AND CO-ORDINATION
- APPLICATIONS OF SATELLITE SYSTEMS
- USER ASPECTS E.G. MARKETING
- REGULATORY MATTERS ETC.

SUBMISSION OF MATERIAL

The journal will consist of refereed papers, short communications, letters to the editors, book reviews and news items. Papers may be of a research, general interest or tutorial nature and the requirements for publication may be briefly stated as originality and significance. Letters to the editors (each limited to 1000 words) will be subject only

to brief refereeing and will generally achieve more rapid publication. A letter to the editors would typically comment on published results, pose some new problem, draw attention to some application or otherwise be of technical interest. All contributions should be sent to one of the chief editors at their respective addresses.

QUARTERLY — STARTING AUGUST 1983

SUBSCRIPTION DETAILS

Volume 1	(Aug-Dec 1983)	2 issues	UK: £25.00	US: \$42.50
Volume 2	(Jan-Dec 1984)	4 issues	UK: £50.00	US: \$85.00

SPECIAL OFFER of Volumes 1 & 2 together (Aug 1983 - Dec 1984) 6 issues at:
UK: £62.50 US: \$106.00 (offer valid until 31 December 1983)

For a specimen copy and/or further information please write to the most convenient address below.

Journals Department,
John Wiley & Sons Ltd.
Baffins Lane · Chichester,
Sussex PO19 1UD · England



Subscription Department 'C',
John Wiley & Sons Inc.
605 Third Avenue · New York,
N.Y. 10158 · U.S.A.

NOWCASTING II



3-7 SEPTEMBER 1984
NORRKÖPING, SWEDEN

THE SECOND INTERNATIONAL SYMPOSIUM ON NOWCASTING

MESOSCALE OBSERVATIONS AND VERY SHORT-RANGE WEATHER FORECASTING

The second International Nowcasting Symposium will be held in Norrköping, Sweden, on 3-7 September 1984 under the sponsorship of IAMAP, WMO, ESA and SMHI.

The title "Nowcasting" is interpreted to include methods and systems for providing detailed observations and analyses of the current state of the weather, and for making site-specific forecasts over the period 0 to 12 hours ahead (both by simple extrapolation of mesoscale observations and by the application of mesoscale dynamical models). The aim will be to cover all aspects of local weather.

There will be invited and contributed papers covering the following major areas:
Mesoscale phenomena - structure and evolution, dynamics.

Observations - observational methods and systems, analysis and interpretation.

Forecasting - extrapolation, physical models, numerical dynamical methods, total systems.

In addition there will be a discussion session on user requirements and the economic benefits of nowcasting.

Persons interested in attending should write to the Chairman of the Local Organising Committee, Dr S Bodin, Swedish Meteorological and Hydrological Institute, Box 923, S-601 19 Norrköping, SWEDEN.

Persons wishing to present a paper should submit an informative abstract to the Chairman of the Programme Committee, Dr KA Browning, Meteorological Office Radar Research Laboratory, RSRE, Malvern, Worcs., UK, WR14 3PS.

Deadline for submission of abstracts is 1 November 1983. Papers that are accepted will be required in camera-ready form by 1 May 1984 for inclusion in a preprint volume.

Overall numbers will be limited. Individuals wishing to show posters and companies wishing to mount trade displays should also contact Dr Bodin. There will be a conference fee of US \$ 50.

In 1984 the City of Norrköping will be celebrating its 600th anniversary. This might cause a shortage of hotel accommodation. Because of this the Local Organising Committee has

arranged that several hotels have set aside blocks of rooms for symposium participants.

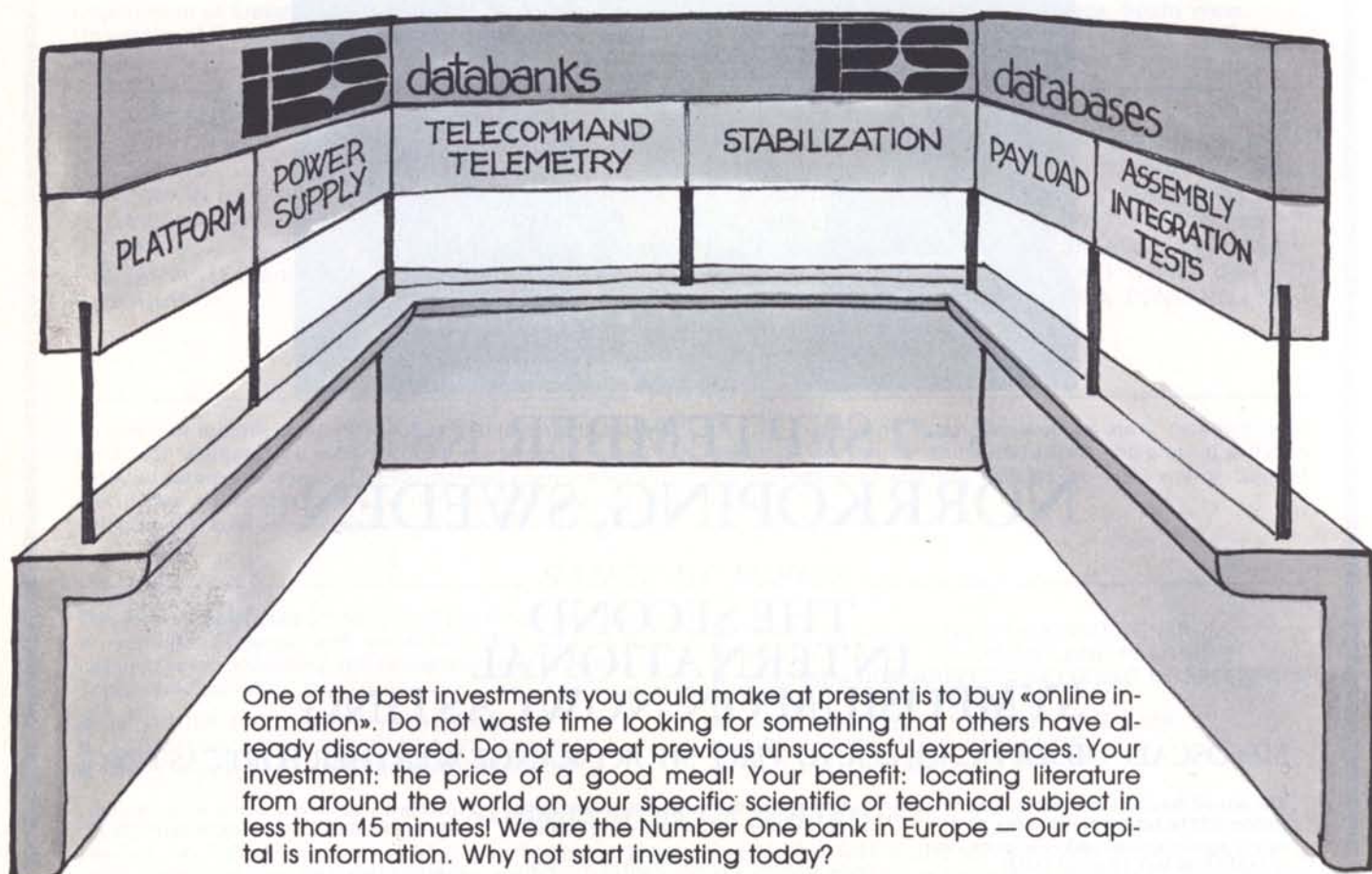
Applicants are requested to indicate whether they want room reservations to be made or not. In the former case an indication of preferred price range should be made.

During 1984 the City of Norrköping will sponsor many local arrangements and offer improved general services.

SMHI


NORRKÖPING
600 år 1984

SAVE TIME AND MONEY WITH ESA-IRS.



One of the best investments you could make at present is to buy «online information». Do not waste time looking for something that others have already discovered. Do not repeat previous unsuccessful experiences. Your investment: the price of a good meal! Your benefit: locating literature from around the world on your specific scientific or technical subject in less than 15 minutes! We are the Number One bank in Europe — Our capital is information. Why not start investing today?

coverage:

aeronautics, space, astronomy, astrophysics, pollution and environment, earth and ocean sciences, energy and combustibles, metallurgy and material sciences, physics, electronics, data processing, agriculture, water management; electrical, electronic, chemical and mechanical engineering; nuclear sciences and applications; news; organic and macromolecular chemistry; biochemistry, medicine, food sciences, management, translations of reports of all kinds.



the European approach to online information

ESA - Information Retrieval Service
Esrin, Via Galileo Galilei, - I 00044 Frascati (Italy) tel: (39/6) 94011 - twx: 610637

Availability of ESA and NASA Publications

Publications	Series	Available as	From
Periodicals			
ESA Bulletin		Available without charge as a regular issue or back numbers (as long as stocks last)	
ESA Journal			
Special Publications	SP	Hard (printed) copy as long as stocks last; thereafter in microfiche or photocopy	ESA Scientific and Technical Publications Branch, ESTEC, 2200 AG Noordwijk, Netherlands
Brochures	BR		
Tribology series	TRIB		
Scientific Reports, Notes and Memoranda	SR, SN, SM		
Technical Reports, Notes and Memoranda	TR, TN, TM		
Scientific and Technical Reports	STR		
Scientific and Technical Memoranda	STM		
Procedures, Standards and Specifications	PSS		
Contractor Reports	CR	Microfiche or photocopy only	
	CR(P)		
	CR(X)	Restricted distribution; not for sale	
Electronics Component Databank Catalogue	ECDB	Hard (printed) copy as long as stocks last	
Technical Translations	TT	Microfiche or photocopy only	
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

Currency:		AS	BF	CDS	DKR	FF	DM	I£	LIT	DFL	NKR	PTS	SF	SKR	£	US\$
Price code	Number of pages															
E1/C1	1-100	200	415	16	80	60	25	7	12,600	28	70	1,007	22	55	6	15
E2/C2	101-200	290	620	24	120	90	38	10	19,000	42	104	1,510	33	80	9	22
E3/C3	201-500	440	950	37	185	140	58	16	30,000	65	162	2,317	51	124	14	34
E4/C4	over 500	560	1,200	47	230	175	73	20	37,000	82	208	2,920	64	160	17	44

1 Photocopies will be supplied if the original document is out of print, unless microfiche is specified.

2 Prices subject to change without prior notice.

3 Postal charges (non Member States only): Austria AS 90; Canada CDS 8; Norway NKR 35; other countries US\$ 7.

ORDER FORM FOR ESA/NASA PUBLICATIONS

TO: DISTRIBUTION OFFICE
 ESA SCIENTIFIC & TECHNICAL PUBLICATIONS BRANCH
 ESTEC, POSTBUS 299, 2200 AG NOORDWIJK
 THE NETHERLANDS

From:

Customer's Ref.: Signature:

No. of copies			ESA or NASA Reference	Title	Price code	Date of order
Printed	Micro- fiche	Photo copy				



IF OUT OF PRINT SUPPLY IN MICROFICHE
 DO NOT SUPPLY

MAILING AND INVOICING ADDRESS (Print or type carefully)

Name or function

Organisation

Street address

Town, Province, Postal code

Country

ADDITIONAL INFORMATION

- Publications are available in printed form (as long as stocks last), in microfiche and as photocopies.
- Publications in the following series are not available in printed form:
 - the ESA TT series;
 - all NASA series.
- Publications in the CR(X) series are not available from ESA as they have a very restricted distribution in printed form to the States participating in the relevant programme.
- If a publication ordered in printed form is out of print, a microfiche copy will be supplied unless indicated otherwise on the Order Form.
- Printed copies are despatched from ESTEC, and microfiche and photocopies from ESA Head Office. They will arrive in different packages at different times.





europaean space agency
agence spatiale européenne

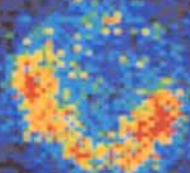
member states

belgium
denmark
france
germany
ireland
italy
netherlands
spain
sweden
switzerland
united kingdom

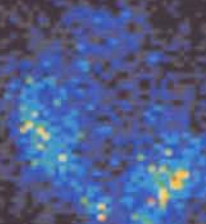
etats membres

allemagne
belgique
danemark
espagne
france
irlande
italie
pays bas
royaume-uni
suède
suisse

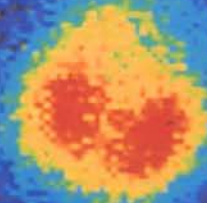
LE2 CMA



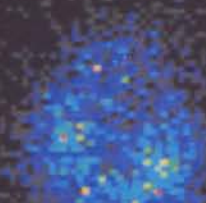
LE1 CMA



LE1 PSD : TOTAL



LE1 PSD : HARD



EXOSAT OBSERVATIONS OF THE

SUPERNOVA REMNANT CAS A