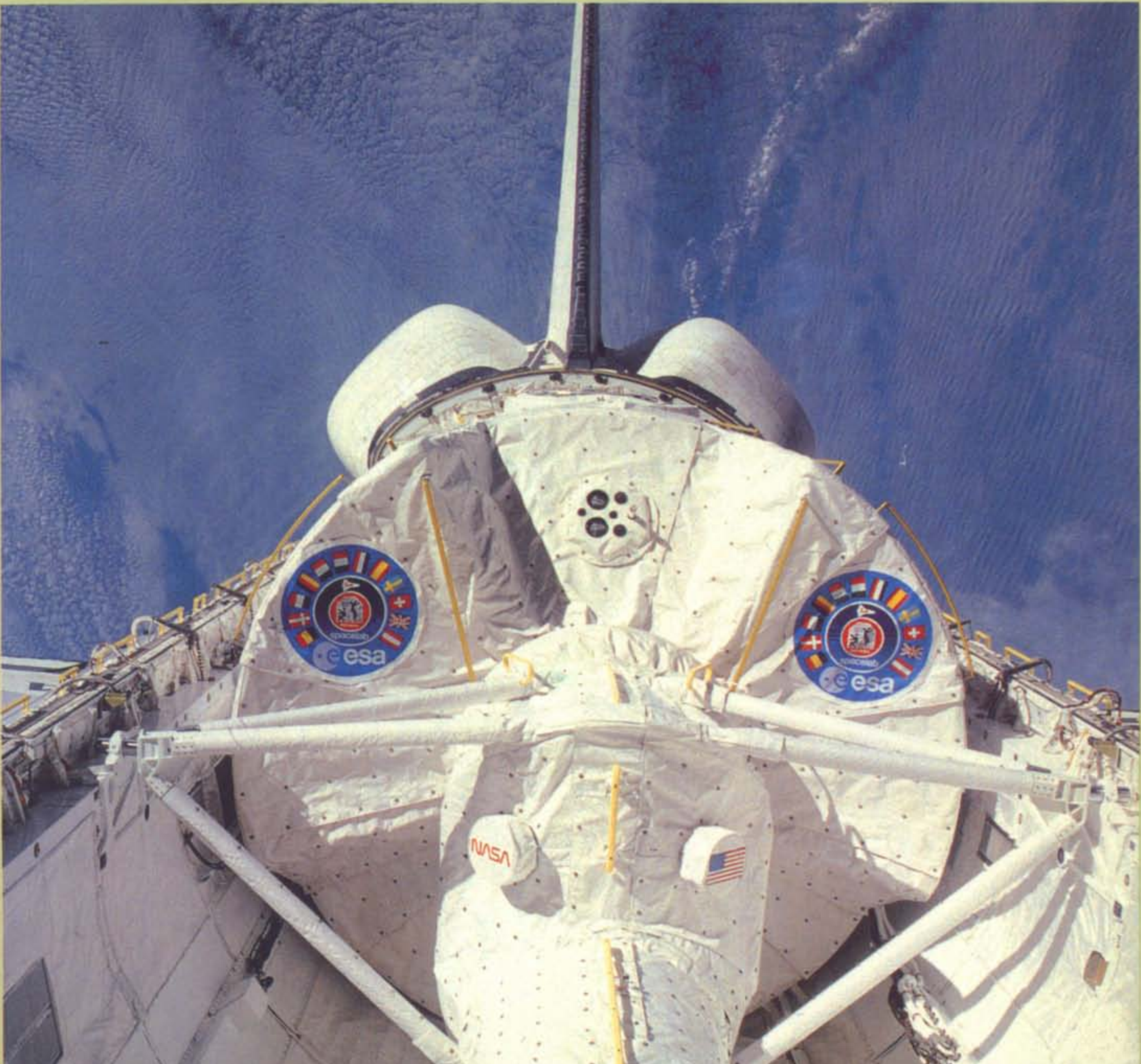
esa bulletin

number 37

february 1984

XX years of european cooperation in space
european space agency
ELDO 1964 esa 1984 ESRO
agence spatiale européenne
XX ans de coopération spatiale européenne



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 Operations, and the Director of Administration.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

ESRIN, Frascati, Italy.

Chairman of the Council: Prof. H. Curien (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.

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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 des Opérations et du Directeur de l'Administration.

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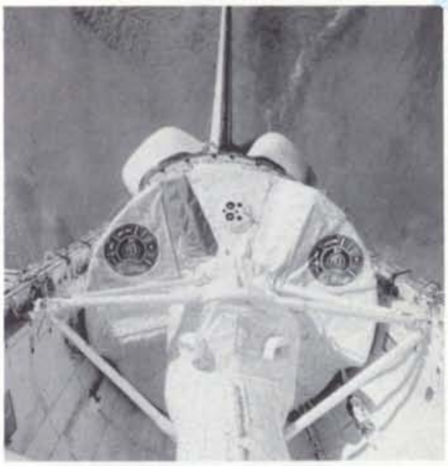

Front cover: Spacelab-1 in orbit

Back cover: Shuttle/Spacelab-1 crew alight at Edwards Air Force Base in California

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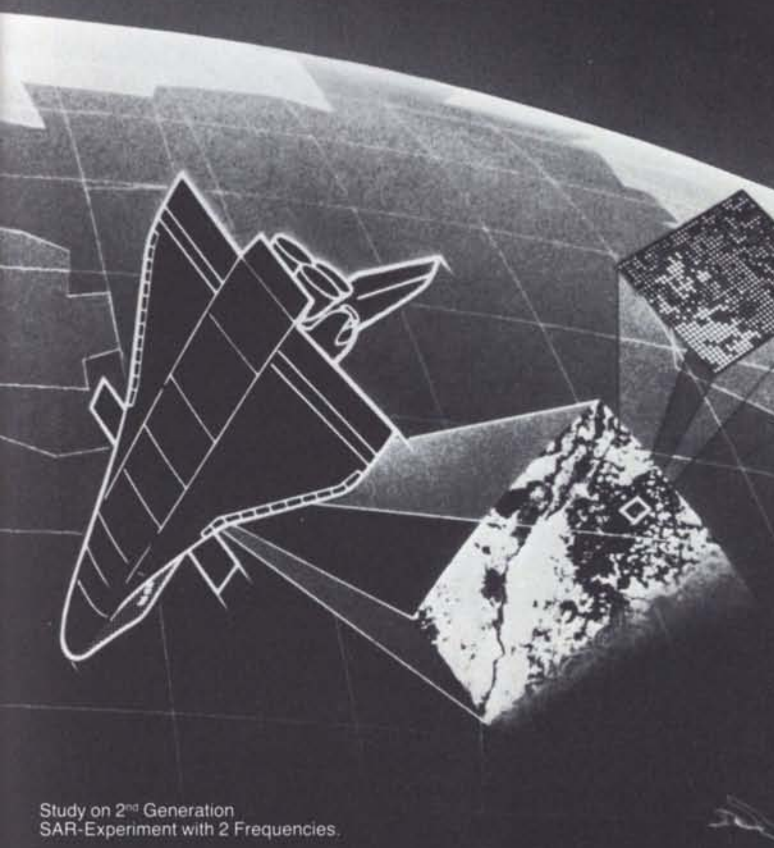
Remote Sensing



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Ready for lift-off

The Spacelab-1 Mission

Progress Through Cooperation

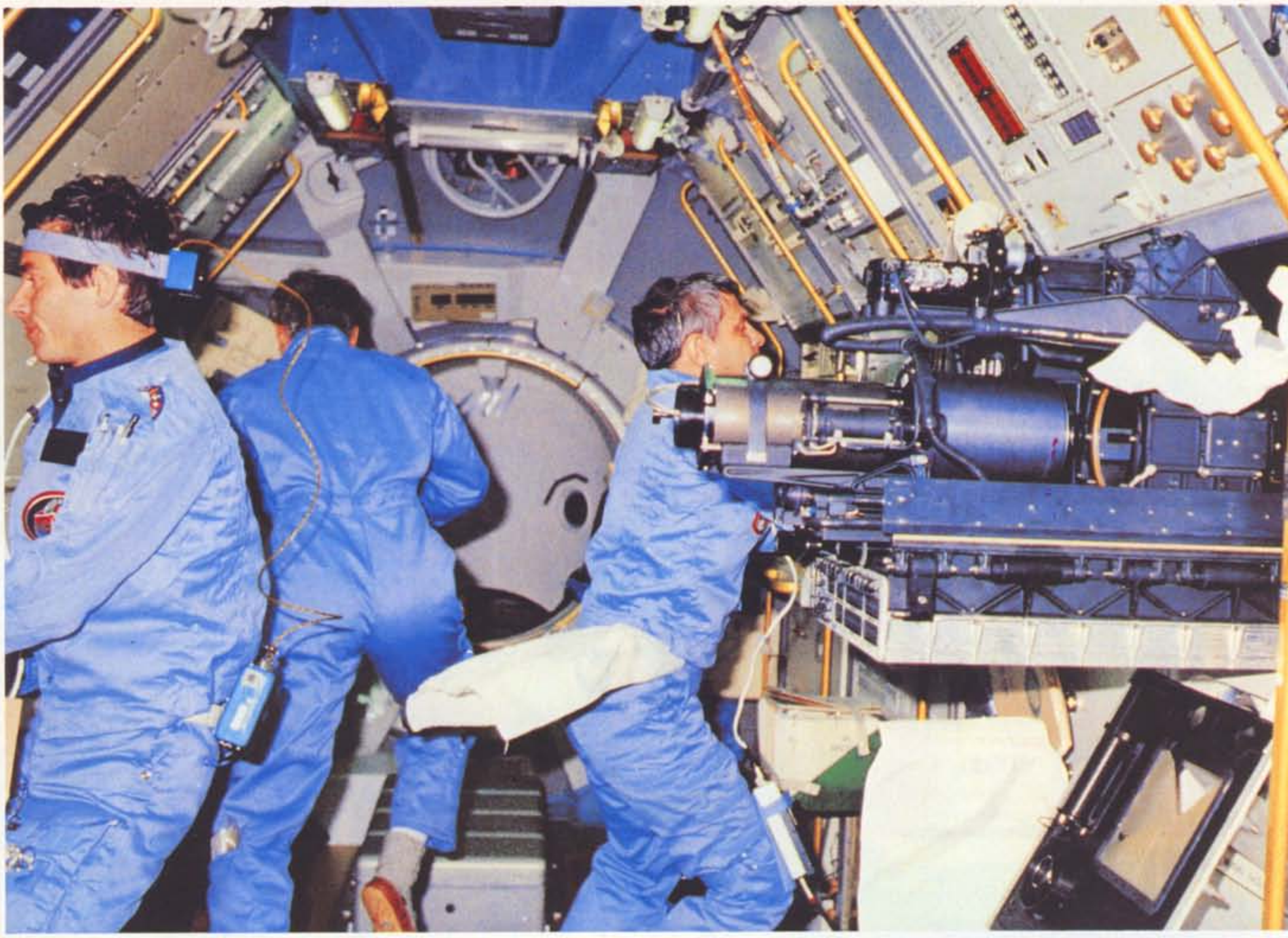
Mission Specialist Owen Garriott and Payload Specialists Byron Lichtenberg & Ulf Merbold (left to right)

European Spacelab Payload Specialist Ulf Merbold

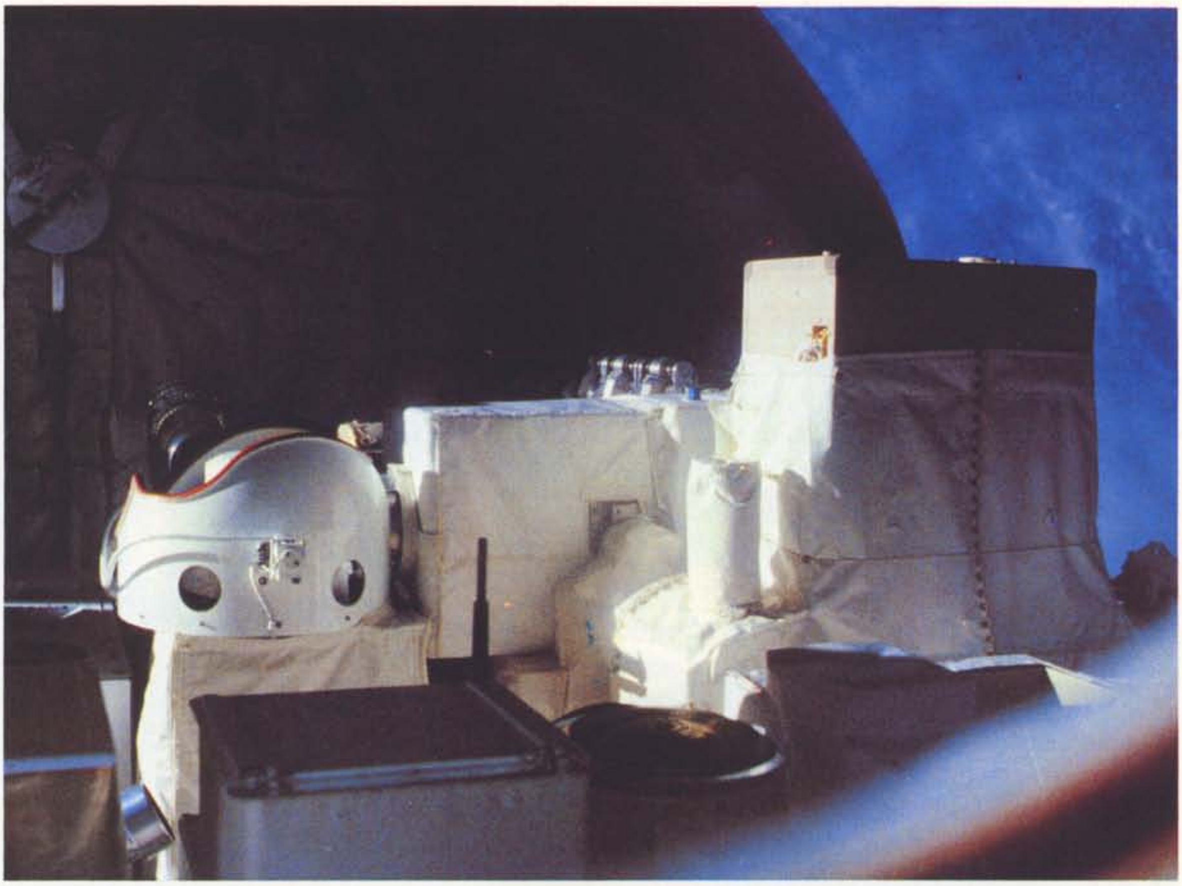
44 minutes to launch

Lift-off at 16.00 UT on 28 November 1983

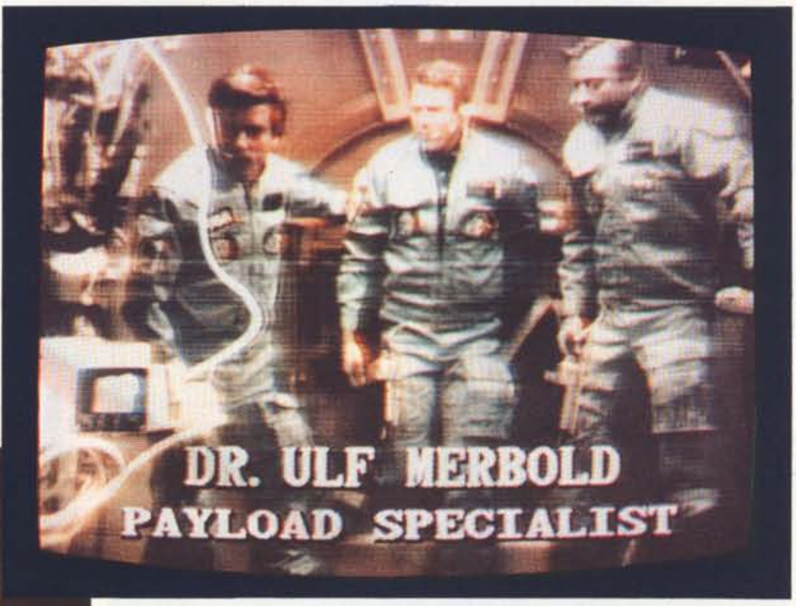
Early on-board and ground activities

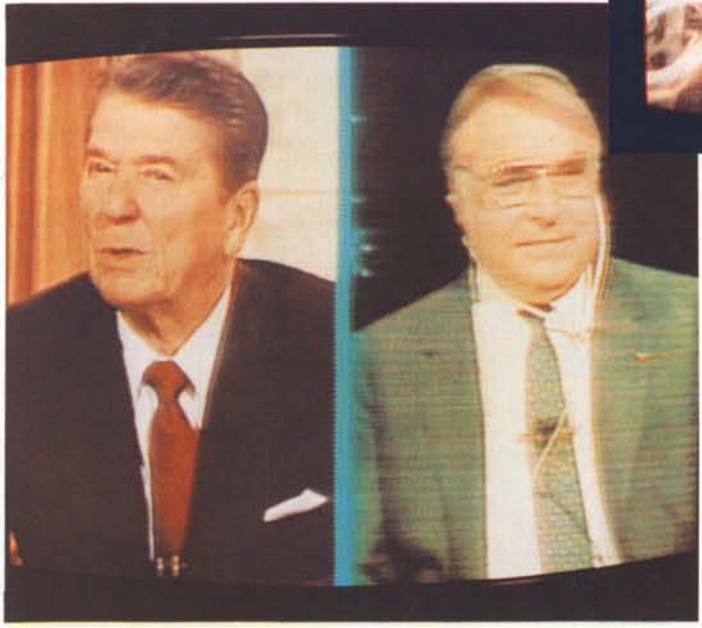


On-board scientific activities in full swing (see page 16 for details)



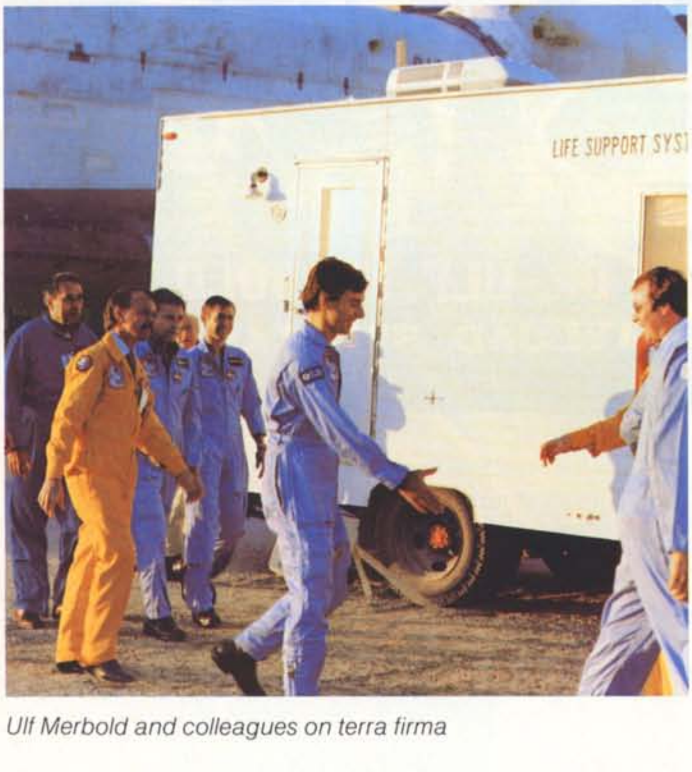
The Pallet-mounted experiments seen from the Spacelab Module



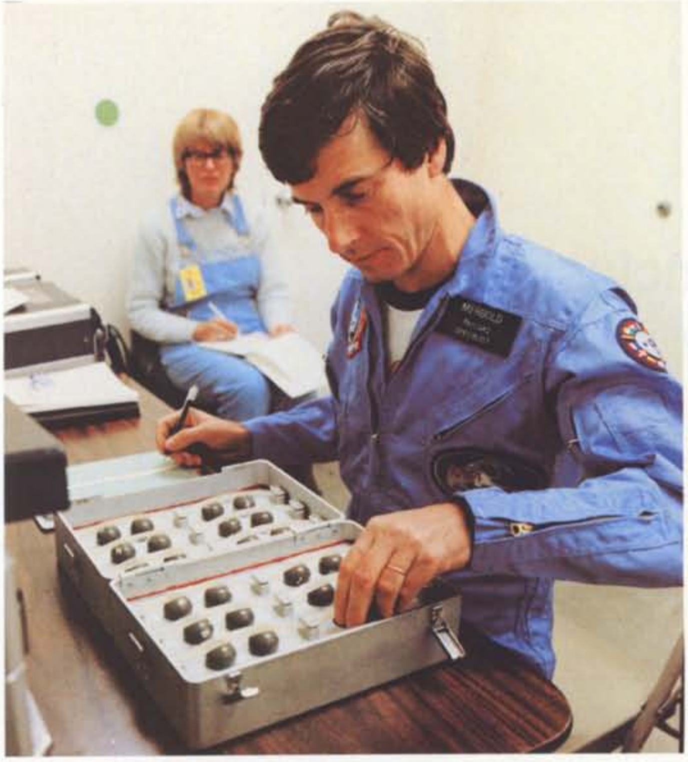


US President Reagan and Germany's Chancellor Kohl in teleconference with the Spacelab crew in orbit

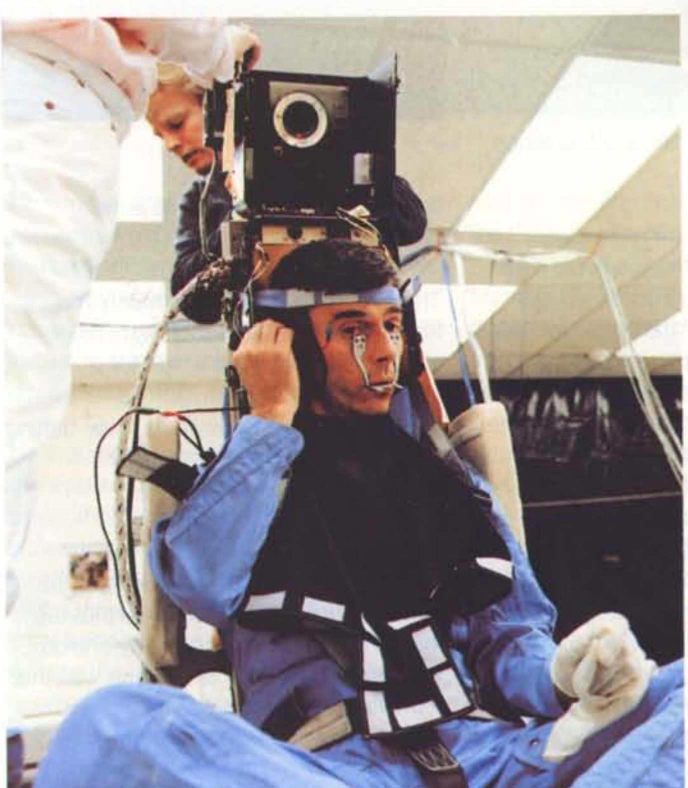
Touch down at Dryden Flight Research Center (California) at 23.47 UT on 8 December



Ulf Merbold and colleagues on terra firma



Post-flight medical tests in progress at the Dryden Baseline Data Collection Facility



Spacelab – Triumphant Conclusion to a Decade of Cooperation

E. Quistgaard, Director General, ESA

A drawback of being the Agency's Director General is that you are very unlikely to see the outcome of the programmes that you initiate, but on the other hand you do have the chance to nurture the crop that your predecessors have sown and reap the harvest. It has fallen to me to reap considerable rewards, as so many programmes have reached fruition during my four years in office:

- After teething troubles, Ariane has proved itself, and has successfully launched its first commercial payload.
- The first European operational maritime satellite Marecs-A has been commissioned and put into service by Inmarsat.
- ECS-1 has been handed over to Eutelsat as the first of a series of operational communications satellites.
- In the scientific domain, Exosat is providing exciting data for astronomers.

Throughout the four years there has been the steady build-up towards the launch of Spacelab. Although we speak of a decade of cooperation, one has to go back 14 years, and three of my predecessors in office, to the day when the NASA Administrator, Dr. Thomas O. Paine, invited ESA (then ESRO) to participate in the Post-Apollo Programme.

We have just witnessed the outcome of the largest international cooperative space programme yet to be undertaken. Developed and funded in Europe at a cost of approximately one billion US dollars, Spacelab signals Europe's entry into the manned-space endeavour.

Throughout the decade ESA staff and European industry and scientific researchers have worked in the fullest cooperation with engineers and scientists from NASA to ensure, firstly, that Spacelab should fulfil all that was required of it as a major element in the US Space Transportation System, and secondly that the payload for the first Spacelab mission should be ready and integrated on time.

As the Shuttle was also being developed in parallel, and therefore parameters for Spacelab's physical and performance levels were regularly being updated, cooperation between NASA and ESA had to be precise, and had to ensure quick responses. Both Agencies learned much from the experience.

After so many disappointments over postponed launch dates, the event itself came as a spectacular success. Unlike the initial slow climb of the larger rockets, the Shuttle seems to spring away from its pad. The best films and tapes cannot capture the living, orange compact flame as the main engines and boosters combine to thrust the Shuttle upwards and onwards. Before spectators had stopped admiring the visual spendour, they were enveloped in a sonic boom seemingly powerful enough to knock them off their feet.

The heartfelt thanks that the first moments had been negotiated successfully then gave way to a little apprehension as we waited for the Orbiter's cargo-bay doors to open, and for the crew to enter Spacelab for the first time.

The brief problem with the hatch into the tunnel can now be seen as light relief, although tensions were high for a moment. Then the television cameras were recording the payload crew drifting through the entrance tunnel into Spacelab, and all was well.

As I write, the success of Spacelab has been endorsed by the decision that the mission should be extended by one day. We can reflect now that not only was this a proving flight, but it was also a very complex mission in its own right with 72 experiments from so many different disciplines.

The number of technical problems has been remarkably small for a first flight. The quiet efficiency with which they were mastered speaks volumes for the preparations and documentation without which a mission of this complexity cannot be mounted or fully exploited.

The arguments against the need for man's presence on board have been very convincingly refuted. The crew successfully repaired the high-data-rate recorder, released the jammed film in the Metric Camera, and ensured that the mirror furnace operated correctly. Perhaps the most astonishing vindication occurred with a fluid-physics experiment, for which the Principal Investigator on the ground and the Spacelab crew were able to redesign the approach during the mission, thereby enhancing the value of the data recovered.

Many of the life-sciences experiments depend, of course, on man's presence, and the extra day in space enabled additional data to be collected.

Knowing that they can examine, repair, and refurbish or alter the instrumentation when it returns to Earth is a new, invigorating challenge to experimenters and technologists alike.

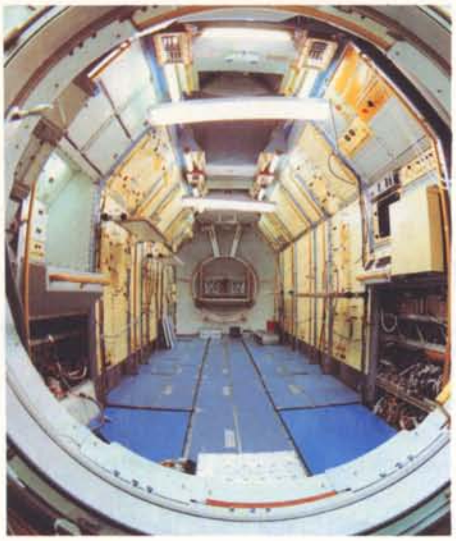
A question that naturally arises is: 'Does ESA plan to follow up this success by seeking a role in any space-station development?'. One must be cautious in predicting the future policy of ESA Member States, but I am certain that ESA will not be putting all its eggs in one basket. There has to be a balanced European programme, with science, applications, and space-transportation systems each having a viable share.

Having said that, it would be wrong not to accept the enthusiastic acclaim of NASA that Europe now has the capability and capacity to be a partner in future manned flight activities. At the same time European industry understands that it has experience and expertise that it should not lose. Money will not be available for a completely new approach, but so many elements of the Spacelab Programme are capable of being extended, and could find a place in a variety of space-station configurations.

We are only now realising what possibilities and potential have been opened to us by Spacelab. Together with Eureca, it gives us a firm foundation for an active role. The scope of that role will depend on the political will of Member States, but I am confident that the user communities, when they too have digested the lessons of the early Spacelab flights, will put pressure on Governments to participate in future joint ventures.

I spoke at the beginning of reaping what others have sown. I would like to think that during my time in office the seeds for Europe's participation in the exciting future in Space Transportation Systems have fallen on fertile ground, and will provide a full harvest for those to come.

My personal thanks go to all those engineers, scientists, technicians and support staff throughout Europe and the USA, and especially to the ESA and NASA teams, who have achieved so much with the first Spacelab flight.



The Scientific Accomplishments of Spacelab-1 – An Early Assessment

K. Knott, Spacelab Project Scientist, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

On its maiden flight, Spacelab carried 3000 kg of scientific instrumentation supporting more than 70 investigations from the Agency's Member States, the USA, Canada and Japan. The first flight was a multidisciplinary mission, covering seven primary areas of research: Life Sciences, Material Sciences, Solar Observations, Astronomy, Earth Observations, Atmospheric Physics and Space Plasma Physics. The launch took place at 16.00 UT on 28 November 1983, after an earlier opportunity at the end of October had been missed due to problems with the Space Shuttle's solid-rocket boosters.

The timing of the Spacelab launch was dictated by a number of scientific considerations. The time of day mainly determines how much of the orbit is spent in sunlight and how much in shadow. The time of month is dictated by a requirement for the occurrence of a new Moon during the mission, in order to have a dark sky background for sensitive optical observations. The time of year is determined by ground-illumination conditions needed for Earth-observation purposes.

For November, a compromise between science and Orbiter-safety requirements led to a launch at 16.00 UT, which caused relatively short orbital nights in the first seven days of the mission and left the Orbiter in continuous daylight from the eighth day of the mission onwards. The time of the month was, however, ideal, with a new Moon occurring on Day 6 of the mission. The time of year was less ideal, because illumination conditions in central Europe are poor in the November/December time period.

As a result of the compromises that had to be made in launch time of day and year, and despite timeline rearrangements undertaken to ensure a reasonable scientific return for all instruments on-board, seven (of the seventy) experiments were identified prior to the mission for reflight, among them the Metric Camera and the Grille Spectrometer.

The Shuttle carried Spacelab into an almost perfect orbit, with an altitude of 240 km and a 57° inclination. The inclination is important from an Earth-observation and plasma-physics point of view. Altitude and therewith orbital period had to be correct in order to be able to carry out the mission and the experiments to their pre-defined timeline. Spacelab's activation proceeded without major problems and the scientific programme could be started just six hours after launch.

The first day of the mission was devoted to Life Sciences. The adaptation of the crew's vestibular and general physiological systems to zero gravity was determined. In parallel, most Pallet instruments that could be commanded from the ground were switched on and checked out.

On Day 2, the 'cold test' was initiated. In the course of this test, which formed part of the technical verification programme for Spacelab, the proper functioning of the space laboratory system under the lowest possible temperatures was tested. To reach these temperatures, the attitude of the Shuttle must be such that no solar radiation or albedo from the Earth enters the Cargo Bay. The Shuttle's cold-test attitude and conditions permitted just a few Pallet instruments to be operational, but material-sciences processing and other Module activities were initiated in the course of this second day. On completion of the cold test, the full scientific programme could be started. For several days, the Shuttle's attitude was continuously changed between celestial pointings for astronomy, Earth-pointing attitudes, special attitudes with respect to the geomagnetic field, and special attitudes for atmospheric research.

Figure 1 – Payload Specialist Ulf Merbold exchanging a cartridge in the Gradient Heating Facility, which forms an integral part of the Material Science Double Rack (MSDR)

All systems were operating nominally and it was not until Day 4 that the crew's repair skills were required to service facilities that had developed anomalies. The single most important achievement in this respect was the successful recovery of the High-Data-Rate Recorder (HDRR). Loss of this device would have jeopardised more than 50% of the science on all subsequent days of the mission. The Metric Camera had successfully exposed its first magazine of infrared-film, but shortly after the second magazine had been inserted the film jammed and further exposures seemed impossible. The crew, with excellent support from the Alternate Payload Specialists on the ground, succeeded in removing the suspect magazine, reinserting the film and getting the camera back into normal operation. In the Materials-Science Double Rack (MSDR), which had operated flawlessly up to this point, a power problem affecting both the Isothermal and Mirror Heating Facilities developed. The crew succeeded, however, in modifying the power-supply harness in such a way that the Mirror Heating Facility could resume normal operations (Fig. 1).

At the end of Day 7 the last orbital night occurred, and on the eighth day the hot test could be carried out as planned. The aim of this test was to operate the Spacelab/Shuttle composite under the extreme temperatures encountered during continuous solar illumination. During this solar-pointing attitude of the Shuttle and Spacelab, the solar spectrometers and radiometers carried out intensive observations. On Day 9, those experiments that could still operate in daylight continued the predefined programme.

In view of both the excellent performance of all onboard systems and the considerable margins of consumables remaining (critical Orbiter supplies, including fuel-cell reactants and propellants, etc.) it had been decided to extend the mission by one day. During this extra day, previously missed experiment opportunities (very few) were rescheduled and additional science could be carried out. Optional observations and investigations on Day 10 were scheduled for the disciplines of X-Ray Astronomy, Atmospheric Physics (airglow), Plasma Physics, Solar Physics, as well as for Life Sciences and Fluid Physics.

Immediately following the Space-Shuttle's landing at Dryden Flight Research Center, California on 8 December at 3.47 pm local time (23.47 UT) the two Mission and two Payload Specialists were transferred to the Baseline Data Collection Facility to complete their post-flight medical programme, which was an integral part of the life-science investigations, and was pre-planned long in advance of the mission. In parallel, samples, specimens, plants and film were removed from the Spacelab Module and handed over to the respective investigators.

The following paragraphs are an attempt to summarise some of the major achievements in the different disciplines, in so far as they can be apparent just a few days after the completion of the mission. It will be several months before all film, samples and video recordings can be analysed and a more comprehensive scientific assessment made.

Material Sciences
More than 80% of the planned processing and experimentation (a total of 36 investigations) in this discipline was completed successfully. For the first time a large single crystal of silicon has been produced in space. Production of this crystal in the Mirror Heating Facility by the travelling-heater method turned out to be more difficult than anticipated, but was nevertheless very successful. The existence of Marangoni convection in space was demonstrated for the first time in the Fluid-Physics Module (FPM). This phenomenon, which may influence the production of flawless crystals even in zero gravity, is caused by differences in surface tension. It remains to be seen to what degree the quality of the space-grown crystal is degraded by this secondary effect. A lot was learned from the FPM, including the discovery of a new reformation mechanism for free-floating liquid zones, and unexpectedly slow demixing of oil and water in zero gravity. The behaviour of fluids in closed containers in zero gravity when subjected to rotation and vibration was investigated and this will help to achieve a better understanding of fluid sloshing in spacecraft carrying large quantities of propellant or cooling agent.

Figure 2 — Crew members Owen Garriot and Byron Lichtenberg conducting medical-science experiments, taking blood samples to determine changes in red blood cell and hormone concentration in weightlessness and measuring the central venous pressure.

Figure 3 — Crew members Robert Parker and Ulf Merbold carrying out a 'ballistocardiography' investigation in which the recoil acceleration resulting from bodily blood motion is measured with the help of supersensitive accelerometers.

Life Sciences

In this scientific domain the adaptation of the human body's vestibular and physiological systems to zero-gravity was investigated in detail. Here, the Spacelab-1 flight offered the first opportunity to carry out extensive life-science studies, thanks to the availability of the Mission and Payload Specialists, who underwent a long series of pre- and post-flight baseline medical data-collection examinations (Figs. 2 & 3).

The importance of the eye as a source of orientation in zero-gravity and the coupling between the eye and the vestibular system were studied. It was found that in weightlessness the eye takes over an important role in the human body's orientational system. In the course of these investigations it was found that after a few days of space adaptation, the occular reflex called 'nystagmus' can also be provoked in weightlessness. This reflex was previously assumed to be induced by convection in the inner channels of the ear, a theory that will probably have to be revised in the light of what was observed on Spacelab-1. A number of observations were carried out to investigate changes in spinal reflexes and postural behaviour in weightlessness.

The experiment on mass determination in space showed that the crew adapted more quickly to weightlessness than had been expected prior to the flight.

A number of biological studies were also carried out. One of them looked at the proliferation of lymphocytes in response to antigen injection. It was found that proliferation is considerably lower in zero gravity compared to 1 g conditions.

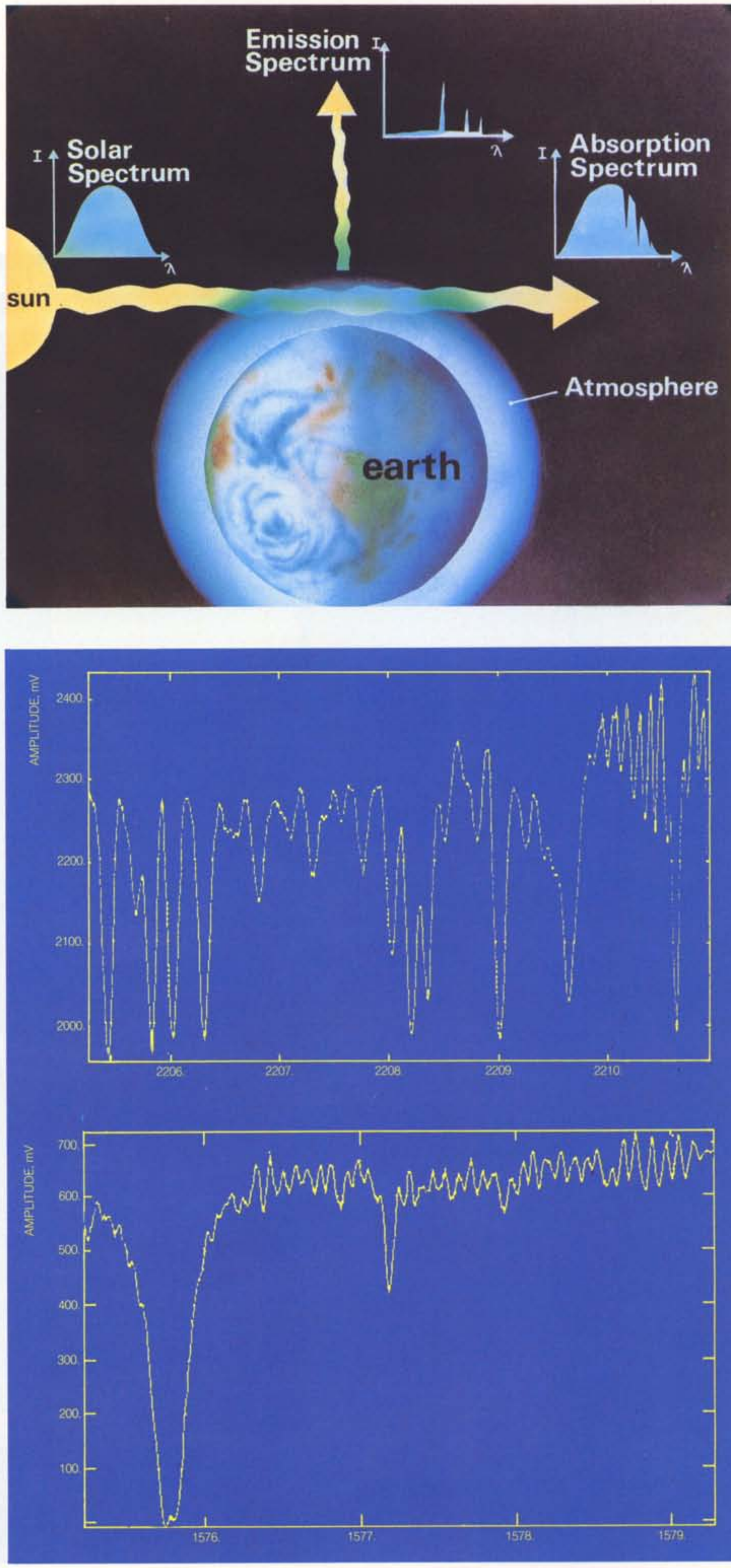


Figure 4 — Remote sensing of atmospheric composition was accomplished on Spacelab-1 by both absorption and emission spectroscopy. The Grille Spectrometer concentrated on absorption measurements. The top part of the figure illustrates the technique's principle in very simplified terms. The lower part shows absorption spectra obtained during the flight

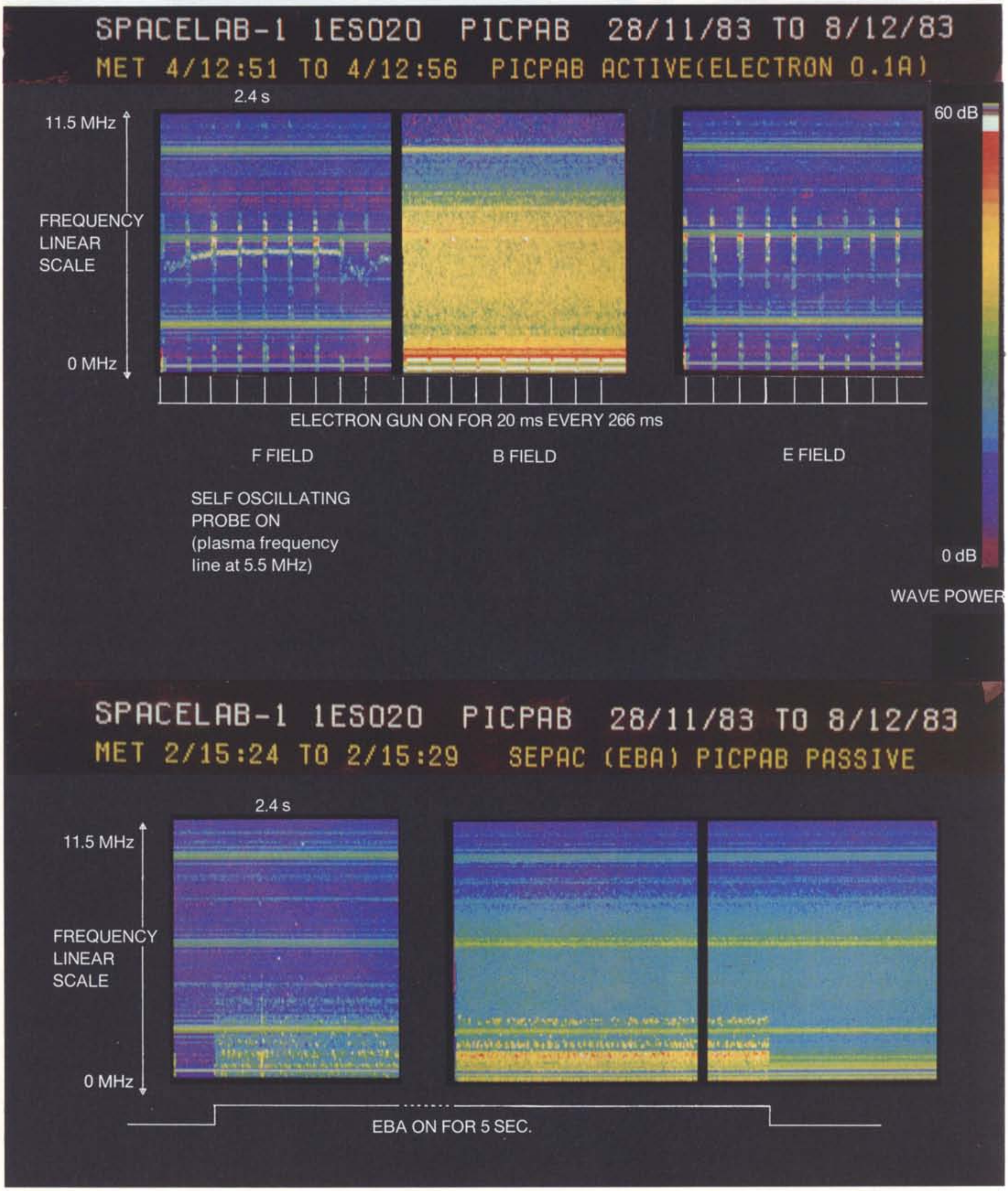
Atmospheric Physics

In the area of Atmospheric Physics, considerable new information was obtained during the mission and much more is expected from the offline analysis of the data gathered (Fig. 4). Various spectrometers on-board Spacelab allowed sensitive and accurate measurements to be made of minor atmospheric constituents. Despite their low concentrations, these constituents are of major importance for the chemistry and dynamics of our atmosphere. In this context the discovery of CO_2, H_2O and CH_4 in the mesosphere, the precise determination of the altitude profile for ozone, and the quantification of the amount of deuterium in the thermosphere are major achievements. Spacelab's remote-sensing instruments have measured atmospheric composition on a global scale with unprecedented accuracy and a basic set of reference measurements of the atmosphere has been obtained. Further flights will be necessary to monitor whether or not any long-term changes in composition are occurring due to the influences of industrial pollution, air traffic, etc.

Space Plasma Physics

An ensemble of four large instruments cooperated in carrying out active plasma experiments (Fig. 5).The modification of the ionospheric environment by the Shuttle itself and by particle beams, plasma clouds and neutral gas plumes was investigated. The charging and discharging of the vehicle was measured, the plasma ram and wake characteristics were determined, and the surrounding environment's response to beam injection was studied. Instabilities like the beam plasma discharge phenomenon were triggered and the acceleration of ionospheric particles in the artificially created instabilities (waves) was observed. In many instances the pre-

Figure 5 — Electrostatic and magnetic waves generated by the active plasma experiments on board Spacelab-1. Data are presented in three-dimensional plots showing wave frequency on the vertical axis, time on the horizontal axis and wave intensity by colour coding. The top panel shows the plasma wave perturbations induced by the (pulsed) PICPAB electron beam (100 mA, 8 kV). In the bottom panel, PICPAB, in a passive mode, is diagnosing the wave perturbation induced by the (continuous) SEPAC electron beam (0.3 A, 5 kV). The two electron accelerators were located on the Pallet and the wave measurements were performed by the passive package mounted in the Airlock.



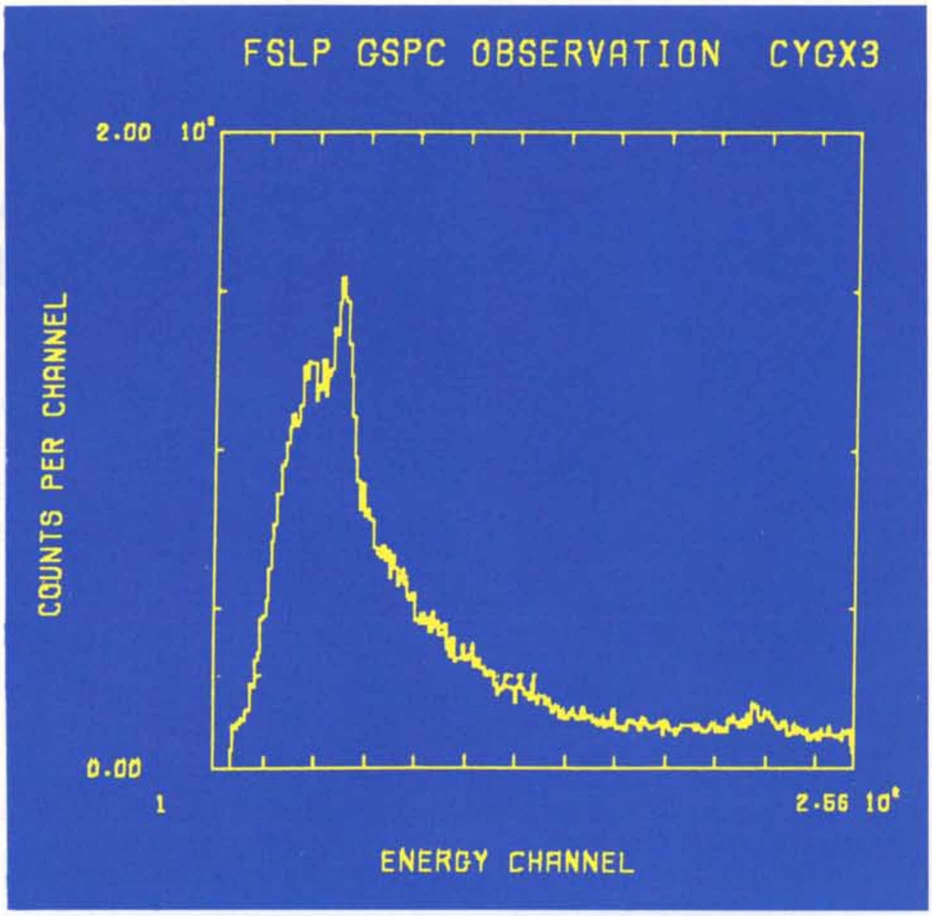


Figure 6 – 'Quick-look' energy spectrum from the galactic X-ray source Cyg X-3 as observed by the Spacelab X-ray spectrometer. These data were transmitted in real time to the POCC. The peak showing a line at 6.4 keV due to the flourescent radiation of iron is significant.

planned operational scheme could be changed in real time by the crew and Payload Operations Control Centre (POCC) interaction. Iterative science, in which the results from one experiment run were used to determine instrument settings for the next run was practised and the Shuttle/Spacelab combination turned out to be a really effective space plasma laboratory.

Earth Observation

Spacelab carried a Metric (photographic) Camera and a Microwave Remote-Sensing Instrument (MRSE). The Metric Camera's operations suffered to a certain extent from low solar elevation angles in the Northern Hemisphere in November, but the experimenters were extremely lucky in finding excellent weather conditions over most pre-selected targets. The Camera also benefitted from the successful troubleshooting by the crew, mentioned earlier. Close to 1000 good-quality photographs have been obtained. One example is shown on page 105. The MRSI experiment suffered a failure in its High-Power Amplifier (HPA) and could therefore only operate in its passive radiometric mode. The cause of the HPA failure is under investigation.

Solar Observations

Three solar instruments in the payload measured the radiation received from the Sun by the Earth, the so-called 'solar constant', with high precision. The benefit in performing these measurements from Spacelab stems from the need for post-flight instrument calibration. All of the instruments performed well. At the beginning of the solar-pointing period, strong absorption in the UV part of the solar spectrum was noted. This effect disappeared later and is attributed to the low solar elevation angle on day 8 causing some atmospheric absorption. Future reflights of these instruments are expected to discover whether there are any long-term variations or trends in the solar constant. Changes as small as 0.5% per century are expected to lead to considerable climatic anomalies on Earth.

Astronomy

Of the three Astronomy experiments on board Spacelab, two brought their data back on film. For these investigations good exposure opportunities were obtained. In the meantime, film from the European Very Wide Field Camera has been developed and it has been found that during sufficiently dark orbital nights the expected high-quality sky images could be obtained. The X-ray spectrometer (Fig. 6) worked well and obtained data complementary to Exosat observations. The detector noise, which depends on the cosmic-ray background radiation, was found to be a factor of three lower in Spacelab's orbit compared with the Exosat orbit. The Shuttle's pointing was of the required accuracy and the misalignment between Shuttle and Pallet was well within the specified limits.

Conclusion

All in all, the scientific success of this first Spacelab mission must be rated as high, despite the fact that this statement can be based only on the results that became apparent during the mission itself and on the quality of the observational and processing opportunities offered. The Shuttle and all Spacelab subsystems supported the payload well. The fact that only one TDRSS satellite, rather than the two originally planned, was available for data transmission did not jeopardise the science return at any point, thanks to the good working of the High-Data-Rate Recorder (HDRR). The latter was able to store all data on board when no data link was available, and to play it back at high speed at the next available opportunity. The skill and hard work of the crew were an important element, without which the scientific returns would have been considerably impaired.

It should also be noted that those experiments that had already been identified for reflight already prior to the mission did obtain valuable data, and that the total return from this November flight plus the reflight will be considerably greater than would have been obtained from a single flight in September or October this year.

It will be some months before the individual experimenters will be able to publish detailed results from the particular elements that made up the first Spacelab Payload. Only then will it be possible to judge the true scientific value of the flight in terms of new discoveries and their implications and benefits for the future.

Spacelab-1 Mission – Systems Performance

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ESA Directorate of Space Transportation Systems,
ESTEC, Noordwijk, The Netherlands

The successful completion of the STS-9/Spacelab-1 mission represented a convincing demonstration of the enhanced capabilities of the NASA Space Transportation System now available to users with the addition of the European developed and funded, reusable, modular Spacelab. Although the primary objective of the mission was verification of the Orbiter/Spacelab combination, a significant amount of science was also accomplished, as reported elsewhere in this Bulletin.

The main elements of the Spacelab system hardware and software from which the Spacelab-1 configuration was built were delivered to the NASA Kennedy Space Center (KSC) in Florida in December 1981 after an extensive integration, test and acceptance phase at the prime contractor's facility (ERNO) in Bremen, Germany. Delivery of these major Spacelab elements to NASA, accomplished by one USAF C5A Galaxy and one Lufthansa 747F aircraft, represented a major milestone in the Spacelab Programme.

Four Module experiment racks remained in Europe at that time for integration of the European Spacelab-1 Module experiments and subsequent checkout of these together with the European Pallet experiments.

After inspection in the Operations and Checkout (O&C) Building at KSC, the hardware entered the Spacelab-1 'ground-processing flow', through which it progressed during 1982 and the first half of 1983. This relatively long processing time had been planned from the outset to accommodate installation of the special nonstandard verification instrumentation provided by NASA and required for the first flight, and integration of the very complex ESA/NASA experiment complements with the basic Spacelab for the first time. A number of schedule margins were also included in the planning to allow for problems of the type that could be expected during the first flow.

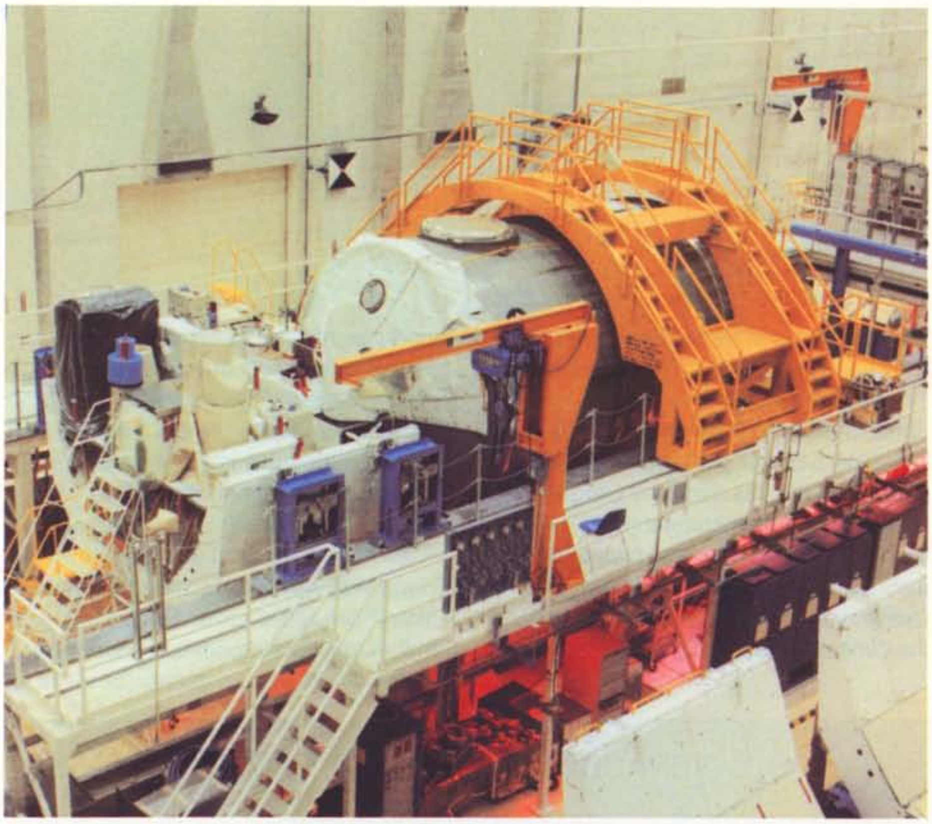
This conservative approach proved to be a sound planning basis and ensured that the fully integrated Spacelab-1 was ready for installation into Shuttle-Orbiter 'Columbia' in time to meet the planned launch date of 30 September 1983 (Fig. 1). Unfortunately, due to problems with the Tracking and Data Relay Satellite (TDRS) stationing and the Shuttle Solid-Rocket Boosters, the launch date had to be rescheduled for 28 November 1983.

Spacelab-1 ground processing

The ground-processing flow can be broken down into a number of major activity phases:
- Staging
- Level-IV integration
- Subsystem verification
- Level-III/II integration
- Level-I integration.

The staging process involves configuring the Spacelab experiment racks and the Pallets in readiness for installation of the experiment hardware. This was accomplished for the European experiment racks at Bremen during the second quarter of 1981 and for the NASA experiment racks and the Pallet at KSC during the first four months of 1982.

Level-IV integration comprises the installation and checkout of experiments into individual experiment racks and onto the Pallet. Level-IV integration of the European experiments was carried out in Bremen during the latter part of 1981 and the first half of 1982. The corresponding level-IV integration of the NASA experiments was carried out at Kennedy Space Center in Florida during the period April–August 1982.



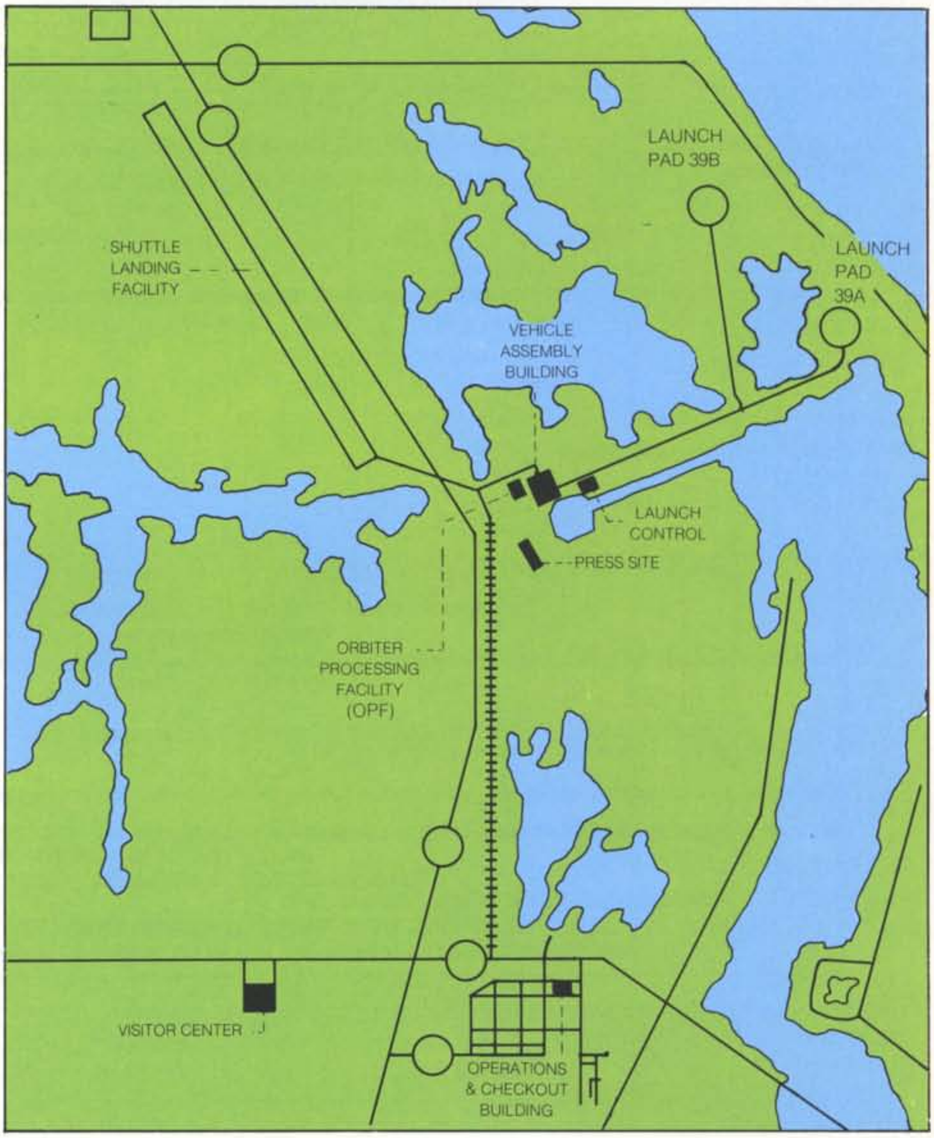


Figure 1 – Spacelab-1 fully integrated and ready for installation into Space Shuttle-Orbiter Columbia

Figure 2 – Map of the major Shuttle/Spacelab facilities at Kennedy Space Center (KSC)

For Spacelab-1 a combined ESA/NASA level-IV experiments phase had been planned. This took place during the period September–December 1982 at KSC, following delivery of the integrated ESA experiments from Bremen and the integrated NASA experiments from MSFC. This was the first time that the full Spacelab-1 experiment complement was tested together.

Subsystem verification involves configuration and checkout of the basic Spacelab subsystems prior to integration with the level-IV integrated experiment complement. For Spacelab-1 this was carried out in the O&C Building at KSC (Fig. 2) during the period May–September 1982, in parallel with the level-IV integration activities. It was the first time that Spacelab had been tested in a fully operational hardware/software configuration, as opposed to the generic test configurations used during the system integration and test phase in Europe.

Level-III/II integration comprises assembly and testing of the fully integrated Spacelab, including basic Spacelab subsystems, the full Spacelab experiment complement and the flight software. For Spacelab-1 this occurred during the period January–May 1983 in the O&C Building at KSC and included a mission sequence test, which was used to verify selected 'slices' of the in-orbit mission timeline.

Level-I integration covers the installation of the totally integrated Spacelab into the Shuttle-Orbiter and combined checkout of the Orbiter/Spacelab systems in the Orbiter Processing Facility (OPF), stacking of the Orbiter with the External Tank and Solid-Rocket Boosters (SRBs) in the Vehicle Assembly Building (VAB), and the final countdown tests on the launch pad.

For Spacelab-1 an additional level-I activity was scheduled prior to installation into the Orbiter. This was a Spacelab/Orbiter interface test performed in the O&C Building during the period June–August 1983 using the Cargo Integration Test Equipment (CITE). This equipment includes actual Orbiter flight avionics hardware and simulators and uses the Orbiter flight software to verify the Orbiter-to-Orbiter cargo functional interfaces. A closed-loop data and command flow test between Spacelab and the Payload Operations Control Center (POCC) at the NASA Johnson Space Center (JSC) in Texas was also successfully performed during this additional test phase.

Spacelab-1 was installed into the Shuttle-Orbiter 'Columbia' on 16 August 1983 and combined Orbiter/Spacelab systems testing and closeout was completed by 22 August. This phase included a total 'end-to-end' data and command flow test involving the experiments, Spacelab, the Orbiter, the Tracking and Data Relay Satellite (TDRS), and NASA ground stations and control centres.

The Orbiter/Spacelab combination was moved to the Vehicle Assembly Building (VAB) on 22 September for integration with the Shuttle External Tank and Solid-Rocket Boosters to form the STS-9 stack.

No Spacelab testing was performed in the VAB.

The STS-9 stack was moved from the VAB to launch pad 39A on 28 September and the countdown demonstration testing was completed by 10 October. It was then rolled back from the pad to the VAB following a NASA decision to replace the nozzle on SRB 9B. The Orbiter was demated from the stack and returned to the OPF whilst the nozzle change was carried out.

The joint ESA/NASA decision to commit Spacelab-1 to a 28 November launch was taken on 2 November by the ESA Director General and the NASA Administrator. The Orbiter was moved back to the VAB for restacking on 3 November. The rebuilt STS-9 stack was moved onto the pad for the second time on 8 November and, following a flawless countdown, lifted-off Pad 39A at 16.00 h GMT on 28 November for the planned nine-day mission.

STS-9/SPACELAB-1 MISSION STATISTICS

LAUNCH:	11.00 H EST (16.00 H GMT) 28 NOVEMBER 1983 PAD 39 A – KENNEDY SPACE CENTER, FLORIDA	
MISSION DURATION:	10 DAYS 7 HOURS 47 MINUTES	
LANDING:	15.47 H PST (23.47 H GMT) MAIN RUNWAY – EDWARDS AIR FORCE BASE, CALIFORNIA	
INCLINATION:	57°	
ALTITUDE:	240 KM	
TAKE-OFF MASS:	2 MILLION KG	
LANDING MASS:	100 THOUSAND KG	
SHUTTLE PAYLOAD MASS:	15 063 KG	
SPACELAB PAYLOAD MASS:	11 539 KG	
EXPERIMENT/ ASSOCIATED EQUIPMENT:	3982 KG	
EXPERIMENT EQUIPMENT VOLUME PRESSURISED:	22 M^3	
UNPRESSURISED:	33 M^3	
POWER CONSUMED BY SPACELAB/EXPERIMENTS:	AVERAGE	6 KILOWATTS
	MAXIMUM	8 KILOWATTS
ENERGY CONSUMED:	1400 KILOWATT HOURS	
DATA HANDLING:		
• TRANSMISSION THROUGH ORBITER/TDRS	UP TO 48 MBIT/SECOND	
• ON-BOARD STORAGE	UP TO 32 MBIT/SECOND	
• TAPE STORAGE CAPABILITY	3.8×10^{10} BITS	
• TOTAL DATA COLLECTED	2×10^{12} BITS	

CREW	RED TEAM	BLUE TEAM
ORBITER	J. YOUNG	B. SHAW
MISSION	R. PARKER	O. GARRIOTT
PAYLOAD	U. MERBOLD	B. LICHTENBERG

Mission time history

Spacelab-1 was activated on the pad at launch minus 24 h to provide limited power for essential services prior to launch (e.g. avionics fan in the low-speed mode; subsystem-inverter, freon and water-pump packages on). These services were to provide a fire-detection capability and to allow the Verification Flight Instrumentation (VFI) and experiments to function prior to launch.

One hour prior to launch, the freon-pump

Figure 3 – Spacelab-1 Mission Timeline. During the 10-day mission, more than 200 replanning requests and 800 operation changes were implemented

package was turned off, as planned, leaving only the fire-detection and VFI capability on for launch and ascent. Launch occurred at 11.00 h EST (16.00 h GMT) on 28 November 1983, within milliseconds of the start of the planned launch window. After achieving a circular, 240 km orbit inclined 57° to the equator, Spacelab activation was commenced 2 h 30 min into the mission and completed with nominal operation of all subsystems 2 h later. No back-up or redundant system elements were required to establish the system, except for the Spacelab telemetry downlink (PCM Master Unit) which had to be set to the back-up coupler due to an Orbiter PCMMU malfunction.

The overall mission timeline is shown in Figure 3 (including the bonus day). As mentioned previously, the primary objective of this mission was to verify the performance of the Spacelab system and its ability to operate as an integral part of the Orbiter system whilst supporting experiment/crew operations.

For this verification a large number of sensors (VFI) had been installed by NASA in addition to the standard flight instrumentation, and the flight profile was arranged to test the Spacelab system under all worst operating conditions, including maximum power and thermal loading, solar and deep-space pointing (Fig. 4).

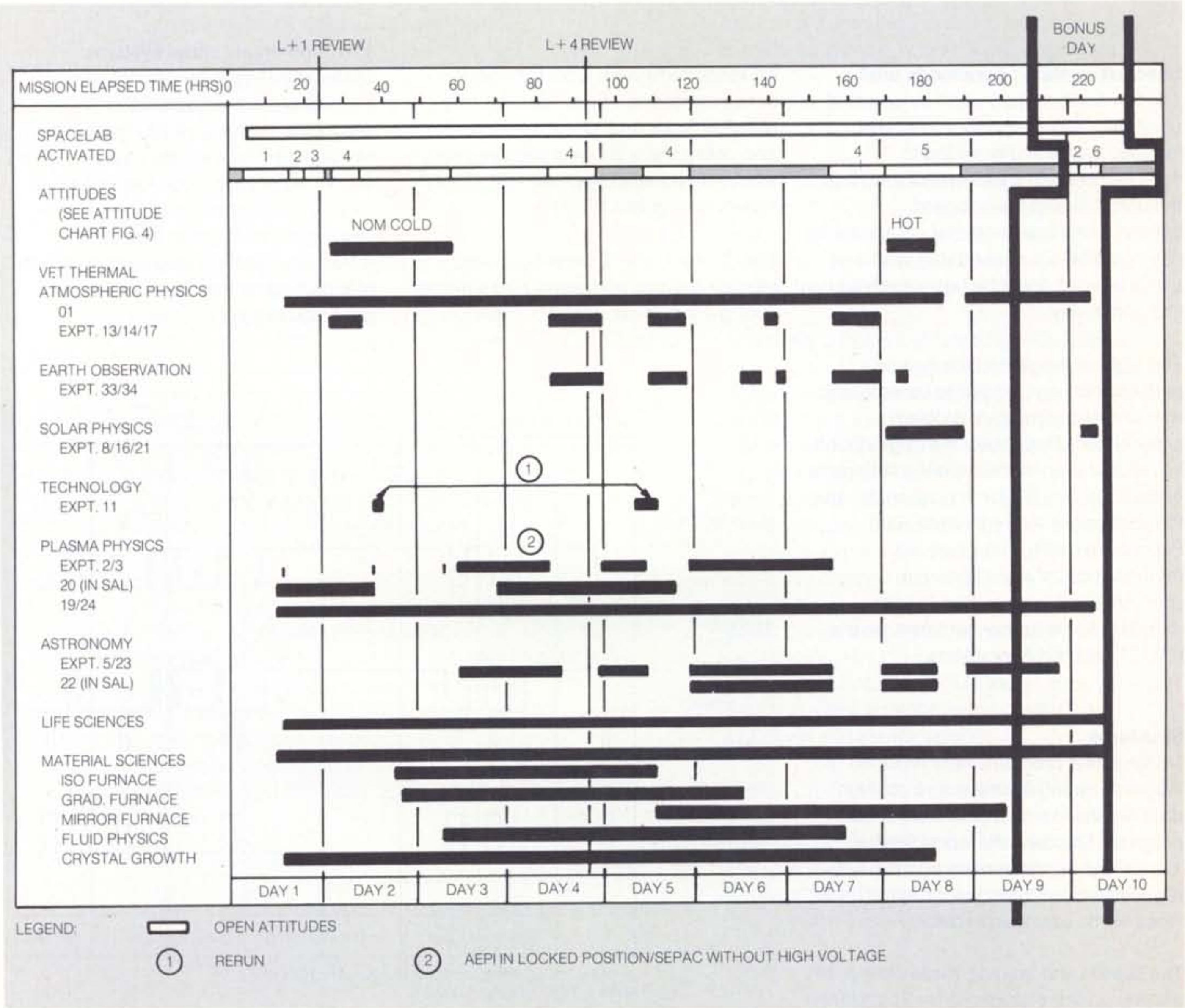


Figure 4 – Major Orbiter/Spacelab attitudes as indicated in the Mission Timeline. During the STS-9/Spacelab-1 mission, more than 200 attitude changes were made to accommodate both the Spacelab Verification Programme and experiment operation

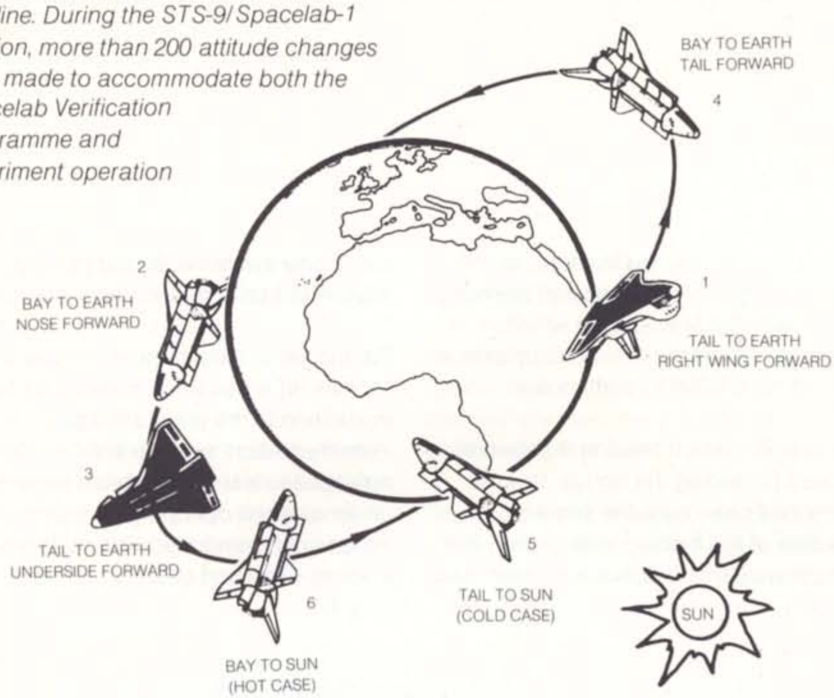
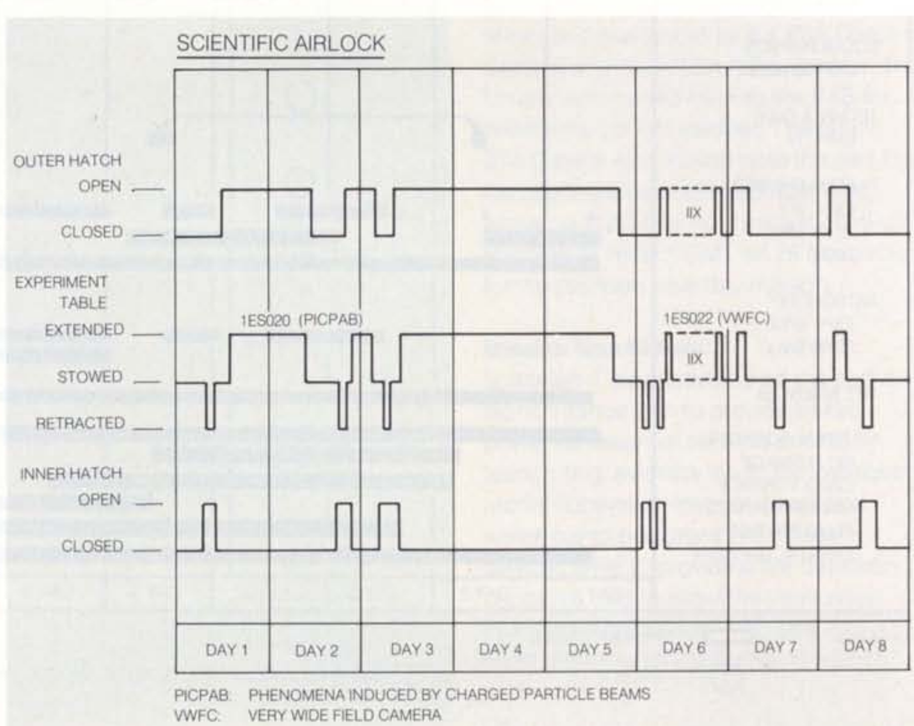


Figure 5 – Scientific Airlock operation during the mission



Spacelab system operation in orbit

The Spacelab system was fully powered up during the mission for 231 h. This includes the extra day added to the mission when it was established that the usage rate of the onboard consumables was such that an additional day could be accommodated, and that useful science could be performed during this bonus day.

Throughout this period the system's performance was judged to be excellent, with only two significant problems experienced. These were the degradation in the operation of the experiment Remote Acquisition Unit (RAU) in position 21, and the jamming of the High-Data-Rate Recorder (HDRR). The observed performances of each Spacelab subsystem are summarised below, including some further comment on the RAU 21 and HDRR problems.

Structures

No structural problems were reported or recorded during the mission. Post-flight data reduction and assessment is still in progress. The crew did report several 'bangs' during the mission and the data (Spacelab and Orbiter) recorded at these times will be assessed in detail.

The launch and landing loads were within the pre-launch predictions for Spacelab-1.

No loose items were reported after the crew's ingress into Spacelab. Subsequent post-flight examination of the air filters and debris traps showed that Spacelab was exceptionally clean, with an absolute minimum of debris found.

The Orbiter Cabin/Tunnel/Spacelab Module composite showed zero leakage during the mission.

The structural temperatures were also within the design assumptions for both the cold and hot operating extremes (shadow and full-Sun operation).

Scientific airlock

The scientific airlock operated faultlessly throughout the mission (Fig 5). It was de/repressurised six times, and the outer and inner hatches were opened and closed 22 times. The experiment table was moved in and out 23 times in support of two experiments and the hot and cold soak tests. No anomalies were recorded for this hardware.

Environmental control systems

System performance was nominal throughout the mission, with recorded parameters closely matching the pre-flight predictions. No anomalies were recorded for the water loop, freon loop, cabin air loop or avionics air loop. The passive thermal-control system (multilayer insulation blankets) also performed well, maintaining temperatures within the predicted ranges.

EXTRACTS FROM THE MISSION DIARY

Day 1 Orbiter payload bay pointed to Earth. Spacelab O_2/N_2 subsystem used to supply the total habitable volume of the Spacelab and the Orbiter. Crew enter Spacelab 3.5 h into the mission. First Scientific Airlock (SAL) operation performed. Problems discovered in the operation of experiment Remote Acquisition Unit (RAU) in position 21, but this unit not required by experiments immediately.

Day 2 Cabin temperature was lowered according to mission plan using the cold-case configuration for the Environmental Control Subsystem (ECS). The SAL was closed and repressurised. Orbiter attitude was changed so that the payload bay faced deep space for Spacelab cold test. SAL operated in cold environment. RAU 21 operated successfully, probably due to reduced temperature.

Day 3 Orbiter payload bay still pointing to deep space. Structure temperatures were not as low as predicted (10–20°C above prediction) for the cold case. SAL was retracted and the hatch closed. RAU 21 was still operating successfully.

Day 4 Experiment inverter actuated to support the life-sciences hop-and-drop experiment 104. Orbiter was manoeuvred from the cold attitude at end of cold test. RAU 21 problems recurred with increasing temperatures. The High-Data-Rate Recorder (HDRR) malfunctioned during operation, due to suspected mechanical jamming. Payload recorder used for data recording ($\leqslant$1 Mbit/s). Payload bay pointed to Earth. Extra mission day under discussion.

Day 5 Troubleshooting performed on the HDRR by crew. Blocked capstan drive freed and after fast forward/rewind operation HDRR returned to nominal operation. RAU 21 operation was in a degraded mode using uplinked software patches. Some errors detected on other experiment RAUs during the day. Condensate tank was dumped per procedure. Payload bay pointed to Earth again.

Day 6 Electrical power in the Module reduced as far as possible to reduce freon temperature on Pallet to lower RAU 21 operating temperature. Several SAL operations performed with the Very Wide Field Camera (Experiment 022). The extension/bonus day for additional science observations was decided upon.

Day 7 Airlock operations concluded for Experiment 022. Condensate tank was dumped again. RAU 21 continued to operate in reduced mode.

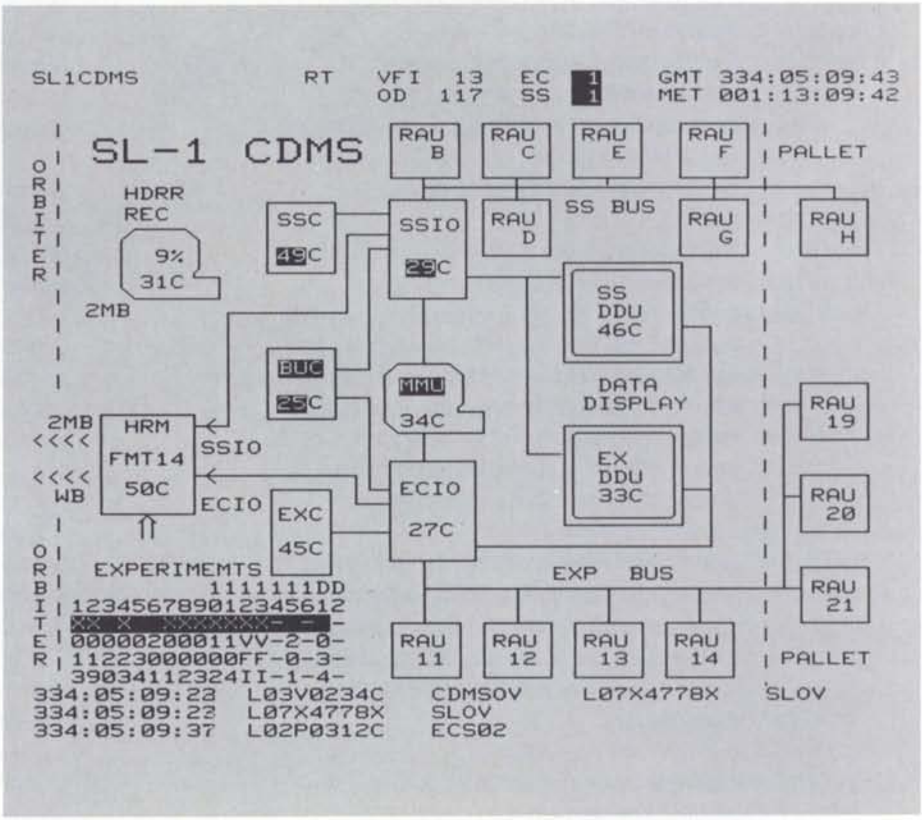
Day 8 Orbiter payload bay pointed towards the Sun and the ECS reconfigured for hot-case operation. The O_2/N_2 subsystem was switched to the redundant branch in order to check its performance. RAU 21 stopped operating due to the increased temperatures in the solar-pointing mode. Airlock operated during the hot test. Orbiter attitude changed to avoid overheating of the Imaging Spectrometric Observatory (ISO) experiment.

Day 9 Orbiter payload bay in Earth-pointing attitude. Completion of scientific objectives and additional unplanned experiments performed. Spacelab preparation for re-entry begins, including stowage of airlock.

Day 10 Additional checkout of Spacelab subsystems with check of O_2/N_2 function by reduction of cabin pressure, introduction of O_2, and monitoring of the resultant N_2 flow. Solar-pointing attitude for 4 h allowed additional experiment operations, checking of temperature profiles and RAU 21 operation. Orbiter attitude changed for normal Orbiter operation. Experiment computer software-controlled crash/dump and reload. Orbiter circulation-pump interference on Spacelab power quality checked. Attempt to troubleshoot RAU 21 by controlled gradual switch-off of RAUs on CDMS experiment data bus. Crew egress from Spacelab 9 d 17 h 5 min into the mission.

Day 11 Shuttle Orbiter lands at Edwards Airforce Base, California, at 15.47 h PST (23.47 GMT), 10 d 7 h 47 min after lift-off, five orbits later than planned, due to problems with two of the five Shuttle-Orbiter flight computers and one inertial measurement unit.

Figure 6 – Command and Data-Management Subsystem display generated in the Huntsville Operations Support Centre (HOSC) from real-time data received through the TDRS/NASCOM link. It indicates the on/off status temperature and out-of-limits situation for each equipment item. The data flow/downlink telemetry formats are indicated for the HRM, as well as the percentage of HDRR tape used. The top of the display shows real-time or alternate downlink path and time. The lower lines indicate the most recent time-tagged error messages generated in Spacelab.



Due to the negligible leak rate of the Orbiter/Tunnel/Spacelab combination, the O_2 and N_2 controllers in the cabin atmosphere control system were not called upon to operate fully during the mission. To verify their correct operation, a special test was successfully conducted during the bonus day.

The crew reported that the atmosphere in the Spacelab Module was very fresh, and the temperature cool and comfortable. Relative-humidity levels were below 40% throughout the mission and no local condensation was observed.

Electrical power distribution system/System activation and management

System performance was nominal throughout the mission, including the extended power-up phase prior to lift-off and subsequent to landing, and no anomalies were recorded in the system itself. To accommodate an experiment anomaly, the inverter configuration was successfully changed twice during the mission.

The Module lighting was adequate for crew operations and closed-circuit TV. The fuel cell provided by the Orbiter supplied input voltages of 30–32 V to Spacelab, which was 2–4 V higher than predicted. Voltage drops through the Module and Pallet were as predicted. The power consumption by subsystems and experiments was 1.2 kW below pre-mission estimates.

Command and Data Management System (CDMS)

Operation of this complex integrated system was judged to be extremely good throughout the mission (Fig. 6). A number of transient Data Display System (DDS) anomalies were reported and/or recorded during the mission. In each case the problems could be traced to other parts of the system and the DDS could be easily restored by the crew. No anomalies were recorded in the onboard computers, input/output units or the mass memory unit. No use was made of backup systems. The High-Rate Multiplexer/Recorder performed excellently. The HDRR was used much more than originally envisaged due to the fact that there was only one TDRS in orbit. Some data overflows in the HDRR input channel of the HRM were experienced. These will be investigated post-mission.

Nine hours and ten minutes into the mission, RAU 21 exhibited a data-transmission problem (skip bit set), which resulted in the temporary loss of experiment data through this RAU (Fig. 7). This problem recurred throughout the mission in one form or another (Fig. 8). Extensive investigations were performed on the ground to try to establish the cause of the problem. Although these were not conclusive, a number of 'software patches' were uplinked to the onboard computers and these resulted in maintaining degraded performance through this RAU for the majority of the mission. In addition, some actions were taken to maintain the temperature at the freon cold-plate input of the RAU below 22°C, this appearing to be some kind of trigger to the onset of the problem. After the mission, the RAU was removed and subjected to bench testing at KSC. It performed satisfactorily in all of the standard bench tests, although a problem could be induced by running a special test at elevated temperatures with the throughput of continuous analogue data. Investigation of the RAU interface to the cooling system is continuing.

Eighty-six hours into the mission the High-Data-Rate Recorder exhibited a sharp increase in motor current and was powered down immediately. Investigations were initiated on the ground and these led to the implementation of an inflight maintenance procedure by the crew, who checked the various capstan drives and rollers within the recorder for jamming. In executing this procedure, the crew found that the delta drive capstan was stiff (Fig. 9). Manual rotation freed the

Figure 7 – The problematical experiment RAU (serial number 15, address 21) was mounted on a cold plate on the Pallet, connected to the freon loop. Next to it were a subsystem RAU, an experiment power-distribution box and a stack of four interconnecting stations. All units were covered by a tent of thermal-insulation material. The adapter plates and the thermal filters are visible on the left

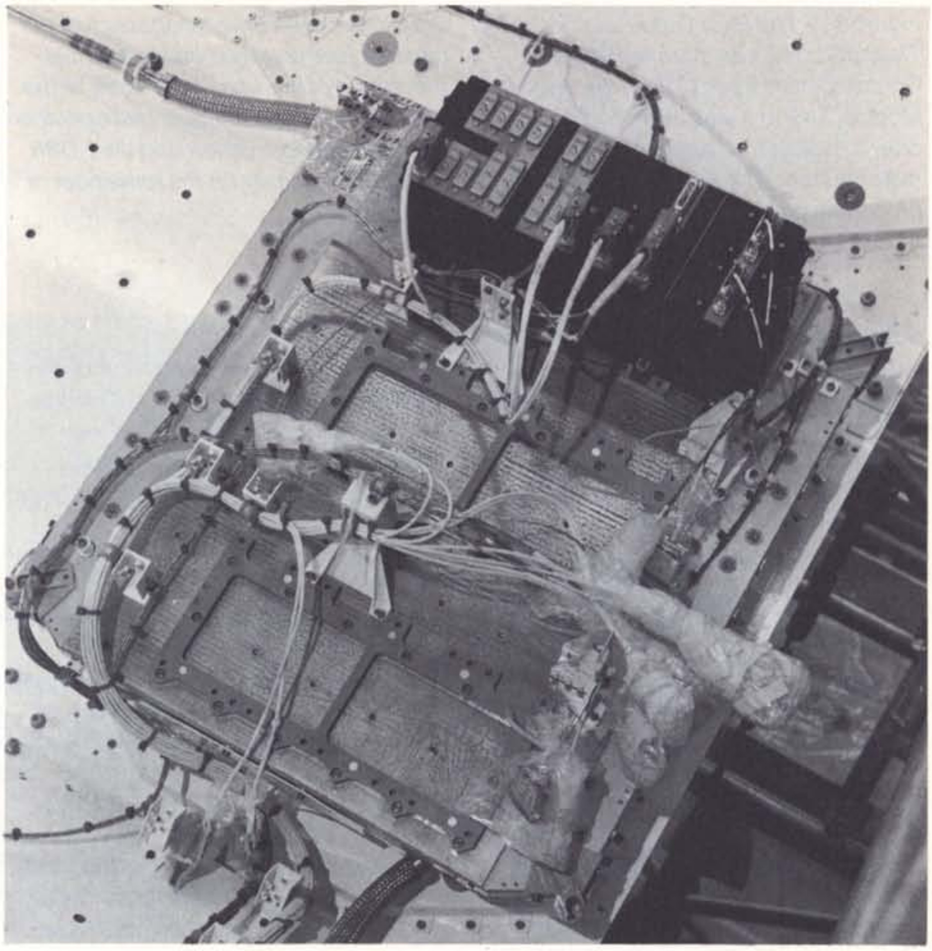
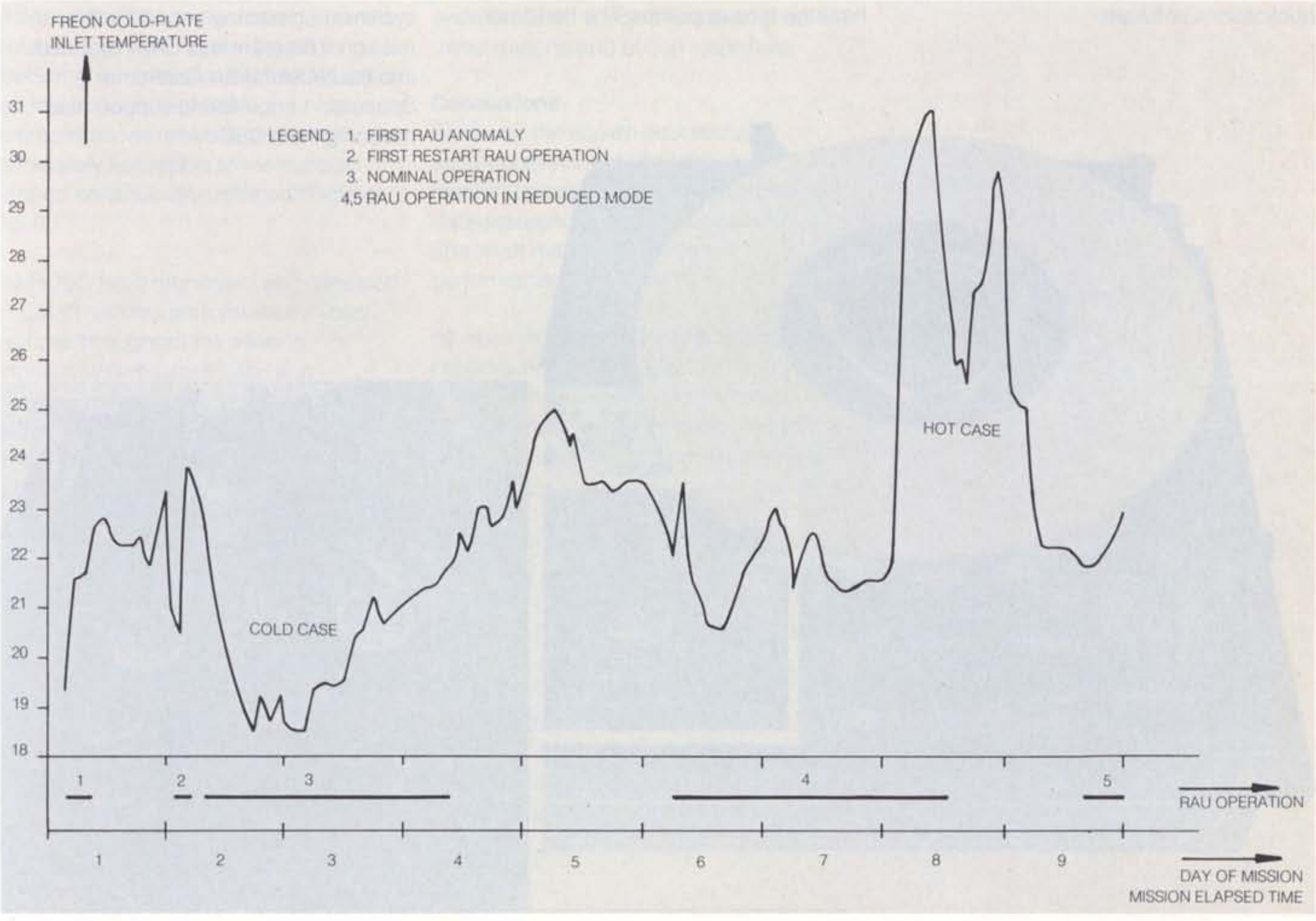


Figure 8 – Experiment RAU 21 operation as a function of Mission Elapsed Time (MET) and the freon cold-plate inlet temperature at the Pallet



blockage and the recorder was successfully brought back into full operation 12 h after the failure. The recorder has been returned to the supplier for investigation.

Software

Subsystem Computer Operating System (SCOS) software performance was nominal throughout the mission. A number of minor problems were encountered with the Experiment Computer Operating System (ECOS) software, but these were corrected by software patches or procedural changes. The crew objected to the time some of the experiment displays took to appear on the screen of the Data Display Unit (up to 30 s), this being a function of how the CDMS is used, the limitation of the onboard mass-storage medium and the amount of computer memory available for applications software.

Intercom system

There were no anomalies recorded with this system during the mission. The crew did, however, criticise the limitations imposed on crew operations by the Spacelab intercom system. It may require improvement to monitor more than one voice loop simultaneously.

Caution-and-warning, fire-suppression and smoke-detection system

The system operated correctly throughout the mission, with no reported onboard anomalies. No fire/smoke alarms were triggered.

Crew habitability

The crew reported that the general noise level was very low in the Module. The recorder was noticeable during fast wind operations, but only in the immediate neighbourhood of its rack. They could not hear the fans or pumps. The hand-rail locations were regarded as excellent, with the ceiling rails being especially beneficial. The crew's primary method of locating items was Velcro, and they have requested more Velcro on board for future missions. At times all six crew members were in the Module together and it was clearly quite large enough to accommodate this number of people. The ceiling containers and rack stowage containers operated very easily indeed. The onboard tool kit was regarded as adequate. Surface finishes/colours were regarded as fine and the crew liked the controls and displays.

European mission support

A combined ESA and ERNO Consortium team of some 60 engineers was located in the Huntsville Operations Control Center (HOSC) at MSFC throughout the mission to provide around the clock Spacelab systems-engineering support to the mission. This team was fully integrated into the NASA/NASA-Contractor Spacelab-1 engineering support team manning the HOSC.

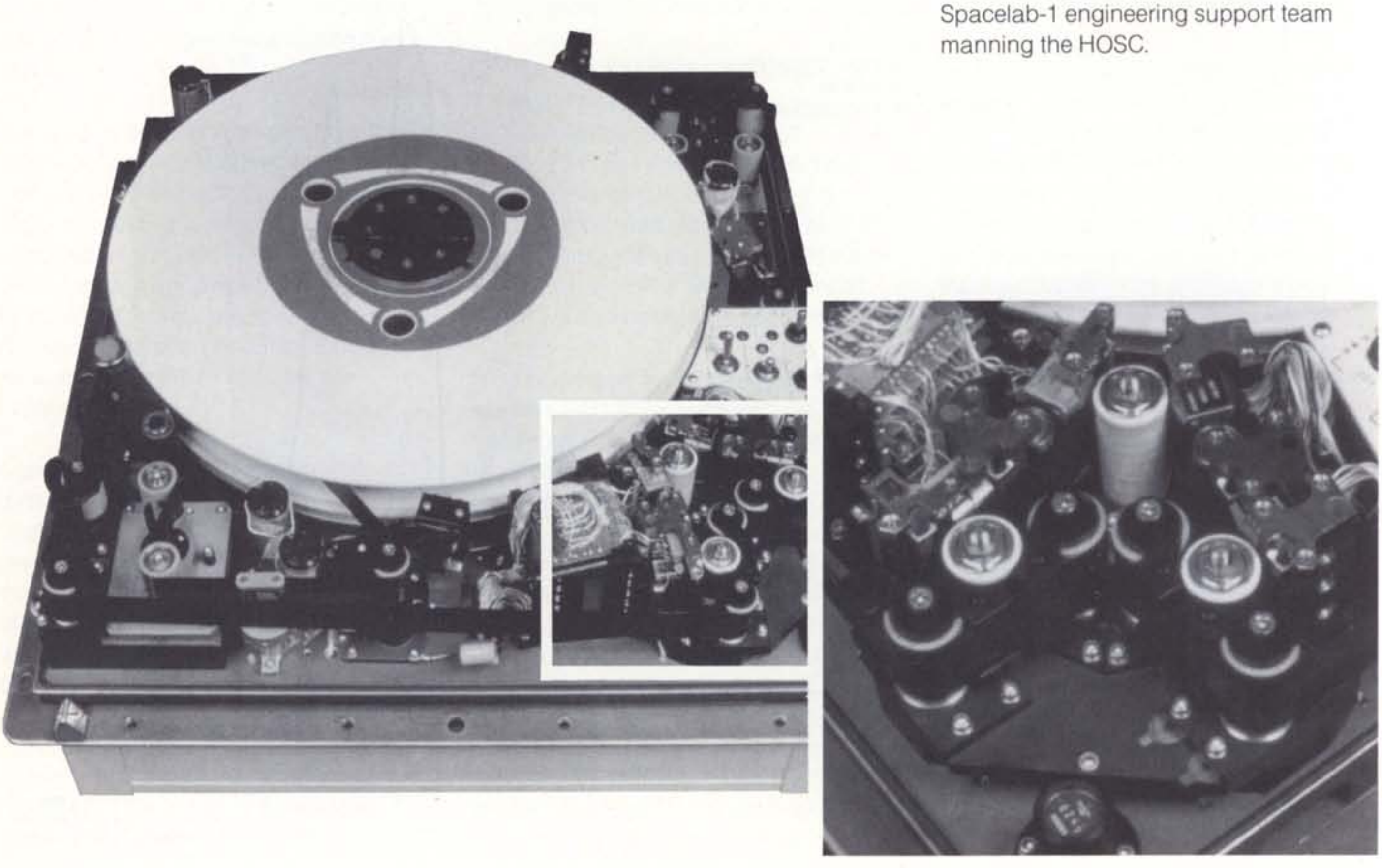


Figure 9 – The High-Data-Rate Recorder Transport Unit was mounted in the Control Center Rack CCR in the Spacelab Module. This unit was examined by the crew to isolate the cause of the high motor current. The inflight maintenance procedure pinpointed the mechanical drag in the delta drive mechanism of the capstan (see enlarged detail). Manual movement of the white inner roller of the delta drive and subsequent fast operation removed the obstruction and the HDRR operated nominally for the remainder of the mission

STS-9/SPACELAB-1 MISSION FIRSTS

The STS-9/Spacelab-1 mission was characterised by many significant firsts in spaceflight history:

- Spacelab-1 carried more experiments (70 total) than any other single mission.
- It carried the largest crew complement (six) of any manned spaceflight.
- It was the first manned US flight with a non-American crew member.
- Spacelab-1 was the heaviest payload (15 063 kg) yet carried into orbit and returned to Earth by the Space Shuttle.
- Spacelab-1 carried more experiments, in terms of payload weight, than have been carried on all ESRO/ESA satellites combined in the last 20 years.
- Full Orbiter/Spacelab ground and in-orbit operations were conducted around the clock throughout the mission.
- There was direct voice communication between crew and the Principal Investigators.
- It was the first Shuttle flight to be flown at 57° inclination to the equator.
- It was the longest Shuttle flight to date.
- It was the Shuttle's most demanding mission in terms of power, heat rejection, attitude manoeuvres, payload weight and communications.
- Spacelab-1 used the highest downlink data transmission rate to date (48 Mbit/s), resulting in the return to Earth of 20 million TV frames and 2 trillion (2×10^{12}) bits of data.

All Spacelab onboard systems data were routed to the HOSC in real time during TDRS or ground-station signal acquisition periods, through the NASA communications network, and were immediately accessible to the support team via continuously updated displays (Fig. 6).

The HOSC team monitored and assessed Spacelab systems performance in near real time throughout the mission. Onboard systems anomalies and problems were analysed, and appropriate recovery actions passed to the JSC flight-control team in the Mission Control Center for uplinking to Spacelab.

In addition to the HOSC team, three ESA Project Team representatives were located in the Mission Control Center Customer Support Room (CSR) at JSC throughout the mission. This small team, together with three representatives from the MSFC Spacelab Program Office, manned the Spacelab Systems Console in the CSR around the clock. They were responsible for controlling the interface between the JSC flight-control team and the HOSC support team in respect of all Spacelab-system-related support requests, problem investigations and action responses.

Conclusions

Based on the known successful accomplishment of all of the major mission objectives and the engineering data assessed to date, it is clear that Spacelab met all of its systems performance requirements.

All initial indications are that Spacelab provides an excellent platform and working environment, in its manned Module/Pallet mode, for performing a wide range of scientific investigations in all the major space-science disciplines.

Verification of the unmanned Spacelab Pallet-only mode and Instrument Pointing System (IPS) is now awaited. Full verification of the total Spacelab system will not be achieved until successful completion of the Spacelab-2 flight, currently planned for the first half of 1985. Only then will the full scientific potential of the reusable modular Spacelab concept be fully realised.

Cooperation in Space: 20 Years After*

Prof. Massimo Trella, ESA Technical Director and Director of ESTEC, Noordwijk, The Netherlands

It is a great honour for me to be here today and to present some considerations on the theme of this 34th IAF Congress. These considerations are certainly biased, since like many of you in the audience I have had the privilege, for more than 20 years, of being part of a wide international community, with similar educations and common motivations, working together for the exploration and exploitation of space. It has certainly been a very exciting experience.

Firstly, I must express my gratitude to the IAF for the very valuable role it has played and continues to play in promoting and stimulating space cooperation; for quite some time the IAF provided the only opportunity for scientists and engineers from all parts of the World to sow the first seeds for and to exchange ideas on some of the most important initiatives in space. Also, we should not forget that cooperation in space was not the obvious solution: the ΔV that separated us from space was spanned as a result of the 'race' in the 1950s, and this could have rendered space an arena exclusively for competition and confrontation. Instead we can claim fairly that the degree of cooperation has grown and broadened steadily and surely and perhaps much more readily than in many other spheres of scientific and technical endeavour. This positive outcome can be attributed both to the wisdom of the people who inspired the major decisions, and to the scale of the problem in hand. In the course of this address I would like to stress this aspect because it puts the future of cooperation in space on very solid ground and can also provide a useful indication of the form that cooperation in the next decades should take. If it is true that scale dictates cooperation, then we can use as a first indicator of the value of a venture the number of professional people who feel attracted by the chosen objective and actively contribute to its achievement.

If we look back over the past 20 years, cooperation in space has taken the form of ventures that have transcended national boundaries through the joining together of scientists and engineers of different nationalities to work on *specific* projects, either through one-off bilateral or multilateral agreements, or within the framework of an international organisation such as ESA. The European Space Agency can claim a particular place in the history of space cooperation, since it is an institution formed with the sole aim of fostering cooperation in space research, space applications and space technology: 11 European nations are permanent Members of ESA, two are Associate Members and one has Observer status, and ESA in turn cooperates with other nations on specific projects.

This week* we are just six months away from the anniversary of 20 years of joint European endeavour in space. The beginnings of European cooperation in space research can be traced back to April 1959, when a few eminent scientists first talked together about collaboration on artificial Earth satellites. In January of the following year, at a COSPAR meeting in Nice, further discussions on the possibilities of a cooperative European effort in space research were held with

* Invited Lecture to the 34th Congress of the International Astronautical Federation (IAF), Budapest, Hungary, on 10 October 1983.

Figure 1 — Participants of the Intergovernmental Conference at Meyrin, near Geneva, in November 1960.

other scientists. In April 1960, at the invitation of the Royal Society, a meeting in London was attended by scientists from 10 European countries.

These various discussions culminated, in June 1960, in the formation in Paris of the study group known as the 'Groupe d'Etudes Européen pour la Recherche Spatiale' (GEERS). Its task was to consider the establishment of a preparatory committee to investigate a joint European programme in space research.

As a result of the work of that study group, an Intergovernmental Conference was called at CERN's premises at Meyrin, near Geneva, in November 1960. On the last day of that Conference, the 11 participating nations signed the 'Meyrin Agreement', setting up the 'Commission preparatoire européenne de Recherches spatiales' (COPERS).

Its primary function was to prepare a draft Convention for a European Organisation for Space Research, including a scientific and technical programme, a budget and rules and regulations for the calculation of contributions and the decision process, including the rights and obligations of the partners.

The agreement on COPERS entered into force in January 1961, and while it was originally intended to last for only one year, it was extended several times and COPERS continued in existence until the European Space Research Organisation (ESRO) came into being on 20 March 1964. A few weeks earlier, on 29 February 1964, the European Launcher Development Organisation (ELDO) had been created for the development of European launchers. ESRO and ELDO were the forerunner organisations of ESA, which came into being in May 1975.

It was appropriate to mention the long birth cycle of our organisation, almost five years, in order to underline the fact that the faith of a few illuminated people was stronger than the scepticism of many others, given the great complexity associated with large-scale cooperative efforts. Cooperation introduces additional problems and many considered our goal an impossible task! Today the results can be measured by the successful completion of 12 scientific satellites, six applications satellites, and an operational launcher. We are currently very close to two further important dates for ESA, (i) the first purely commercial launch by Ariane of Intelsat-V (F7) on 18 October, and (ii) the flight of Spacelab aboard the Space Shuttle in October/November as the result of a major, exciting and rewarding cooperative programme between ESA and NASA.

Twelve projects are currently underway within the Agency and another ten are being studied as possible future projects.

Looking back over the past 20 years, there are always two particular moments in our cooperation in difficult endeavours that it is important to remember: the solidarity that manifests itself on occasions of failure and helps in overcoming the disappointment, and the enthusiasm that pervades at the moment of success! Our emotions at the launching of the first ESRO satellite in May 1968 for study of the ionosphere and magnetosphere, the excitement of the Cos-B venture in 1975 for gamma-ray astronomy, the receipt of the first images of the Earth from Meteosat, the

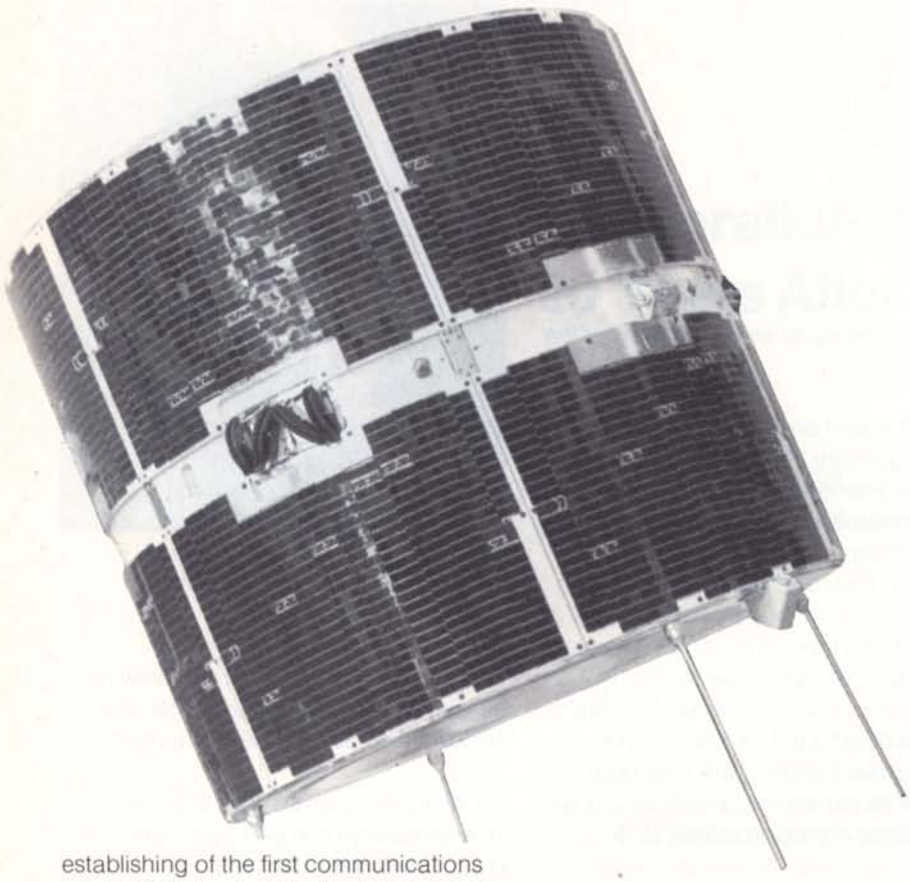


Figure 2 – ESA's Cos-B satellite

Figure 3 – ESA's Giotto spacecraft

establishing of the first communications link by OTS, the first lift-off of Ariane, and our expectations for the Exosat mission all spring to mind. They are very similar, I am sure, to those felt by many of you during other equally important cooperative ventures. All mark important chapters in the history of the past 20 years.

In the time available here, I would like to touch on two examples of recent cooperative initiatives that, in my opinion, have important implications for future cooperation.

The first is a current space project that has already captured widespread interest among scientific and technological researchers alike, not only in the Member States of my own Agency, in Japan, in the United States and in the USSR, all of whom are directly involved in the project, but around the World. I am speaking, of course, of the Halley exploration and the planned fly-by mission to comet Halley in 1986. More than 20 nations are now involved in this cooperative venture – the USSR and several other eastern European countries, including Hungary, and Austria, through Intercosmos; Japan through its Institute of Space and Aeronautical Science (ISAS); the USA through its National Aeronautics and Space Administration (NASA); and the 11 countries involved through their membership of ESA.

The European Giotto mission, the USSR's Vega-1 and -2 missions, and the Japanese Planet-A mission are all post-perihelion comet fly-by missions and all encounters with the comet will take place in March 1986. Many aspects of mission planning, spacecraft and experiment design and data evaluation are common to all missions. The cooperative nature of the approach, with the setting-up of an efficient, worldwide organisation for coordination of the international effort – 'The Interagency Consultative Group (IACG)' – is playing an essential role in maximising the chances of success for this difficult space endeavour. The IACG meets annually and informally coordinates all matters relating to the space missions to Halley's comet, and has formed three Working Groups.

Through Working Group 1, the World's leading comet scientists are working together to understand, model and quantify the cometary environment. Their results are enabling the engineers to evaluate the probability of spacecraft survival. This has a direct impact on the mission planning for all four spacecraft and will allow the various investigators to optimise their experiment designs, and thereby increase the overall scientific return for all concerned.

Working Group 2, the plasma-science working group, is evaluating the unique possibilities provided by six spacecraft travelling close together in interplanetary space, in a novel 'constellation'

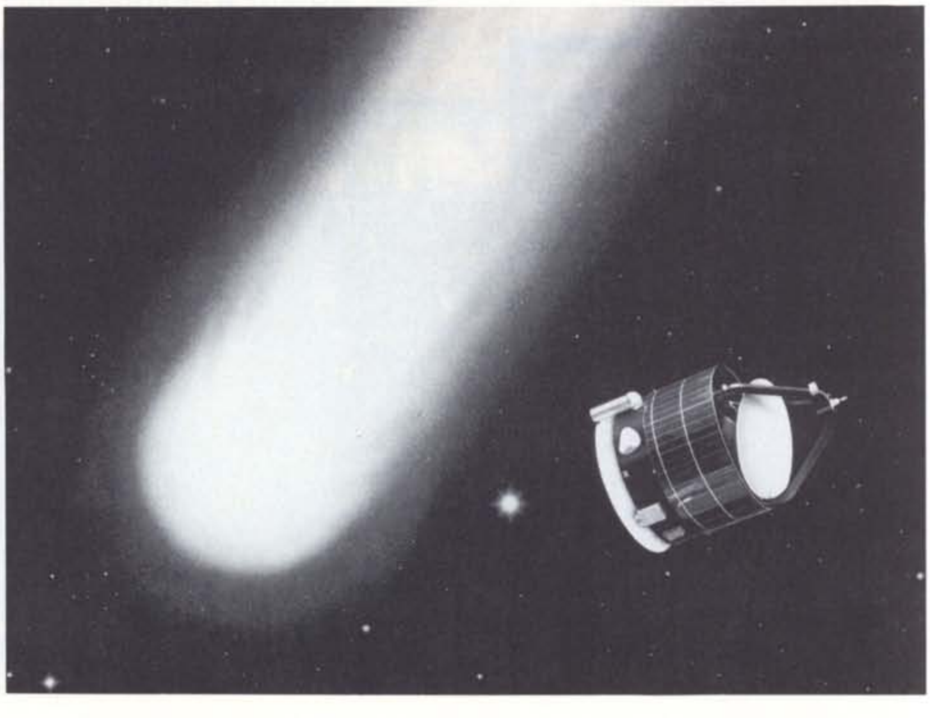
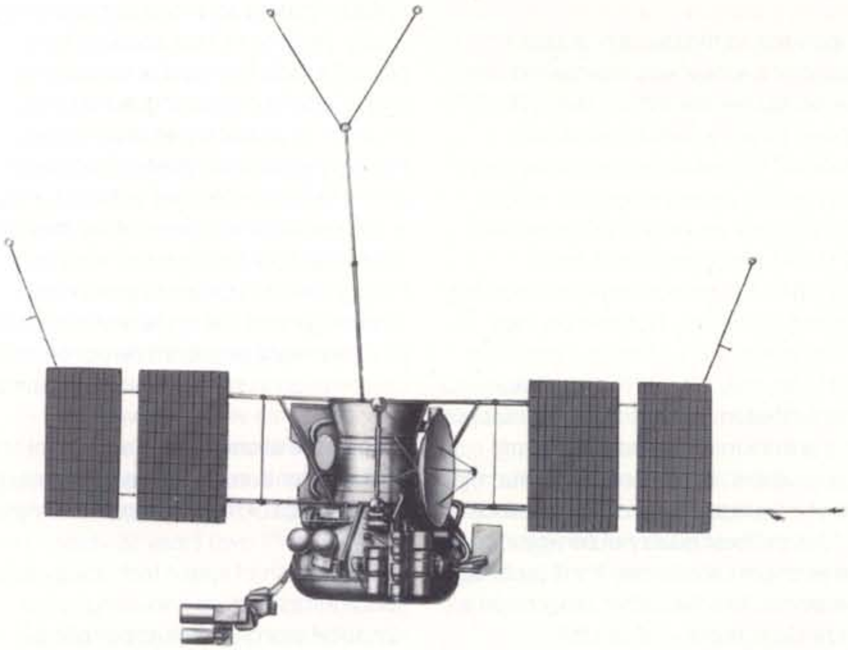


Figure 4 – The USSR's Vega-1 spacecraft

configuration. It will also undertake a collaborative effort to try to understand any adverse effects of the impact-generated plasma that will surround the spacecraft (generated by the high-velocity dust/gas impacts).

Working Group 3 is concerned with spacecraft navigation and mission optimisation. With the so-called 'pathfinder concept', Vega-1 will attempt to establish the position of the nucleus within the cometary coma so that Giotto's course can be corrected to pass very close to the nucleus. A determined attempt will be made to optimise the scientific return from the various missions through data exchange, under the aegis of Working Group 3.

The in-situ observations of the various spacecraft in the cometary environment will be complemented by a worldwide network of ground-based observations. This global effort, called the 'International Halley Watch' (IHW), is supported by 727 professional astronomers from 43 countries, involving all the major ground-based telescopes.



This vast cooperative effort for Halley's visit is an extremely good example of evolving wider scientific cooperation in the pursuit of scientific achievement, compared with many of our earlier projects. It not only proves once more the dynamism and creativity of the scientific community, but it also demonstrates how effective a cooperative effort can be, given a clear and concrete objective and a firm date to which all plans have to be anchored, in Giotto's case the comet's perihelion passage in February 1986 – the next passage is 76 years later, unless Halley is frightened off by the impressive fleet of terrestrial ships awaiting it this time and never shows up again!

My second example of recent cooperative initiatives is ESA's participation, with its Meteosat spacecraft, in the Global Weather Experiment of the international Global Atmospheric Research Programme (GARP). Founded through an agreement reached in October 1967 by the World Meteorological Organisation (WMO) and the International Council of Scientific Unions (ICSU), the GARP must still be considered one of the most complex and ambitious cooperative efforts yet undertaken.

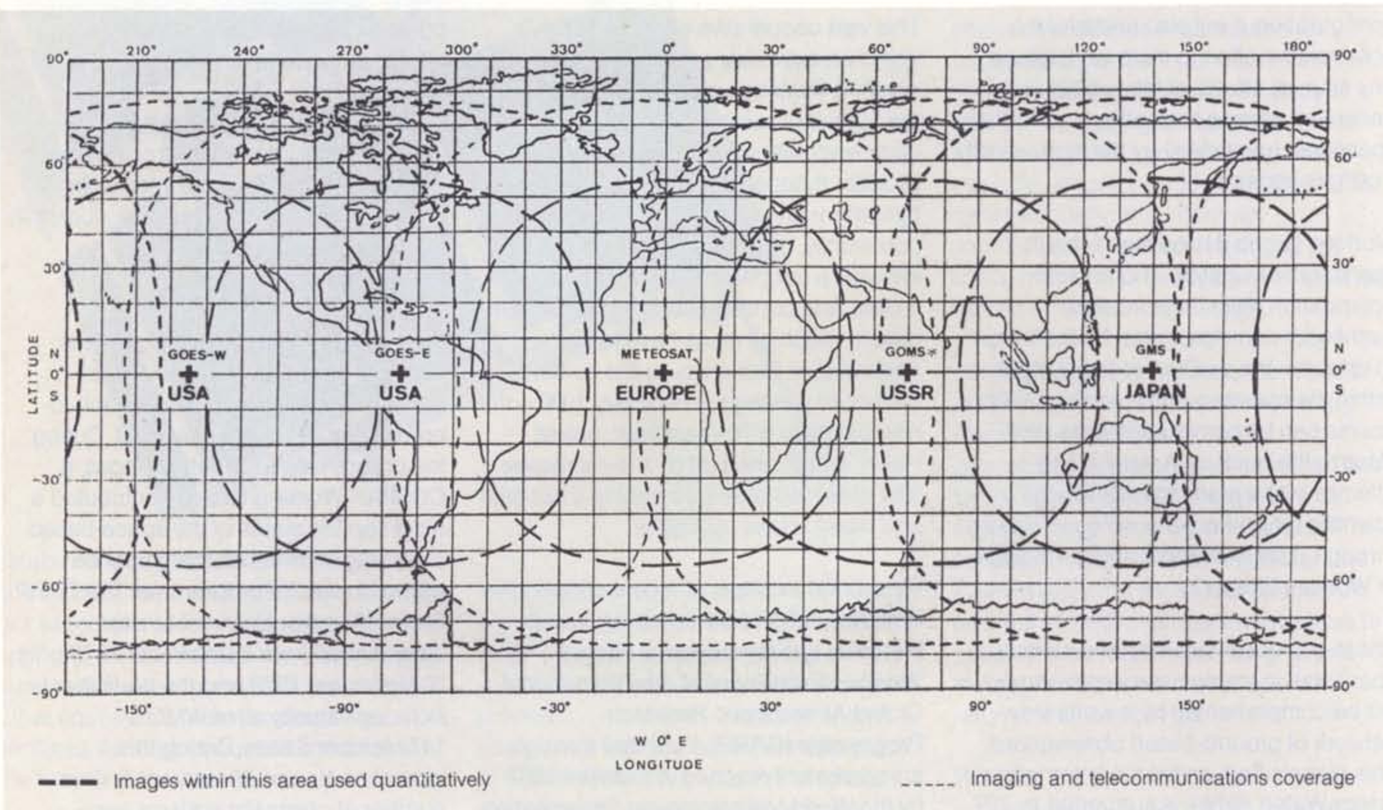
It serves as a shining example of how a governmental international organisation and a non-governmental international organisation can collaborate successfully for our mutual benefit and the advancement of science.

The main goal for the GARP was the eventual formulation of a model of atmospheric behaviour from which to predict global weather patterns. During the programme's formative stages, a COSPAR Working Group contributed a report on the status of the space-based observing techniques that might be utilised in such a programme. The GARP Global Weather Experiment was 'operational' from 1 December 1978 until 30 November 1979 and the participants included virtually all of WMO's 147 Member States. During this 'operational year' an unprecedented number of observing systems were deployed around the World to provide the most effective data set yet acquired for use by atmospheric and oceanographic research groups.

Some of the major sources of data were:
- the normal World Weather Watch surface-based stations providing routine information
- four polar-orbiting meteorological satellites
- five geostationary meteorological satellites
- special aircraft, releasing parachute-borne instruments
- specially deployed ships
- free-floating high-altitude balloons
- buoys drifting in the ocean
- commercial aircraft and ships equipped with meteorological and oceanographic instruments.

The system of five spacecraft in geostationary orbit, more or less equally spaced around the equator, provided a global view of the Earth, with only the polar regions excluded (the latter being

Figure 5 — Coverages of the geostationary spacecraft involved in GARP, Global Weather Experiment, from 1 December 1978 until 30 November 1979



covered adequately by polar-orbiting satellites).

This system was a World first when it came into use for the operational year, with the three GOES spacecraft provided by the USA, the GMS spacecraft provided by Japan and Meteosat by ESA. Although provided by different nations and organisations, the system as a whole was coordinated successfully so that the services were compatible even though the spacecraft themselves differed somewhat in technical detail.

The global system of geostationary meteorological satellites in operation throughout the World's first Global Weather Experiment demonstrated not only the practicality of generating, processing, distributing and storing satellite images routinely, but also that such large-scale cooperative efforts can more than repay the extra organisational effort needed to get them started and to bring them to fruition.

I would like now to try to examine possible future trends in space cooperation, considering some of the most important domains separately.

Cooperation in the domain of space applications is now well established. We have worldwide institutions like INTELSAT for point-to-point communications, INMARSAT for maritime communications, and WMO for meteorology. On a more regional scale, we have institutions like EUTELSAT for communications, EUMETSAT for meteorology, and several other organisations. Not only do they provide services on a nondiscriminatory basis to all, they also offer equitable opportunities to the partners to contribute to the definition and procurement of space systems. We can envisage that this form of cooperation will continue, since it provides the best quality of service in the most economical manner. It will probably be extended to cover other services on a worldwide or regional scale for aeronautical communication, navigation, search and rescue, terrestrial mobile communications and Earth resources.

In the domain of space science we have already entered an era of unprecedented vitality. Astronomy has acquired very powerful tools from space technology and its efforts in studying our infinitely large (or large but finite) Universe are moving in parallel with efforts at the other end of the scale devoted to the infinitely small, namely the physics of the intimate structure of matter. There is now the feeling that our studies in astronomy, cosmology and the physics of elementary particles might be more interconnected. Cooperation in space science has already provided some very effective and imaginative avenues here and might find a new dimension, the closer we come to the synthesis of the phenomena of nature.

In the domain of space technology and space infrastructure (including space transportation systems and orbiting stations) and ground facilities, it is

Figure 6 — The 'big machine'

reasonable to expect that national and regional agencies will continue to operate, with bilateral and multilateral cooperation, particularly when the exploitation phases are open to longer-term cooperation.

Within this scenario it is now possible to identify a domain that could very well represent a new major theme and challenge for the widest international cooperation: I am thinking here of that 'big machine' that supports life on Earth via a mechanism that we have yet to understand fully, namely our Sun-Earth system. We have learned recently how to handle big, nonlinear, highly interactive systems in which several subphenomena coexist with different typical time scales, dimensions, masses and energies. The 'big machine' is certainly such a system and the reason why it has not yet been fully understood is simply that a nonlinear problem can rarely be linearised and its solution calls for an integrated approach.

The phenomena within 'the system' include the Sun's activity, the solar flares and sunspots, the solar-constant fluctuation, the intensity and composition of the solar wind, the interactions with the magnetosphere, ionosphere, and troposphere, the ozone layers, the lower atmospheric layers, the clouds and precipitations, the dynamics of the atmosphere and of the oceans, the re-radiation back from Earth to the Universe and, last but not least, the manmade effects on these processes. The complexity of the problem calls for a strategic plan for providing a consistent set of instruments to measure the most significant parameters governing these phenomena with the appropriate time and space resolution.

It is conceivable that 50 satellites might be required, strategically located and operated simultaneously for a period of 11 or possibly 22 years (two 11 year cycles).

I believe that we cannot further postpone the taking of the first steps towards a sound approach to this problem, which has for several years been regarded by a wide community as of primary importance. We should not, however, underestimate the scale of the problem. It will require a cooperative effort an order of magnitude bigger than anything we have been able to achieve in the past 20 years. I think that one order of magnitude is the correct estimate: 50 satellites rather than 5, missions over 20 years rather than 2 years, with 10 000–20 000 people working cooperatively rather than the 1000 associated with a typical mission today. To make it possible at all, it will be mandatory to involve all potential partners from the very beginning in the definition of the plan, to take into account all the experience gained and lessons learnt in the past, and to attract the best professional people to participate in the solution of the inherent scientific, technological and organisational problems raised by this fascinating research theme.

Conclusions

20 years after, then, we can expect the next decades to bring a continuous, vigorous expansion of space activity in the domains of science, applications and technology, in part based on the objectives that can already be identified, but also due to the ability that we have already acquired in cooperating in international endeavours.

Space is now part of the culture of our present age, but equally the cooperation that the global nature of the space phenomena has required has a permanent place in our civilisation. Contrary to the belief that only a genius in isolation can advance science, culture and civilisation, there is now the need and possibility for discoveries to be made by a wide community polarised by a common objective within the wide dimensions and forms that space technology can offer.

A programme for the instrumentation of the space segment of the Sun–Earth system extended over several years will offer not only the prospect of precious results for all mankind, but also an attractive opportunity for a wide community of people to participate in a new form of cooperation an order of magnitude bigger than anything that has gone before.

I share with you all the honour of having served the cause of space cooperation and also the desire to continue to make progress in our exciting profession.

ESA's Plans for Future Earth-Observation Programmes

J.N. de Villiers, ESA Earth-Observation Programme Department, ESTEC, Noordwijk, The Netherlands

The Agency's current Earth-Observation Programme covers the fields of meteorology (Meteosat) and remote sensing of the oceans (ERS-1)*. This article describes the planning and support activities that could lead to future space missions in the areas of advanced land observations, advanced meteorology, climatology and geodesy, as well as to the provision of flight opportunities in space for promising payloads.

Earth observation became an ESA programme element with the advent of the Meteosat meteorological programme in the early 1970s. Meteosat-1 launched in 1977 and a second flight unit launched in 1981 provide Europe's contribution to the World Weather Watch, delivering images of the European/African sector of the globe every 30 min. Continuity of this data until the middle of the next decade will be assured by the launch of three further Meteosat satellites in the framework of the recently approved Operational Meteosat Programme.

In the field of remote sensing, the work of the past five or six years has culminated in the detailed definition (so-called 'Phase-B') of an ocean-monitoring satellite, ERS-1 (Fig. 1). This satellite, with a projected 1988 launch, is being designed by the Agency for the global observation of:
- ocean-surface winds, sea states and waves
- ocean-surface topography
- sea-ice distribution and dynamics.

Planning for future missions is under way,

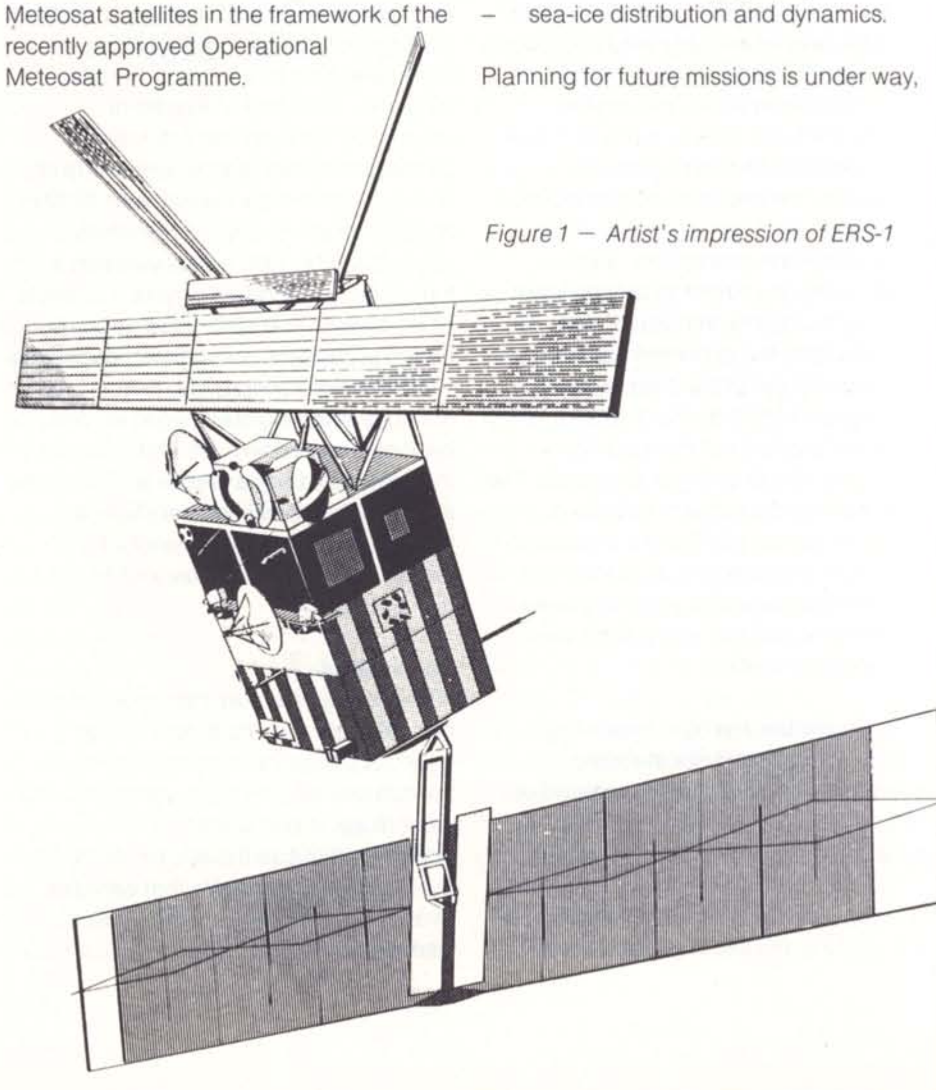


Figure 1 — Artist's impression of ERS-1

* The ESA Remote-Sensing Satellite (ERS-1) Programme was described in detail in ESA Journal No. 1, 1983.

Figure 2 – Images from the Nimbus-7 Coastal-Zone Colour Scanner (CZCS), received by ESA/Earthnet, Frascati, Italy. The colour composites shown were processed by the European Communities Joint Research Centre, Ispra, Italy

a. Colour composites of three CZCS channels after calibration and atmospheric correction:
Blue = Channel-1 subsurface radiance (443 nm band)
Green = Channel-2 subsurface radiance (520 nm band)
Red = Channel-3 subsurface radiance (550 nm band).

b. Computed chlorophyl concentration in kilograms per litre.

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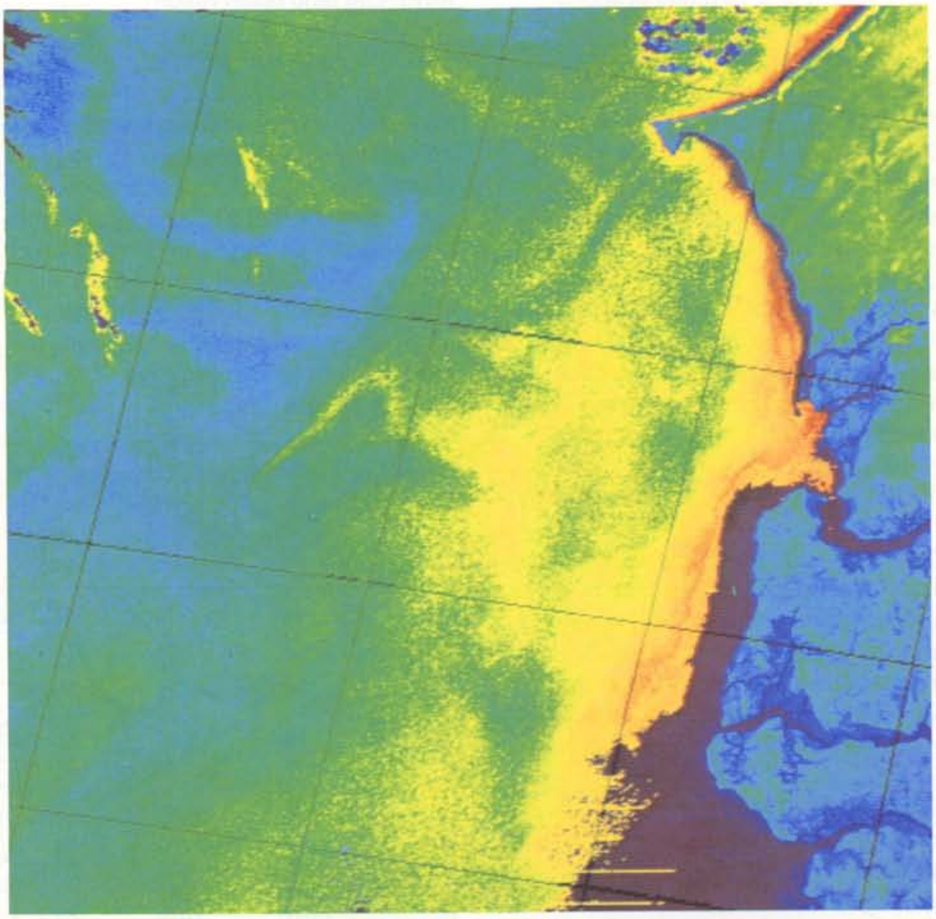


2b.

covering a broad spectrum of disciplines and applications, including:
- a follow-on oceans mission
- advanced land observation mission
- an advanced meteorological mission
- climatology/atmospheric physics
- physics of the 'solid Earth'
- provision of flight opportunities.

The requirements and preparatory work already undertaken for these six areas are described below.

Follow-on oceans mission
The ERS-1 payload consists of an integrated set of active microwave instruments. An ocean-colour-monitoring (OCM) capability included at an earlier stage of its definition was subsequently deleted from the payload (descoping).

Remote monitoring of the bio-productivity and quality of the deep and coastal oceans centres on the measurement of three principal 'substances' – chlorophyl, yellow substance and suspended sediments – together with the measurement of sea-surface temperature (Fig. 2).

Each of the first three 'substances' produces its own unique spectral signature in the observed upwelling visible and near-infrared radiance, signatures that also vary with the concentration of the substance in question. In principle, it is sufficient to process the radiances observed at a number of suitably chosen wavelengths to determine the concentration of each substance. Unfortunately, observations from a satellite are made from outside the Earth's atmosphere and its effect on the radiation must be taken into account. Not only does the atmosphere attenuate the upwelling bulk-reflected radiation, but sunlight backscattered from the atmosphere is added to it. The effect of the atmosphere not only varies with weather conditions, but occurs more strongly the shorter the wavelength. At the blue end of the spectrum the backscattered sunlight can be ten times greater than the upwelling radiance from the water. Channels in the near infrared, where water appears 'black', can be used to assess the atmospheric correction required.

Sea-surface temperature can be measured by observing the thermally emitted radiation from the sea in two parts of the 8 – 14 μm region of the spectrum, corrected for the effect of the atmosphere from measurements made at shorter wavelengths.

The first measurements of water quality in the oceans were made by the NASA Coastal-Zone Colour Scanner (CZCS) flown on Nimbus-7. In the context of preparatory studies leading to the payload selection for ERS-1, a second-generation ocean-colour-monitoring instrument, incorporating additional channels and having improved sensitivity, was studied by ESA. The instrument would weigh up to 100 kg, employ mechanical scanning and acquire imaging data in the 13 bands shown in Table 1, with the performances indicated.

The swath width would be 800 km and the instantaneous field of view 800 m. The use of mechanical scanning leads to a simpler arrangement for incorporating calibration sources, as they can be viewed by the detectors with each revolution of the scan mirror.

Studies have indicated the preliminary compatibility of this baseline OCM with a possible second flight unit of ERS-1, nominally considered for launch in 1990 for planning purposes.

More recent studies have addressed the use of linear detector arrays in the imaging plane of suitable optics to eliminate the scanning mechanism. This arrangement, termed advanced OCM, introduces new effects; specifically, the matching of the individual detector elements in the arrays, the very large dynamic range required, and the need now to introduce a mechanism allowing the instrument to view calibration sources. Further activities will determine whether this concept should replace the baseline, mechanically scanned OCM as the candidate for a possible second flight unit of ERS-1. However, it has yet to be verified whether thermal-infrared detector array developments are sufficiently far advanced to allow their incorporation into flight hardware to meet the nominal 1990 launch date.

Advanced land observation

The USA's Landsat programme has demonstrated the potential of multispectral land-surface observations in the visible and near-infrared portions of the spectrum. The most recent Landsat-D satellite has demonstrated an improved spatial resolution of 30 m, more applicable to the smaller and more randomly-shaped fields in Europe. Unfortunately, Europe is not endowed with such good weather and the Agency is therefore examining the role that all-weather microwave techniques could play.

A land satellite would have to address the areas of:
- agriculture
- forestry
- land-use management
- water resources (including snow and ice) and land-surface processes
- geology
- cartography.

In the agriculture domain, the requirements fall into four areas:
- inventory
- evolution monitoring
- warning/alarm
- development of models for yield forecasting.

The emphasis for Europe is on monitoring *change* during a growing season (it is, after all, sufficient to identify a crop once during a growing season – for which a combination of space and ground techniques can be used). It is felt that coverage will be needed three to four times per season for monitoring purposes.

Forestry requirements are similar to those of agriculture, but the time scale can be relaxed (except for warnings and alarms).

In both cases optical data are preferable, weather permitting. During poorer weather conditions, only synthetic-aperture radar (SAR) data could, in principle, be used. Present studies and

Table 1 — Projected performance data for a second-generation OCM

Band	λ_c (nm)	λ (nm)	NEΔρ / NEΔT	Target parameter
1	400	20	10^{-3}	Yellow substance
2	445	20	5×10^{-4}	First priority chlorophyl
3	520	20	5×10^{-4}	Chlorophyl/turbidity
4	565	20	5×10^{-4}	Turbidity
5	640	20	5×10^{-4}	Turbidity
6	685	20	5×10^{-4}	Chlorophyl fluorescence
7	785	30	5×10^{-4}	Atmospheric correction
8	1 020	60	5×10^{-4}	Atmospheric correction
9	1 600	100	5×10^{-2}	Water/ice clouds
10	3 700	400	0.1 K	Day/night
11	8 500	500	0.1 K	Sea-surface
12	10 800	1 000	0.1 K	temperature and
13	12 000	1 000	0.1 K	Atmospheric corrections

Figure 3 – Concept for an Advanced Land Satellite

future measurement campaigns will determine what types of multifrequency SARs would be needed, and exactly what role they could play.

Similarly, SAR data is expected to be the key for water-resources monitoring. However, studies are identifying the role of high-frequency microwave-radiometer imaging which, although poorer in spatial resolution, has the potential to determine the water-equivalent depth of snow, as well as its 'wetness' or ability to cause severe run-off.

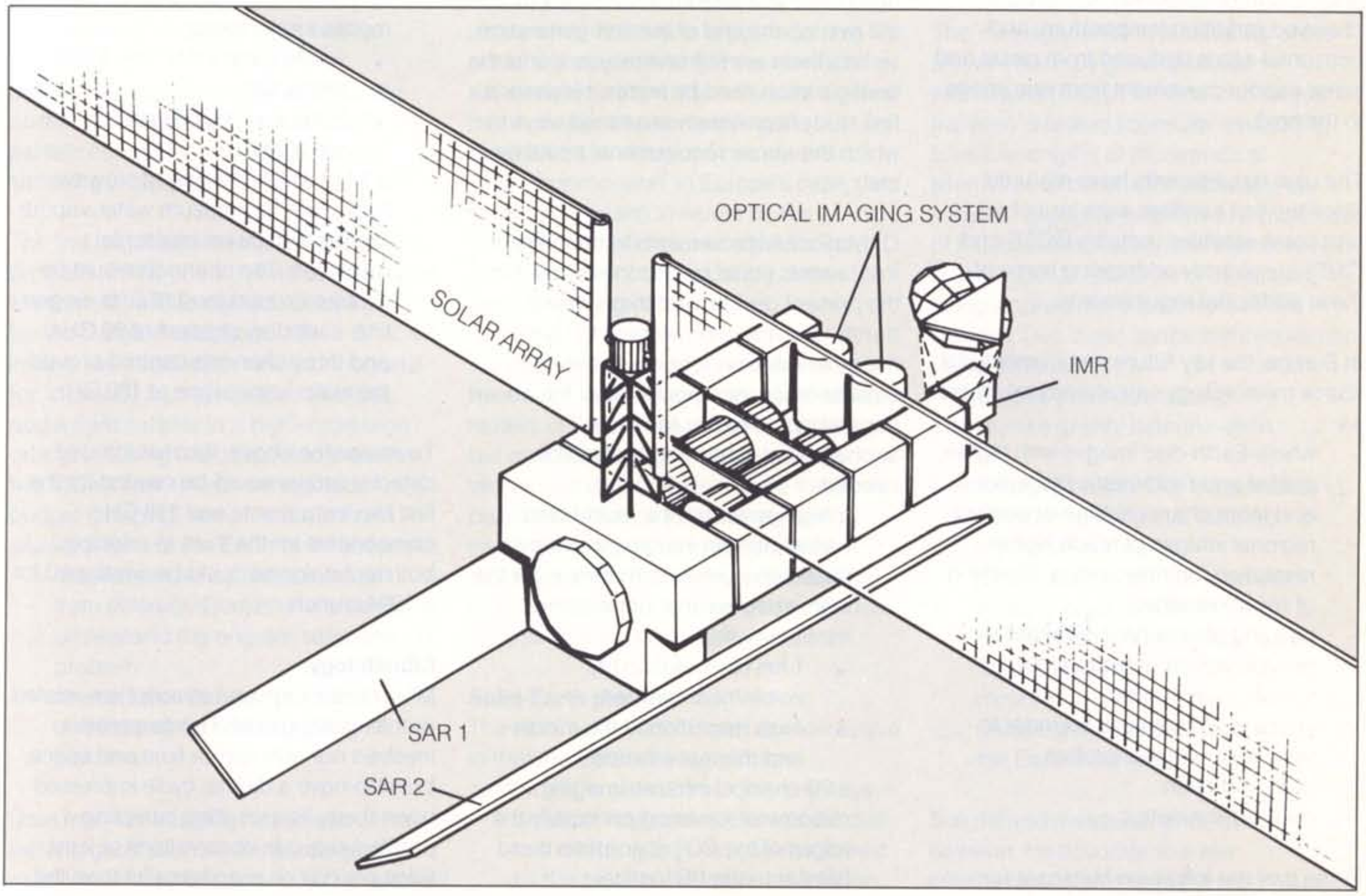
The benefits of optical, stereo-optical and SAR data are already well proven for land-use management, geology and cartography. The necessary instruments can already be specified and their realisation would involve no technical problems.

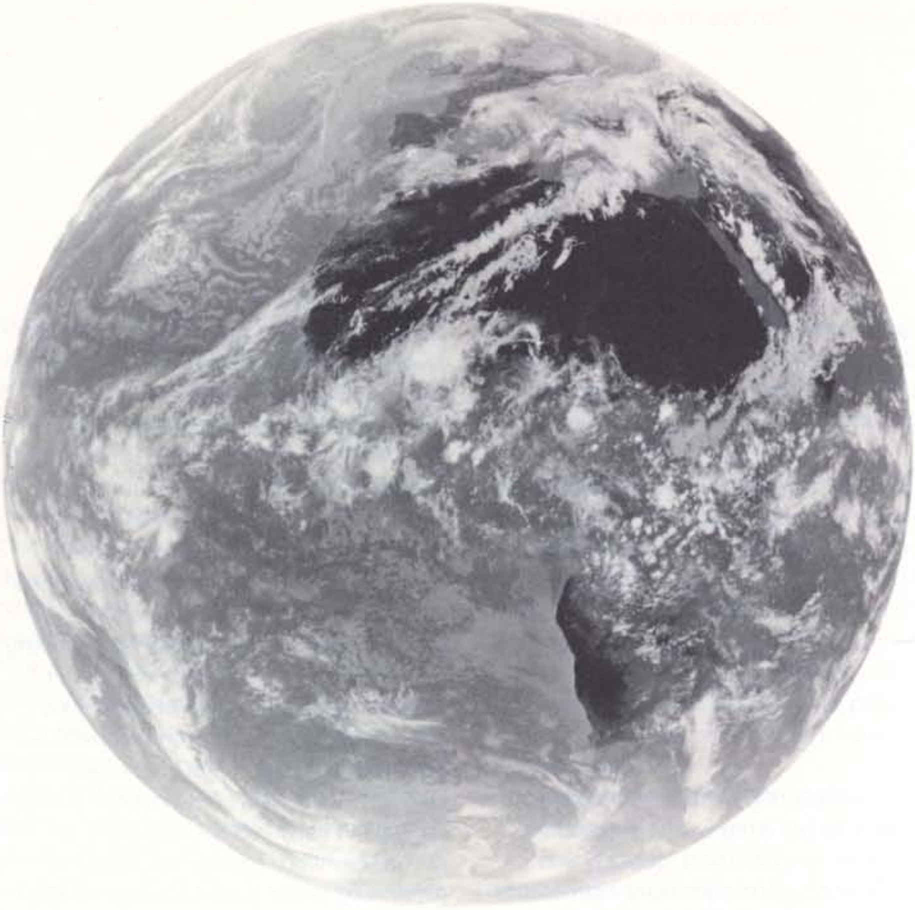
In the early stages of defining ERS-1, the Agency also studied a candidate Land Applications Satellite System (LASS) consisting of a C-band SAR (similar to that on ERS-1) and an Optical Imaging Instrument (OII) based on push-broom linear arrays imaging in the visible and near-infrared as far as 1.1 μm. More recent technological work has advanced the baseline OII to include a middle-infrared push-broom capability, extending the spectral coverage to 3 μm. Further work is under way aimed at realising a thermal-infrared push-broom capability in the 8 – 14 μm region, but it is not yet certain whether this could meet a launch date in the early 1990s. Likewise, preliminary work has started aimed at expanding the performance of the ERS-1 SAR for future missions, specifically by adding a second channel and by widening the swath. Finally, it should be mentioned that a baseline design exists for an imaging microwave radiometer (including a channel at 90 GHz which would yield a spatial resolution of a few kilometres).

The above elements form the basis for a candidate advanced land satellite (Fig. 3), assumed at this stage to include:

- a two-frequency wide-swath SAR
- a high-resolution push-broom optical imaging system covering the visible, near and middle-infrared (possibly with stereo capability)
- an Imaging Microwave Radiometer (IMR), particularly for higher frequencies (also applicable to the oceans and sea ice).

Internal studies have examined concepts for including all such capabilities on a single satellite. More detailed studies are





imminent, geared towards a nominal launch date of 1992.

Advanced meteorological mission
The current Meteosat series of satellites, in geostationary orbit over the prime meridian, provide (and will continue to provide until the end of 1995) an imaging capability in the visible, middle-infrared (water-vapour channel) and thermal-infrared regions of the spectrum. They yield images every half an hour of cloud distribution, water-vapour distribution, and sea-surface temperature.

They also collect data from remote surface measurements and disseminate the imaging data. Together with the other four geostationary meteorological satellites (GOES East and West, GMS and Insat), they provide near-global satellite weather data. In addition to monitoring the movement of clouds, cloud-top heights can be assigned on the basis of observed radiation temperature, and horizontal winds deduced from cloud and water-vapour movement from one image to the next.

The user requirements have matured since the first satellites were launched, and some satellites (notably GOES and GMS) are already addressing some of these additional requirements.

In Europe, the key future requirements for space meteorology can already be stated as:
- whole-Earth-disc images with higher spatial and radiometric resolution and more channels than at present
- regional images of much higher resolution for 'nowcasting' (tracking of severe weather)
- imaging atmospheric sounder to provide vertical atmospheric temperature profiles
- imaging atmospheric sounder to yield water-vapour profiles
- data collection
- data dissemination.

Given that the follow-on Meteosat (or second-generation Meteosat) would not need to be launched until say 1994 (but still overlap the end of the first-generation series), there are still several years until the configuration need be frozen. However a first study has already examined ways in which the above requirements could be met.

Only minor improvements to the present instruments could be accommodated in the present design, and these would hardly give any improvement to users. At the other extreme, a new advanced satellite could incorporate all of the above capabilities. In particular, three sophisticated instruments would be needed:
- a high-performance, multi-band visible/infrared imaging instrument, based on push-broom arrays, for the main imaging and 'nowcasting' missions, with:
  - 1 km resolution in the visible/near-infrared
  - 4 km resolution in the middle- and thermal-infrared
- a 20-channel infrared imaging radiometer, covering principally the edges of the CO_2 absorption band (similar to the US Vertical Atmospheric Sounder) for measuring vertical temperature profiles. Two modes are foreseen:
  - whole Earth's disc with 25/50 km resolution
  - European region with 8/16 km resolution
- a 14-channel imaging microwave radiometer to measure water-vapour profiles with 50 km horizontal resolution. Ten channels would be centred around the 118 GHz oxygen line, a window channel at 90 GHz, and three channels centred around the water-vapour line at 180 GHz.

To realise the above, thermal-infrared detector arrays would be needed for the first two instruments and 118 GHz components for the third. In principle, both technologies could be developed for a 1994 launch.

Climatology
Most climatology and atmosphere-related problems are global. The parameters involved not only vary in time and space, but also have a diurnal cycle impressed upon them. The resulting sampling problem requires observations at least twice per day on a grid smaller than the

scale length of the phenomena in question. In practice it is then necessary to deploy instruments on several satellites in different orbits.

A good example is the monitoring of the so-called Earth's radiation budget. Early space missions employed a single instrument on a single satellite to determine the outgoing flux of radiation emitted by and reflected from the Earth, so that it could be compared with the incoming solar radiation. It is not yet known whether the average incoming and outgoing radiation fluxes balance each other nor, if they do not, whether the difference is positive (which will tend to warm up our planet slowly) or negative (tending to cool the Earth down).

The outgoing radiation varies with:
- time
- position on the Earth's surface
- wavelength
- angle with respect to the vertical.

Since no adequate models exist for the above four dependencies, a single satellite cannot overcome the implied sampling problems.

The first major experiment to address this problem (ERBE or Earth Radiation Budget Experiment) will be carried out by the United States in the period 1984–87. It will involve two satellites in nearly orthogonal (or 'crossed') Sun-synchronous orbits, and a third satellite in a high-inclination orbit precessing with respect to the other two. All will carry the same radiation-budget (imaging) radiometers and will allow portions of the Earth to be observed:
- simultaneously by two spacecraft from different directions in order to understand the angular sampling problem
- several times per day, in order to understand the time-sampling problem.

Data from the imaging radiometer of the existing geostationary meteorological satellites will also be used as far as possible. Beyond ERBE there are no plans for systems to monitor the Earth's radiation budget, despite predictions about how we are changing our climate, for example by increasing the CO_2 'greenhouse' layer. The international community is of the opinion that a satellite system will be needed in the future, but that it can most likely only be realised by embarking appropriate instruments on satellites planned for other purposes. The latter have been identified as:
- the five geostationary meteorological satellites
- the two Tiros-N Sun-synchronous meteorological satellites
- a further Sun-synchronous satellite (perhaps remote sensing).

The Agency is already carrying out simulations of such satellite networks, with different assumed-radiation-budget payloads, to determine their potential. Future studies of the necessary instruments will help to prepare for the possibility of embarking them on such satellites in an internationally coordinated manner (as well as employing the planned meteorological instruments where appropriate). In Europe's case, the satellites in question would be the second-generation series of Meteosat (from, say, 1994) and, possibly, future remote-sensing satellites.

Atmospheric-composition studies do not have such severe sampling problems as studies of the Earth's radiation budget, but on the other hand observational techniques do not always allow the possibility of imaging. Many promising instruments are in various stages of development in the Member States, but flight opportunities are needed to test the various concepts (see below).

Solid-Earth physics

The term 'solid Earth' is perhaps deceptive in that the Earth changes shape continually in at least two different ways:
- on short time scales it 'breathes' due to the changes in net gravity caused by the motion of the Sun and Moon (so-called 'solid-Earth tides').
- on long time scales, the tectonic plates forming the crust drift, causing earthquakes and volcanic activity at plate boundaries.

In addition, the Earth's rotation axis moves (so-called 'polar motion') in a cyclical manner with a period of slightly more than one year. The rotational speed of the Earth also varies. Finally, the Earth's gravity field differs from that of a point mass by virtue of the uneven distribution and density of the material constituting it. Time or frequency transfers to extremely high accuracy, between laboratories located on different continents, are also included in the 'Physics of the Solid Earth' field. This arises because precise ranging to satellites involves extremely accurate measurement of the time taken for electromagnetic waves to propagate over the distances in question.

The investigation and monitoring of the above effects by ground-based techniques (except for time and frequency transfer) is limited (consider measuring baseline lengths of thousands of kilometres to centimetre accuracy, or measuring gravity precisely in a multitude of inaccessible places). It is therefore not surprising that space techniques are being applied more and more in this domain. Two basic space techniques can be considered:
- precise point positioning
- precise gravity determination.

Precise point positioning is applicable to:
- monitoring of crustal distortion in earthquake areas
- determination of inter- and intra-tectonic plate motions
- monitoring the kinematics of the Earth's rotation (including polar motion)
- precise determination of points on the Earth's surface.

The derived measurements must, however, be accurate to a few centimetres. In principle, the technique involves precise ranging to a satellite in a precisely known orbit from a suitable set of ground points. Since orbits are perturbed by the nonuniformities of the Earth's gravity field and by nongravitational forces acting on the satellite (atmospheric drag and radiation pressure), it is necessary to choose an orbit far enough removed from the Earth (but not so far as to make the measurement geometry poor) and to make the satellite small and dense. Even so, residual effects still have to be measured or modelled to achieve a sufficiently precisely known reference orbit. In addition, the ranging measurements to the satellite from the ground points of interest should not be restricted by time of day or by weather.

An advanced-concept satellite called Popsat (Precise Orbit Positioning Satellite, Fig. 4) has been studied by the Agency (see ESA Bulletin No. 31, page 80). It combines the advantages of earlier geodetic satellites without incurring their disadvantages. In particular, it employs a high-altitude orbit (6000–7000 km) together with all-weather, two-way precise range and range-rate microwave tracking (it is planned to test the tracking technique as an experimental German national payload on ERS-1).

Simulations have already shown that such a conceptual satellite could yield the measurements listed with accuracies of a few centimetres. The satellite and principal ground network of some 16 stations would involve no new technologies. It is a possible partner for a dual Ariane launch with a remote-sensing satellite and is considered a candidate for launch around 1992 for planning purposes.

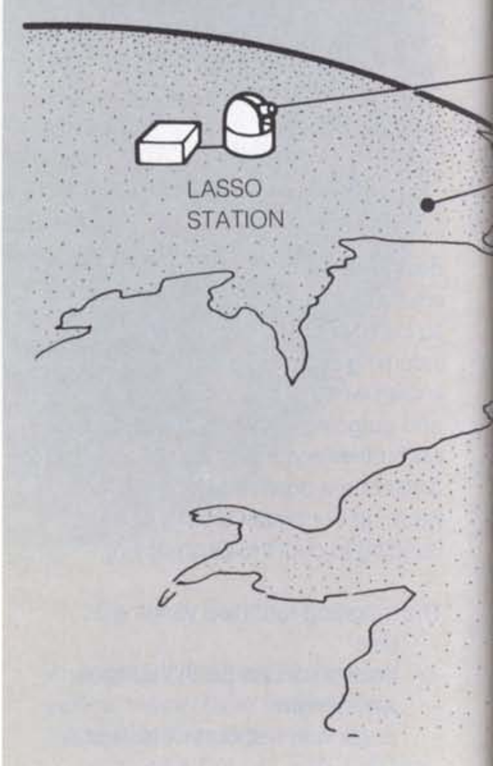
The Popsat-type orbit is quite unsuitable for a gravity mission as it seeks to minimise the effect of gravity uncertainties. In fact one has to fly as low as possible in order to magnify their effects and to be able to measure the short-wavelength components (comparable to the orbit altitude). Two techniques are applicable. The first involves measuring the gradient of the Earth's gravity (so-called 'gradiometry'), but would mean measuring the difference in gravity over a distance of perhaps 1 m. Superconducting gradiometers are under study in the United States, but there are formidable problems. A more interesting technique is to monitor the change in the relative positions of two identical satellites chasing one another in the same orbit, as each is accelerated and decelerated by the gravity anomalies. Such a technique has been studied by the Agency and depends only on the development of a satisfactory spaceborne laser system for measuring range and range rate precisely in space. It is considered a candidate for flight in the 1990s, possibly on a free-flying retrievable carrier of the Eureca type referred to below.

Transfer of time over intercontinental distances to an accuracy of 1 ns is a very real requirement, but it is a long way yet from being routine. This was, however, one of two missions of the Agency's Sirio-2 satellite, which was the victim of a launch failure in 1982. The LASSO system (laser synchronisation of atomic clocks from synchronous orbit) on board Sirio-2 in geostationary orbit would have measured the difference in time of arrival of laser pulses transmitted from two participating ground stations at times noted on their own clocks. A retroreflector array would have returned a portion of each pulse to a receiver at each station, to allow them to determine the time taken by each laser pulse to propagate from its station to the satellite.

It is feasible to accommodate the LASSO system on board the Meteosat satellites, and the possibility of doing so on the next Meteosat (due for launch in 1985) is being examined.

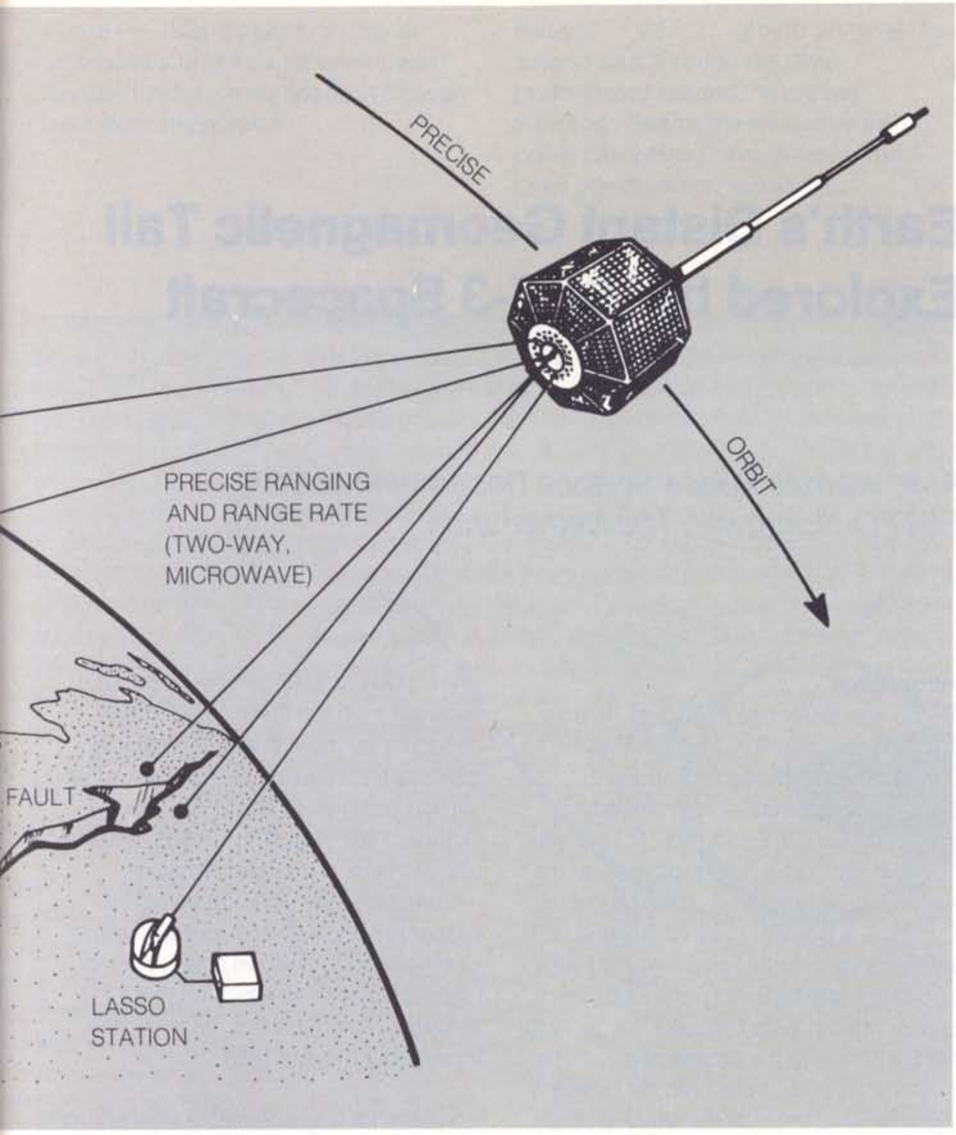
From a geostationary orbit, time synchronisation is restricted to laser stations on those parts of the Earth 'seen' by the satellite. A more interesting arrangement would be to remove this

Figure 4 — Concept for 'Popsat', with potential applications in earthquake research, Earth kinematics, precise surveying, geotectonics and precise time transfer



restriction by using a satellite in a non-geostationary orbit. A recent study has shown that the optimum orbit for this purpose would have a high inclination and a sufficiently high altitude to allow stations separated by intercontinental distances to participate. On the other hand the orbit should not be so high as to restrict the possibility to only the most powerful laser stations. The optimum orbit turns out to be between 5000 and 10 000 km, with an inclination of at least 70°. The Popsat orbit could not be more perfectly suited. As it would already have laser reflectors to allow cross-calibration between laser and microwave tracking stations, it merely remains to fit a suitable laser detector unit connected to the existing, highly accurate on-board clock. This has been shown to be feasible and if implemented on Popsat would provide a global time-transfer service.

Provision of flight opportunities
Most of the missions referred to in the



previous sections justify their own satellites.

However, occasions can arise when it is necessary to provide appropriate flight opportunities for instruments that:

- are still at the experimental stage
- seek to prove new concepts
- need to be deployed on several satellites
- benefit from being recovered.

Two flight opportunities are already being provided for Earth-observation instruments: a metric mapping camera and a multi-mode microwave instrument (scatterometer, SAR and radiometer modes) were flown on the recent 10 day Spacelab flight. Two experimental payloads, to be provided nationally, are planned to be flown on ERS-1. One will investigate new infrared techniques for accurate measurement of sea-surface temperature (the ATSR or Along-Track Scanning Radiometer); it also incorporates a two-frequency nadir sounding microwave sounder to determine the correction needed in processing altimeter measurements to account for the effect of the troposphere. The other will test new, precise all-weather techniques for measuring the range to satellites with centimetre accuracy (the PRARE or Precise Range and Range-Rate Experiment).

It is hoped to repeat the precedent of ERS-1 by offering opportunities to fly experimental instruments on future Earth-observation satellites, the immediate candidates being advanced land satellites and the second-generation Meteosats. Instruments would be selected through an Announcement of Opportunity.

More involved arrangements will be needed (including international coordination) to provide space on future Earth-observation satellites, in concert with other satellite operators, to satisfy those fields that require a set of coordinated instruments to be embarked on a set of suitable satellites (e.g. the long-term monitoring of the Earth's radiation budget).

In other areas, there are missions or experiments requiring only a shorter flight in space (and which may benefit from retrievability); for example,

- metric mapping cameras
- cryogenically cooled instruments
- limited-lifetime laser-based instruments.

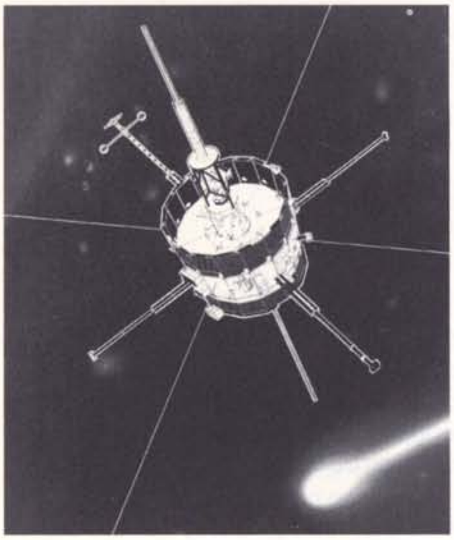
One possible avenue is Eureca (European Retrievable Carrier), an autonomous platform to be launched by the Space Shuttle in 1987, boosted to a higher orbit for a 6–12 month mission, and then retrieved and brought back by a later Shuttle flight. Eureca-1, an approved ESA programme, will address microgravity and involves a Sun-pointing mode for the Eureca carrier. Current studies are examining the practicality of adapting the Eureca concept to an Earth-pointing mode for use in higher inclination orbits to suit Earth-observation instruments. A nominal launch date of 1990 is being assumed for study purposes.

Conclusion

The past and present studies described in the preceding sections are an essential element in the planning and preparation for future Earth-observation missions. However, in many cases more detailed work is required. For this purpose an Earth Observation Preparatory Programme (EOPP) has been conceived, to cover:

- detailed instrument and system studies
- measurement campaigns and modelling
- pre-development of critical areas and technologies.

The EOPP is expected to start in 1984 and would address the mission areas described in this article.



Earth's Distant Geomagnetic Tail Explored by ISEE-3 Spacecraft

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A fundamental aspect of the interaction between the solar wind, a continuous emission of high-velocity plasma from the Sun, and a magnetised planet is the formation of an extremely long downstream region, termed the 'magnetotail'. The existence of a magnetotail on the dark side of the Earth has been known for several decades, but its distant regions beyond the orbit of the Moon were surveyed in depth for the first time in 1983. The International Sun-Earth Explorer-3 (ISEE-3) spacecraft explored field and particle phenomena in the distant geotail during a large part of the year when it was in the Earth's tail, up to 240 Earth radii out. This was achieved with the help of a remarkable class of lunar gravity-assisted orbits. ISEE-3 is now on its way to becoming, in 1985, the first spacecraft to make a close fly-by of a comet. We describe here some first results of ISEE-3's geotail exploration.

Introduction

ISEE-3 was launched in August 1978 as the third spacecraft in the ESA/NASA cooperative International Sun-Earth Explorer programme. It was placed 1.5 million km (or 235 Earth radii, R_e) sunward from the Earth in a halo orbit around the so-called Lagrangian or libration point, L_1. This is a point of balance between the satellite's centrifugal force and the Earth's and Sun's gravitational pulls. At L_1, the spacecraft corotated around the Sun with the Earth during the course of a year. Its scientific payload measured the different ingredients of the interplanetary medium: the properties of the solar-wind plasma, magnetic and electric fields, solar and heliospheric charged particles and galactic cosmic rays.

ISEE-3 also served as a monitor of the solar-wind 'input' to the Earth's magnetosphere, which was simultaneously investigated by the ISEE-1 and -2 spacecraft in identical orbits around the Earth.

The 13 scientific instruments carried by ISEE-3 have been provided by both US and European groups. The payload includes the Low-Energy Proton Experiment jointly designed and built by the Cosmic-Ray Division of the Space Science Department of ESA, the Blackett Laboratory of Imperial College, London and the Space Research Laboratory, Utrecht. Interplanetary observations with this instrument have been described, for example, in ESA Bulletin No. 27, August 1981 (pp. 4–12).

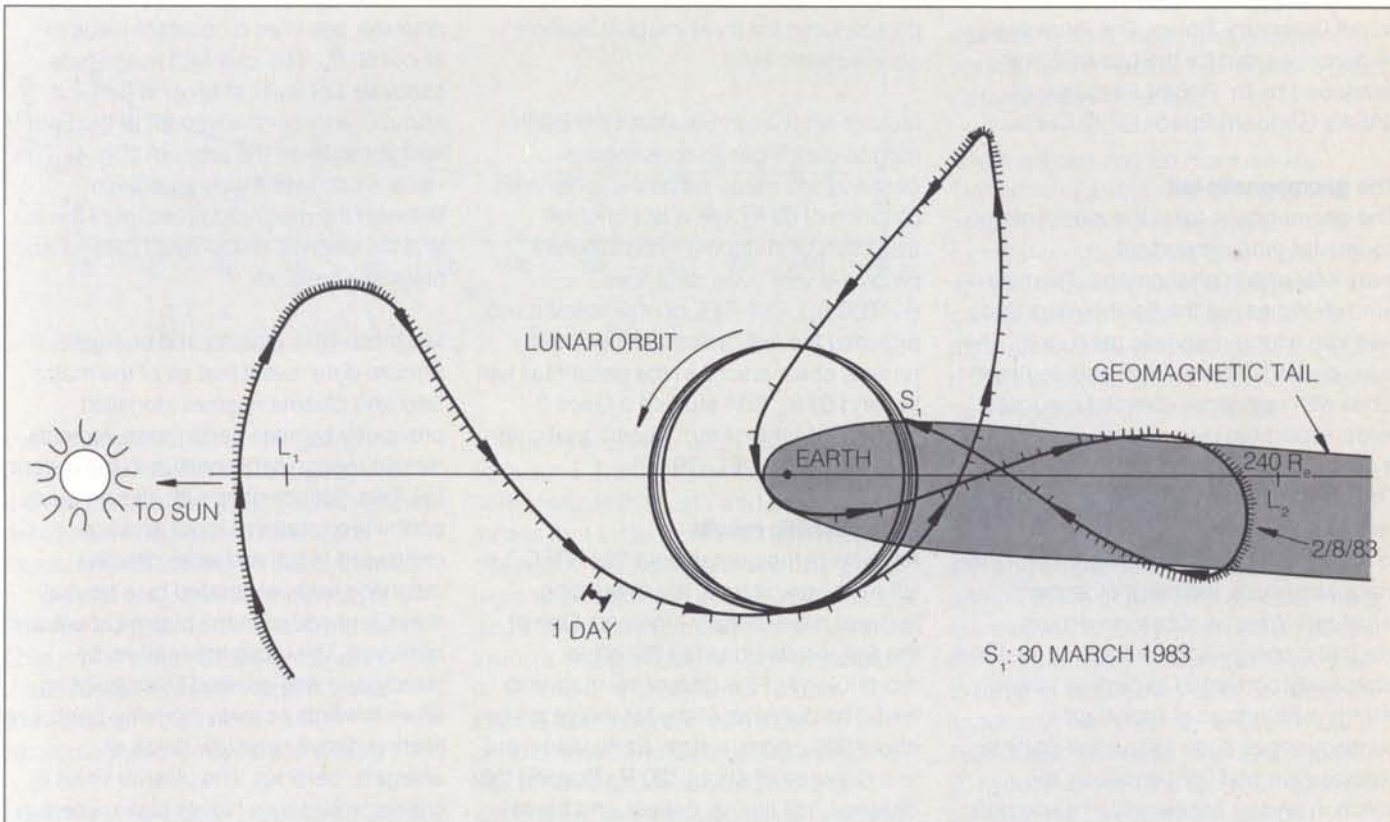
ISEE-3's second life began in mid-1982 when it was redirected from its position sunward from the Earth, which it had occupied for more than four years, to make its first crossing of the geomagnetic tail at a distance of about 70 R_e in October 1982 (Fig. 1). In what is certainly one of the most complex series of manoeuvres ever undertaken with a spacecraft, the well-proven satellite was commanded to perform a sequence of looping trajectories which enabled it to study the distant Earth's magnetic tail throughout most of 1983.

Normally, for a spacecraft in orbit around the Earth, apogee precesses from the sunward side of the Earth to the anti-sunward side and back during the course of one year. ISEE-3, however, has used lunar swing-bys to offset this natural precession and thus increase the time available for studying the geotail.

ISEE-3 had its first deep geotail pass in early 1983. Its apogee of 221 R_e occurred on 8 February. Then on 30 March ISEE-3 was manoeuvred into its first encounter with the Moon (S1 in Fig. 1), which put it into an orbit with apogee at 81 R_e. Precession of this new orbit plus motion of the Moon in its own orbit then allowed the second lunar swing-by (S2 in Fig. 2) on 23 April, sending ISEE-3 back into a second deep geotail pass, the 236 R_e apogee of which occurred on 30 June. Following a third lunar swing-by (S3 in Fig. 2) on 28 September and another small tail orbit with an apogee of $\sim$80 R_e, a fourth lunar swing-by on 21 October placed ISEE-3 into a looping trajectory leading to its final lunar fly-by and interplanetary escape trajectory towards

Figure 1 — ISEE-3 trajectory from its original halo orbit around the sunward libration point, L_1, to its first pass through the distant magnetotail

Figure 2 — ISEE-3 trajectory showing the second pass through the deep geomagnetic tail and the escape trajectory towards the encounter with comet Giacobini-Zinner. S marks the lunar gravity-assist manoeuvres



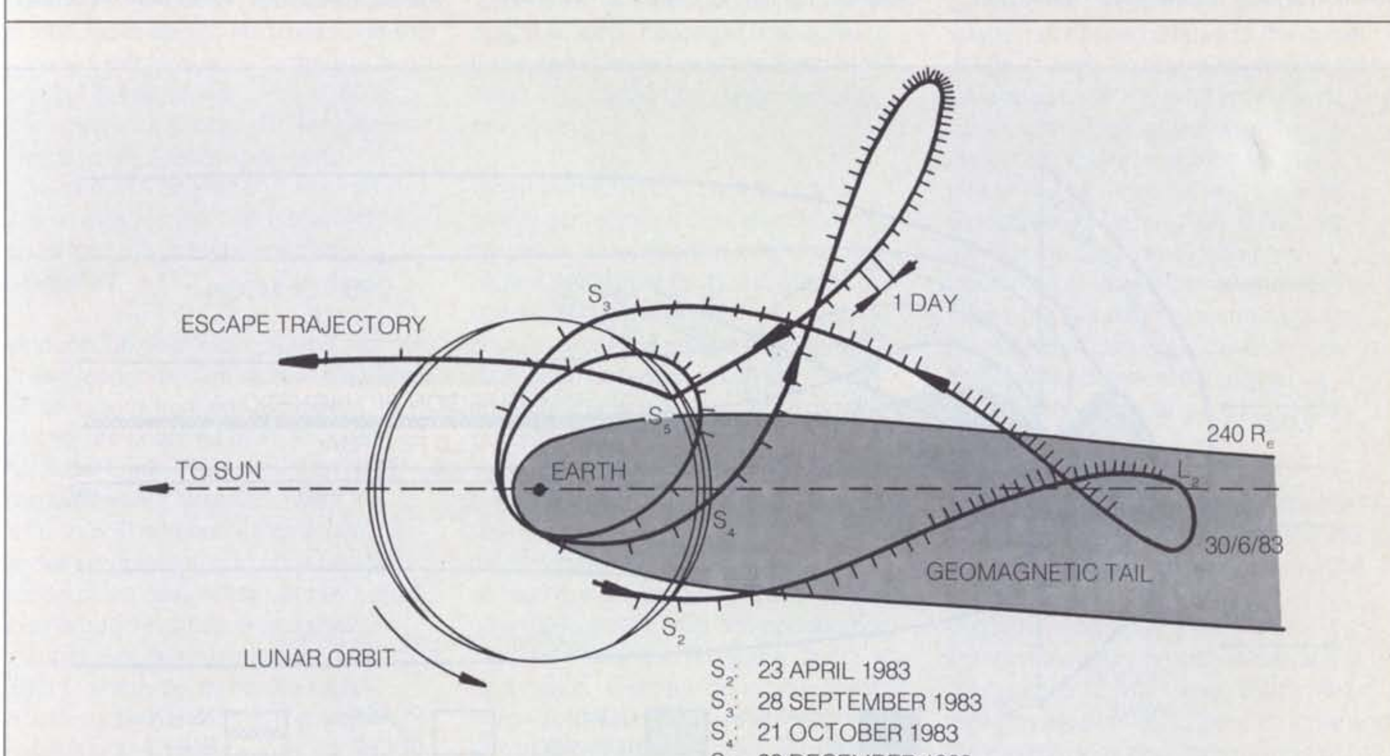


Figure 3 — A summary view of the magnetosphere and the geomagnetic tail, as deduced from earlier spacecraft measurements

comet Giacobini-Zinner. The lunar swing-by concept, used for the first time, was developed by Dr. Robert Farquhar of NASA's Goddard Space Flight Center.

The geomagnetic tail

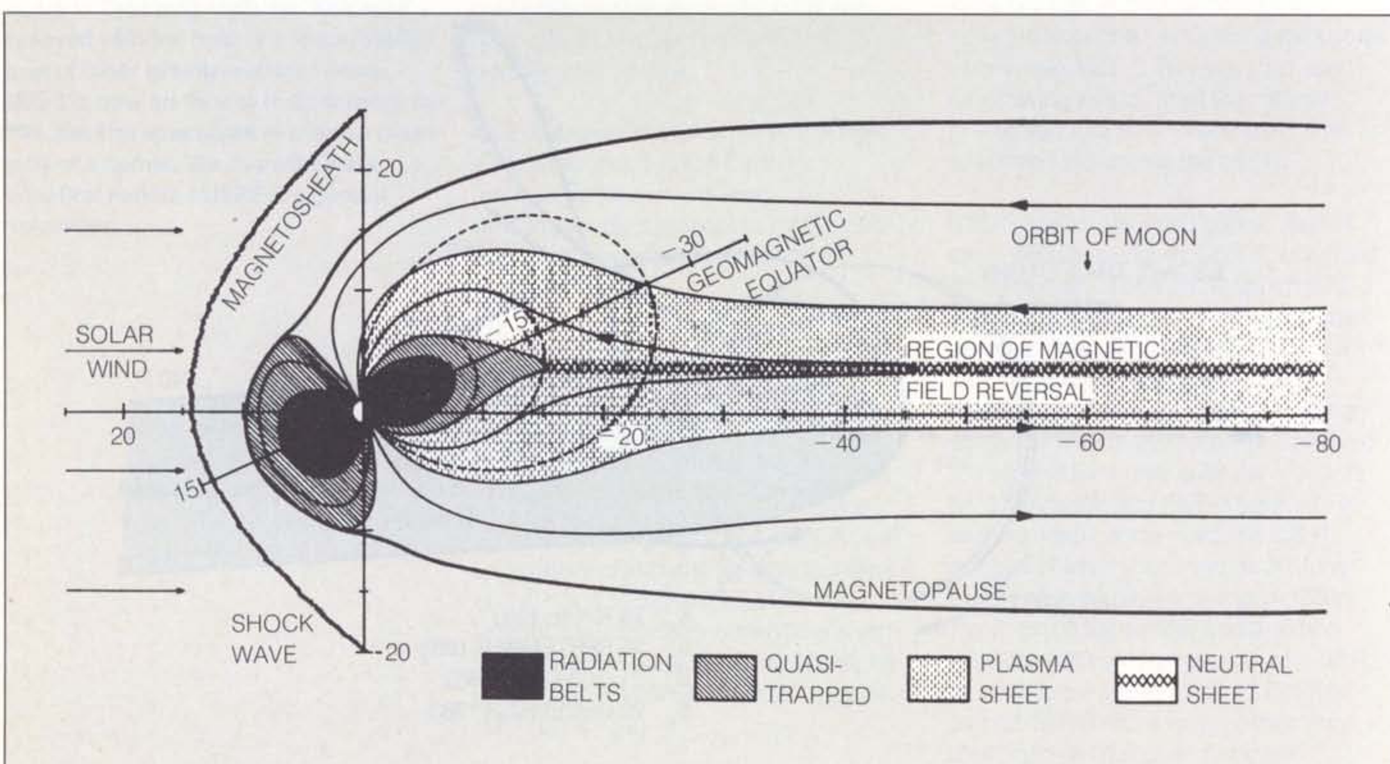
The geomagnetic tail is the main energy source for many important magnetospheric phenomena. The solar wind stretches out the Earth's magnetic field into a long magnetic tail (Fig. 3). The tail is divided into northern and southern lobes with oppositely directed magnetic fields, separated by a neutral sheet which is embedded in a sheet of hot plasma. The tail and its plasma sheet are a giant energy reservoir which, at times, gives rise to the most fundamental instability of the magnetosphere, the magnetospheric substorm. When a substorm occurs, magnetic energy accumulated in the tail is explosively converted to particle kinetic energy, with a host of important consequences, such as auroral particle precipitation and light emission, the injection and/or acceleration of energetic particles into the inner magnetosphere and radiation belts.

Most of what we know about the Earth's magnetotail is based on extensive observations made inside the lunar orbit distance of 60 R_e and a few brief tail traversals by outgoing interplanetary probes at very large distances ($\sim 1000\ R_e$). The ISEE geotail mission has provided the first systematic field and particle observations in the distant tail well beyond 60 R_e. ESA studied a Geos-3 mission into the distant geomagnetic tail in 1979 [ref. ESA/SCI(79)12].

First scientific results

Analysis of the geotail data from ISEE-3 is still in its early stages, but interesting features have already emerged. One of the first results provided the gross morphology of the distant tail magnetic field. The diameter of the tail increases by about 30%, from its near-Earth value, out to a distance of about 120 R_e. Beyond this distance, 'tail flaring' ceases and the tail diameter assumes a constant value of about 60 R_e. The lobe field magnitude becomes constant at around 9 nT (i.e. about one three-thousandth of the Earth's field strength on the ground) (Fig. 4). This value is consistent with equilibrium between the magnetic pressure of the tail and the external (solar-wind) plasma and magnetic pressure.

Magnetic-field, plasma and energetic-particle data reveal that all of the major field and plasma regimes identified previously by near-Earth measurements remain recognisable entities in the distant tail. Two distinct lobes with steady, quiet, earthward (northern lobe) and anti-earthward (southern lobe) directed magnetic fields separated by a neutral sheet, embedded in the plasma sheet, are observed. The lobes are marked by steady and well-ordered fields pointing either towards or away from the Earth, low plasma density and low fluxes of energetic particles. The plasma sheet is characterised by a higher plasma density



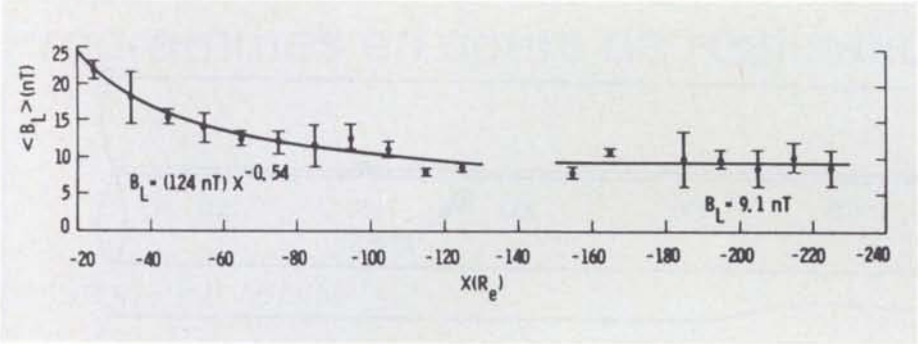


Figure 4 — Average tail magnetic-field magnitude as a function of distance from the Earth as derived from ISEE-3 observations

and enhanced fluxes of energetic ions. Other magnetospheric plasma regions such as the plasma-sheet boundary layer, identified previously with near-Earth measurements, have also been revealed in the distant tail. This boundary layer between the plasma sheet and the tail lobes is often, but not always, present. It is characterised by small magnetic-field decreases and the presence of electromagnetic ion cyclotron waves.

A dramatic increase in plasma turbulence, as reflected in electric-field measurements in the ~1 kHz frequency range, has been found in the distant tail beyond 180 R_e. This turbulence is located in the plasma-sheet boundary layer and is well correlated with bidirectional electron plasma anisotropies. The nature of the associated waves has not yet been established.

Although the near-Earth plasma regimes remain recognisable entities in the distant tail, transitions from one regime to another are observed more frequently than near Earth. There are, at this early stage, different interpretations for this behaviour. The frequent transitions may be due predominantly to back and forth motion of the deep tail caused by typical solar-wind flow direction and pressure changes. Another interpretation is that the distant tail may be, by nature, highly structured, perhaps reminiscent of the visible structure of many ionic comet tails.

The Earth's magnetosphere intermittently suffers sudden losses of plasma and energy that it earlier acquired from the solar wind. The fact that flow is observed both towards the Earth and away from it means that these losses occur not only by dissipation of energy in the Earth's polar regions, as seen in auroral substorms, but also through the formation and departure tailward into the solar wind of 'plasmoids' consisting of a large portion of the plasma and magnetic field stored in the plasma sheet. The ISEE geotail mission has observed such tailward moving 'plasmoids', i.e. blobs of plasma in closed magnetic loops no longer connected to Earth and released near the Earth at the onset of corresponding geomagnetic activity (Fig. 5).

Whilst the near-Earth plasma flow is mostly earthward, a consistent feature of the distant plasma sheet is tailward flow, i.e. flow away from the Earth, of both the plasma and the energetic ion populations. Flow speeds of 500 km/s have been observed, which are considerably higher than those usually observed within the quiet-time, near-Earth plasma sheet. Tailward flow suggests that the acceleration region where the particle flow originates lies between the Earth and the observation point, typically somewhere at a distance of about 60–100 R_e from Earth. The acceleration region is believed to be near a neutral line, i.e. a region where the oppositely directed magnetic field lines reconnect, and the annihilated magnetic energy is converted into kinetic particle energy. Occasionally, earthward flow has also been observed in the distant tail, which may be related to substorm phenomena and auroral activity, as the neutral line moves to great distances down the tail.

There will certainly be more results forthcoming as the scientists involved progress in their data analysis. Correlation studies with other spacecraft are just beginning. Specifically, the correlation of the near-Earth ISEE-1/2 measurements with those of ISEE-3 in the distant tail is expected to demonstrate the scientific power of coordinated multispacecraft observations.

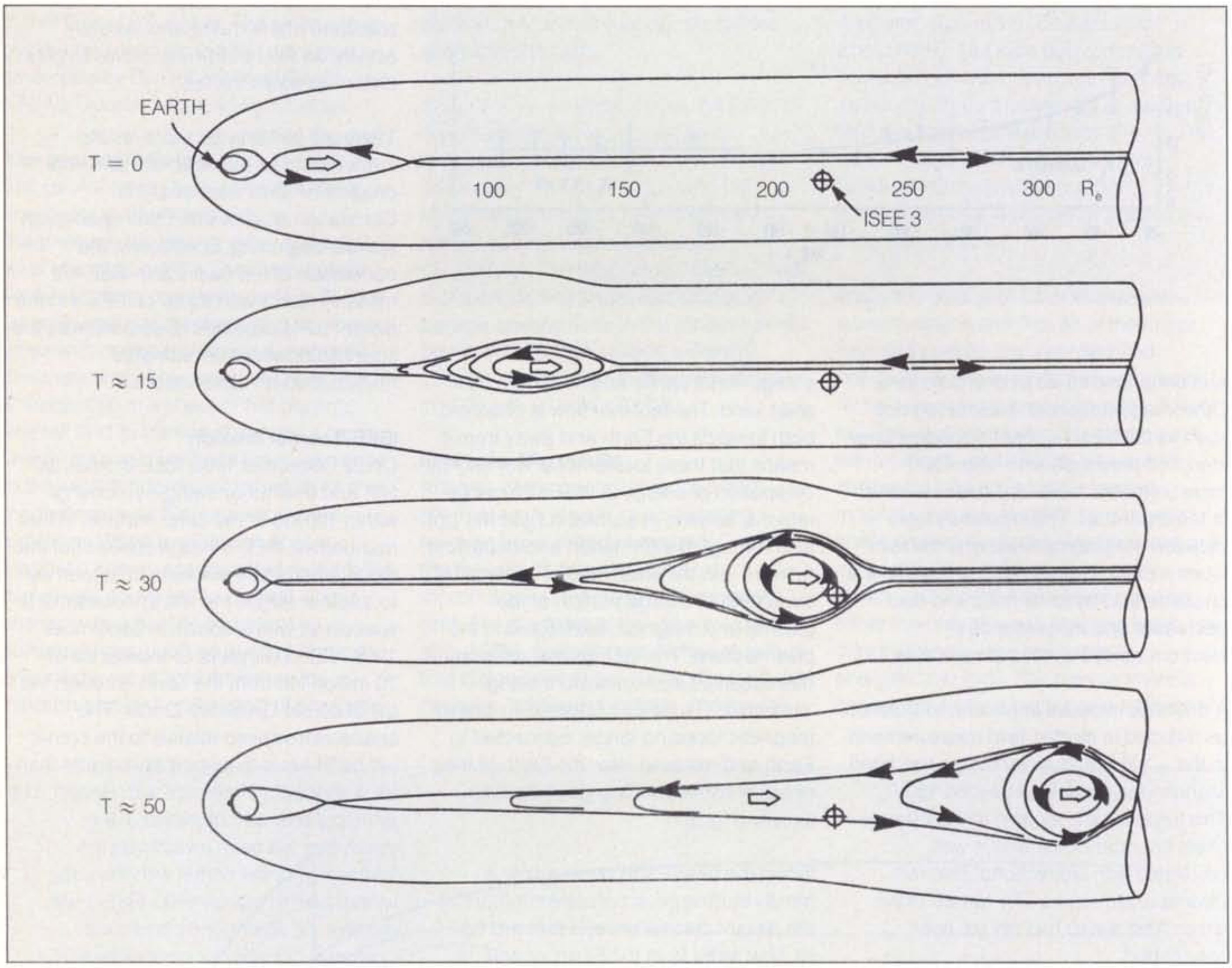
ISEE-3 comet mission

On 22 December 1983, ISEE-3 made its fifth and final lunar swing-by, coming within 100 km of the lunar surface. In this manoeuvre, ISEE-3 was propelled out into the interplanetary medium, on a journey to another target, the first encounter of a spacecraft with a comet. In September 1985, ISEE-3 will pass, at a distance of 70 million km from the Earth, through the tail of comet Giacobini-Zinner. The spacecraft's speed relative to the comet will be 21 km/s (substantially smaller than for a spacecraft intercept with Halley). The principal scientific objective of the encounter will be to investigate the interaction of the comet with the solar wind. Later, in March 1986, ISEE-3 will monitor the solar-wind conditions upstream of Halley's comet while ESA's Giotto, the Russian Vega and Japan's Planet-A missions get a close-up view. ISEE-3 was recently renamed the 'International Cometary Explorer' (ICE).

Conclusion

The ISEE-3 geotail and comet missions were conceived and planned when the spacecraft had already been in orbit for several years and had achieved its original mission objectives. These missions therefore provide a 'bargain of new science' at times when spacecraft missions are tending to become more and more costly; they also demonstrate what can be achieved by human ingenuity years after a spacecraft has been put into orbit.

Figure 5 – Model of a tailward-moving plasmoid, interpreting the ISEE-3 results. The plasmoid is identified by closed magnetic loops. Black arrows depict the magnetic-field direction, white arrows plasma flow. The approximate location of ISEE-3 is indicated. Time T (in minutes) is measured from the start of geomagnetic activity



The International Sun-Earth Explorer programme has been a cooperative three-spacecraft programme between NASA and ESA. It started with the launch, in October 1977, of ISEE-1 and ISEE-2, built by NASA and ESA, respectively, into a highly eccentric orbit around the Earth with an apogee of 23 R_e. These two spacecraft, flying in the same orbit with a controllable separation distance, have provided a wealth of new data on the near-Earth magnetosphere and its boundaries. This international programme has been highly successful and has greatly improved our understanding of many physical processes governing the surroundings of our planet. Many of its achievements will certainly inspire the plans for the International Solar-Terrestrial Physics (ISTP) programme that is currently under study by the scientific communities and space agencies in Europe, the USA and Japan.

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

In Orbit / En orbite

	PROJECT	1984–1990 (J F M A M J J A S O N D)	COMMENTS
SCIENTIFIC PROG.	ISEE-2		
	IUE		
	EXOSAT		
APPLICATIONS PROGRAMME	OTS-2		1.5 YEAR HIBERNATION PHASE
	MARECS-1		
	METEOSAT-1		LIMITED OPERATION ONLY (DCP)
	METEOSAT-2		
	ECS-1		LIFETIME 7 YEARS

Under Development / En cours de réalisation

	PROJECT	1984–1990 (J F M A M J J A S O N D)	COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE		LIFETIME 11 YEARS
	ISPM		LIFETIME 4.5 YEARS
	HIPPARCOS		PRELIMINARY SCHEDULE
	GIOTTO		HALLEY ENCOUNTER MARCH 1986
APPLICATIONS PROGRAMME	ECS-2, 3, 4 & 5		
	MARECS-2		LIFETIME 5 YEARS
	OLYMPUS-1		LIFETIME 5 YEARS
	ERS-1		LAUNCH END 2ND QUARTER 1988
	METEOSAT-P2		
SPACELAB PROGRAMME	SPACELAB	FLIGHT 2	
	SPACELAB FOP		
	IPS		
	SLP		
	MICROGRAVITY		
	EURECA		
ARIANE PROGRAMME	ARIANE PRODUCTION	L8 L9 L10 L11 L12	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

The main IUE antenna at ESA's Villafranca (Madrid) ground station

L'antenne principale d'IUE, à la station terrienne de Villafranca

ISEE

Voir pages 46–50.

IUE

IUE continue à fonctionner de façon satisfaisante et recueille des spectres UV d'objets célestes de toutes classes. La situation du véhicule spatial et des instruments scientifiques sera examinée lors d'une réunion tripartite en octobre 1983 après la saison d'éclipses (no. 12). Pendant les périodes d'éclipse, d'une durée de quinze jours, qui se produisent deux fois par an, le satellite pénètre chaque jour pendant 70 min dans l'ombre de la Terre. Ces périodes sont critiques car plusieurs sous-systèmes doivent être mis hors tension et la batterie de bord est considérablement sollicitée. Il semble toutefois que le satellite traverse ces périodes sans problème majeur et que les opérations scientifiques n'en soient pratiquement pas affectées; en ce qui concerne les Européens le temps d'observation perdu n'est que de 30 min par jour pendant deux semaines.

La mise au point du nouveau logiciel de commande du véhicule spatial basé sur l'utilisation de deux gyroscopes et du détecteur solaire fin est terminée et il a été accepté. Il ne sera mis en oeuvre qu'en cas de défaillance de l'un des trois gyroscopes opérationnels.

Une anomalie de la chambre à grande longueur d'ondes redondante vient d'être décelée: une large tache brillante apparaît lorsque le temps d'exposition est supérieur à une heure. Les ingénieurs responsables de cette chambre pensent que cette anomalie est due à un éclat lumineux qui se produit dans le convertisseur UV. En effet, une réduction de la haute tension du convertisseur UV supprime le phénomène en diminuant de 50% la sensibilité globale. Lors de la réunion tripartite, il a été décidé d'utiliser la chambre principale à grande longueur d'onde comme instrument opérationnel et la chambre redondante comme réserve.

Après la réussite du lancement d'Exosat, on est revenu sur plusieurs propositions IUE approuvées nécessitant des observations simultanées ou coordonnées dans le rayonnement X pour les programmer conjointement avec les observations d'Exosat. Cette opération a demandé, de la part des responsables des calendriers des deux Observatoires, un effort considérable pour tirer le meilleur parti de cette possibilité exceptionnelle d'observations simultanées en rayonnement X et UV (et même dans certains cas les plages optique, infrarouge et radioélectrique). Les premières observations conjointes qui ont commencé en août ont porté sur des objets B Lac, des noyaux de Seyfert et des binaires émettant des rayons X.

L'appel de propositions d'observations pour la septième année a été envoyé immédiatement après la réunion du SPC du 21 juin au cours de laquelle la prolongation de l'exploitation d'IUE en 1984 a été approuvée.

La nouvelle base de données IUE est désormais pleinement opérationnelle à Villafranca. Elle permet une interrogation interactive du journal d'observations le plus récemment mis à jour (plus de 32 000 images) et les astronomes qui viennent de visiter l'Observatoire ont apprécié son utilité pour la préparation des équipes d'observation ou pour la recherche des spectres IUE existants.

La bibliographie IUE augmente régulièrement: 561 articles référencés ont paru dans les principales revues dont 262 basés sur des spectres recueillis à la station européenne.

ISEE

See pages 46–50 of this issue.

IUE

IUE continues to perform satisfactorily collecting UV spectra of all classes of celestial objects. The status of the spacecraft and of the scientific instrument was reviewed at the three-Agency meeting in October, after eclipse season 12. During the eclipse fortnights, which occur twice a year, the satellite enters into the Earth's shadow every day for as long as 70 min. This is a critical event because several subsystems have to be switched off and a considerable current is drained from the batteries on-board. Nevertheless, IUE seems to overcome these critical periods without major problem and with a minimum impact on the scientific operations; on the European side, only 30 min of observations are lost each day during the two weeks.

The new spacecraft-control software, which makes use of only two gryos plus the fine Sun sensor, has been completed and approved. It will be used only in case of a failure in one of the three operational gyroscopes.

An anomaly has recently been detected in the long-wavelength redundant camera: an extended bright spot becomes visible in exposures longer than an hour. Camera engineers believe it is due to a flare in the UV converter. Indeed, a reduction in the high voltage applied to the UV converter cures the problem, with a 50% reduction in the overall sensitivity. A decision to declare the long-wavelength prime camera as the operational one and the LWR as back-up was taken at the three-Agency meeting.

After the successful launch of Exosat, several IUE approved proposals requiring simultaneous or coordinated X-ray observations were unfrozen and scheduled jointly with Exosat. This exercise demanded a considerable effort from the schedulers of both Observatories, in order to take full advantage of the unique opportunity of simultaneous observations in X and UV ranges (sometimes also including optical, IR and radio). The first joint observations, which began in August, concerned BLac objects, Seyfert nuclei and X-ray binaries.

The call for proposals for the seventh year was issued immediately after the SPC meeting of 21 June, where the extension of IUE operations during 1984 was approved.

At Villafranca, the new IUE data base is now fully operational. It allows an interactive interrogation of the most recently updated log of observations (more than 32 000 images) and its usefulness for the preparation of observing shifts or for searching existing IUE spectra has been appreciated by the astronomers who have recently visited the Observatory.

The bibliography on IUE increases steadily: 561 referenced papers appeared in the main journals; of these 262 were based on spectra collected at the European station.

OTS

Following the successful launch of ECS-1, and its entry into service on 12 October 1983, EUTELSAT is now planning to terminate the use of OTS by 30 December of this year.

OTS has operated successfully, well beyond the nominally specified three-year mission period, and will have completed five and a half years of service by the end of 1983, still providing three working channels out of four in the broadband Module-A payload. The platform is fully functional (see page 72 of this issue).

The deadband for north-south and east-west station-keeping was maintained to ±0.1° until the middle of 1983. Since then, station-keeping has been restricted to east-west only to conserve the small amount of fuel remaining. Consequently, the north-south inclination will increase slowly at a rate of about 0.9° per year as a result of luni-solar orbit perturbations.

The other expendables, such as solar power and battery capacity, still show remarkable, above standard performance.

Beginning in January 1984, a series of 'end of service' tests will be performed. Following this, it is planned to execute a one and a half year 'hibernation' phase with OTS, to collect further essential information on the satellite's long-life performance. This information will be of direct relevance to commercial missions such as Marecs and ECS, with their lifetime requirements of seven years, and to future derivatives, with a ten-year life objective.

Meteosat

Space segment

The full Meteosat mission is still carried out by the combined services of Meteosat-1 (receiving messages from Data Collection Platforms) and Meteosat-2 (imaging and dissemination of data). In November, Meteosat-1 passed its sixth year in orbit; it was launched on 23 November 1977. Meteosat-2 has been in orbit two and a half years, having been launched on 19 June 1981.

At the Meteosat Programme Board, held on 17 November 1983, approval was given to prepare and launch the Meteosat-P2 model with the first test of Ariane-4, now scheduled for March 1986.

Ground segment/operations

Meteosat operations have continued in a satisfactory manner, except for a temporary breakdown in the transmission of data between the Odenwald Ground Station and ESOC, resulting in either the loss or corruption of some image data lines. The equipment involved is now seven years old and will have to be replaced in the near future. Ten new DCP receivers and the WEFAX DCP retransmission equipment have been installed in the ground station. The GOES relay in Lannion (France) will continue to operate at least until the end of 1984.

Marecs

While Marecs-A is successfully completing its second year of orbital operation for INMARSAT over the Atlantic-Ocean region, Marecs-B2 reached its final stage of integration and test. Following formal acceptance by ESA, the spacecraft and its ground-support equipment are being

OTS

ECS-1 ayant été lancé avec succès et mis en service le 12 octobre, Eutelsat prévoit maintenant de mettre fin à l'utilisation d'OTS pour le 30 décembre prochain.

OTS a fonctionné de façon satisfaisante bien au-delà des trois ans spécifiés pour la mission et, en fin 1983, il aura en fait assuré cinq années et demi de service avec encore trois des quatre canaux de la charge utile bande-large du module A en état de marche. La plate-forme est pleinement opérationnelle.

Le maintien à poste nord-sud et est-ouest a été assuré avec une précision de ±0,1° jusqu'à la mi-1983. Depuis lors, seul a été assuré le maintien à poste est-ouest, afin de conserver le peu d'ergol restant. L'inclinaison nord-sud va donc augmenter lentement, de 0,9° par an environ, sous l'effet de perturbations orbitales induites par la lune et le soleil.

En ce qui concerne les autres matières consommables, à savoir l'énergie solaire et l'énergie fournie par la batterie, on continue d'observer des performances remarquables, nettement supérieures à la normale.

A partir de janvier 1984 aura lieu une série d'essais de 'fin de service' après lesquels il est prévu de soumettre OTS pendant un an et demi à une phase 'd'hibernation' afin de pouvoir continuer à recueillir des informations essentielles sur la longévité du satellite. Ces données présentent en effet un intérêt direct pour des missions commerciales comme celles de Marecs et d'ECS qui exigent une vie opérationnelle de sept ans, ainsi que pour les dérivés futurs de ces satellites, pour lesquelles on vise une durée de vie de dix ans.

Météosat

Secteur spatial

La mission Météosat continue d'être assurée intégralement grâce aux services combinés de Météosat-1 (réception de messages des plates-formes de collecte de données) et de Météosat-2 (prise d'images et diffusion des données). Météosat-1, lancé le 23 novembre 1977, vient de passer le cap de sa sixième année en orbite tandis que Météosat-2 gravite sur orbite depuis deux ans et demi, puisqu'il a été lancé le 19 juin 1981.

A sa réunion du 17 novembre 1983, le Conseil directeur du Programme Météosat a donné le feu vert à la préparation du modèle Météosat-P2 et à son lancement à l'occasion du vol d'essai Ariane-4, actuellement prévu pour le mois de mars 1986.

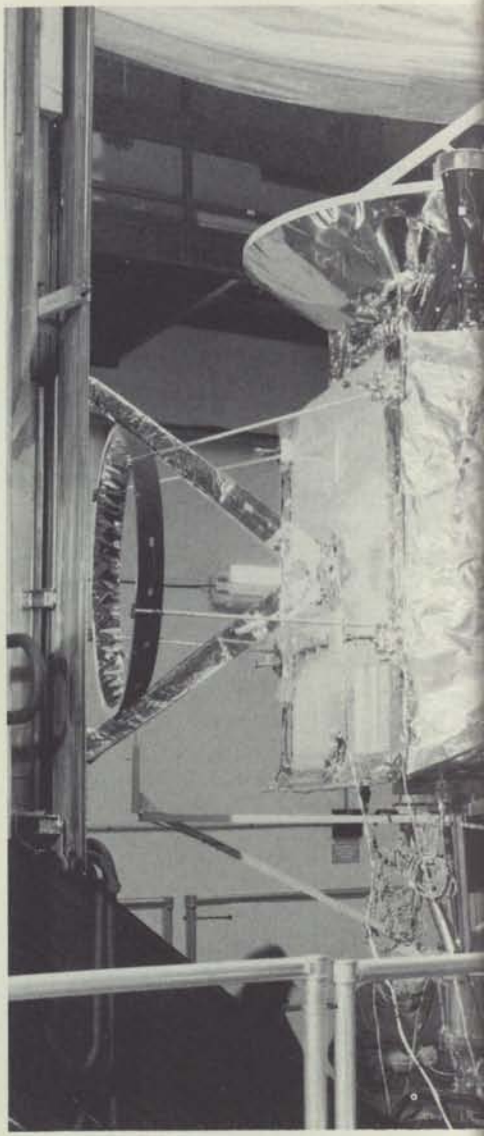
Secteur sol/opérations

Les opérations de Météosat se sont poursuivies de façon satisfaisante, à l'exception d'une interruption temporaire de la transmission des données entre la station sol de l'Odenwald et l'ESOC qui a entraîné la perte ou la dégradation de quelques lignes de données d'image. L'équipement en cause a maintenant sept ans et doit être remplacé prochainement. Dix nouveaux récepteurs de données de DCP et l'équipement de retransmission WEFAX ont été installés à la station sol. Le relais GOES de Lannion (France) continuera de fonctionner au moins jusqu'à la fin de 1984.

Marecs

Alors que Marecs-A termine avec succès, pour le compte d'Inmarsat, sa seconde année d'opérations en orbite au-dessus de l'Atlantique, Marecs-B2 est parvenu au stade final de l'intégration et des essais. Après sa recette officielle par l'ESA, le satellite et son équipement de soutien au sol font actuellement l'objet d'un conditionnement spécial en prévision de la longue période d'entreposage qui les attend avant le lancement.

Marecs-B2 doit être lancé en fin septembre 1984 avec le satellite américain Spacenet-2 par un Ariane-3 (L-12).



Marecs-B2 undergoing solar-simulation testing at Sopemea's facilities in Toulouse (France)

Essai de simulation solaire de Marecs-B2 dans les installations de la Sopemea à Toulouse

Télescope spatial

NASA

La nouvelle date de lancement du Télescope spatial n'a pas encore été officiellement fixée, mais le déroulement du projet se poursuit en fonction d'un lancement à la mi-1986.

Réseau solaire

Le premier modèle de vol du mécanisme de commande du réseau solaire a subi avec succès la totalité du programme des essais de recette et a été livré à BAe, qui en commence l'assemblage avec le mécanisme de déploiement principal et les équipements connexes.

Les boîtiers électroniques ont été livrés à Lockheed, le contractant principal de la NASA pour le Télescope spatial, pour des vérifications d'assemblage avec le véhicule spatial. Les résultats ont été satisfaisants.

Chambre pour astres faibles (FOC)

Au cours de la période écoulée, le modèle de vol de la FOC a subi avec succès l'essai acoustique et un essai thermique sous vide et l'étalonnage a été exécuté dans la chambre d'essais dynamiques (DTC) de l'ESTEC. Après un examen préliminaire satisfaisant avec la NASA, il a

prepared for long-term storage, until called for launch.

Launch is nominally scheduled for the end of September 1984, on the Ariane-3 L-12 vehicle, together with the US spacecraft Spacenet-2.

Space Telescope

NASA
No formal decision on the new Space Telescope launch date has yet been taken, but the project is proceeding on the basis of a launch in mid-1986.

Solar array
The first flight-model solar-array drive mechanism has passed its full acceptance test programme and has been delivered to British Aerospace, who are starting assembly with the primary deployment mechanism and associated hardware.

Electronic boxes were delivered to Lockheed, NASA's Space Telescope prime contractor, for fit checks with the spacecraft. These have been completed satisfactorily.

Faint Object Camera
The Faint Object Camera (FOC) flight model has successfully completed the acoustic test, and a thermal-vacuum test and calibration were carried out in the ESTEC test chamber. After a satisfactory pre-ship review with NASA, it was agreed to ship the FOC to Goddard Space Flight Centre for electrical and software interface testing with the other Space Telescope scientific instruments and the ST Scientific Instruments Command and Data Handling System. This phase will last until March 1984. Subsequently, a further calibration might be considered. The flight-spare Photon-Detector-Assembly programme is proceeding as scheduled.

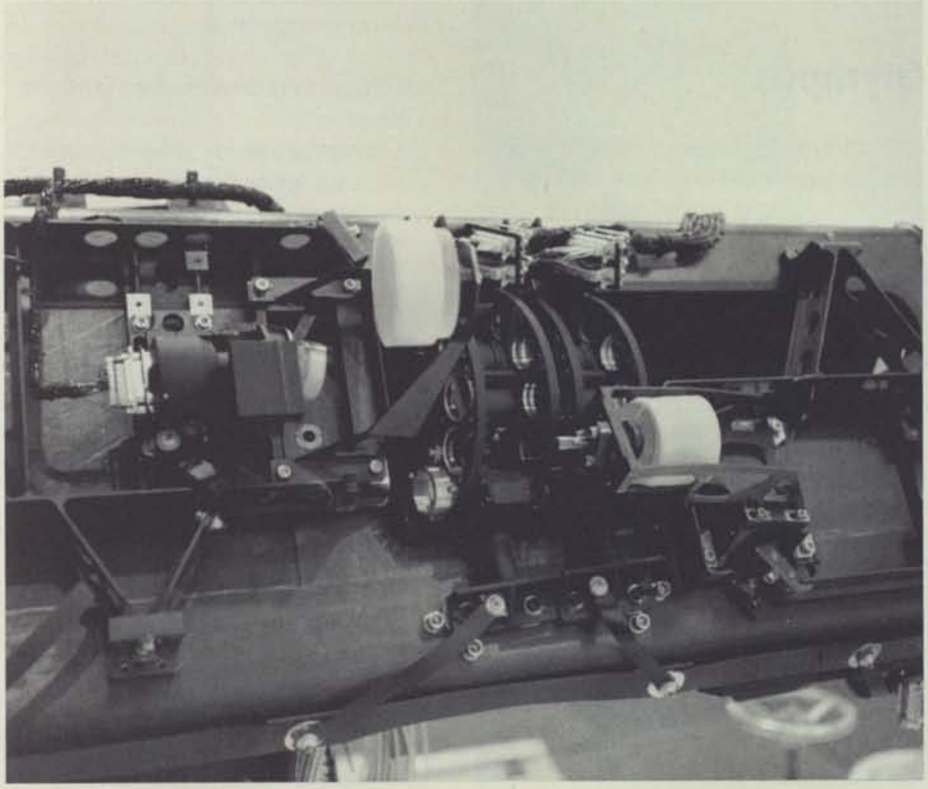
Hipparcos

The industrial proposal for the main development phase (Phase-C/D) of the programme has been received and evaluated by ESA. On the basis of the evaluation results, the Science Programme Committee (SPC) has authorised the initiation of Phase-C/D, and following submission to the Industrial Policy Committee (IPC) – in December – it is expected that this phase will start in January 1984.

In parallel with these evaluation and approval activities, the continuing detailed definition-phase (Phase-B2) work is concentrated on the subsystem-level Preliminary Design Reviews, which are planned to be completed for both payload and spacecraft before the start of Phase-C/D.

Giotto

The electrical-model programme is progressing well, all subsystems and experiment integration having been completed in early November. The first system-level electromagnetic compatibility test was completed by the third week of



Unité de vol de la chambre pour astres faibles du Télescope spatial, avec mécanisme porte-filtres

Flight unit of Space Telescope's Faint Object Camera (FOC), showing filter-wheel mechanism (with filters installed) *été convenu d'expédier la FOC au Centre spatial Goddard pour les essais d'interfaces électriques et logicielles avec les autres instruments scientifiques du Télescope spatial et le système de télécommande et de traitement des données des instruments scientifiques. Cette phase durera jusqu'en mars 1984. Le programme relatif au modèle de vol de rechange du détecteur de photons avance conformément au calendrier.*

Hipparcos

L'Exécutif a reçu et évalué la proposition industrielle relative à la Phase de développement (Phase-C/D). Au vu des résultats de cette évaluation, le Comité du programme scientifique a autorisé la mise en route de la Phase-C/D qui, après soumission au Comité de la politique industrielle en décembre, devrait être mise en route en janvier 1984.

Parallèlement à ces procédures d'évaluation et d'approbation, les travaux de la phase de définition détaillée (B2) se poursuivent; ils sont plus particulièrement axés sur les examens préliminaires de conception au niveau sous-système qui, selon les plans, devraient être terminés, tant pour la charge utile que pour le satellite, avant le démarrage de la Phase-C/D.

Giotto

Le programme du modèle électrique progresse de façon satisfaisante et l'intégration de tous les sous-systèmes et expériences s'est achevée début novembre. Le premier essai de compatibilité électromagnétique au niveau système était terminé pour la troisième semaine de novembre et on en analyse actuellement les résultats. Le véhicule spatial va maintenant être réexpédié à la chambre propre de British Aerospace, Filton, où se poursuivront l'élaboration du logiciel et les essais de pointage d'antenne.

Le programme du modèle électrique devrait être terminé en janvier 1984, après conduite à bon terme des essais de fonctionnement du véhicule spatial au niveau système. Les sous-systèmes du modèle de vol sont en cours de livraison; le sous-système 'structures' doit être livré à Filton avant la fin du mois de novembre. Les livraisons des autres sous-systèmes se poursuivront jusqu'à janvier-février 1984, la charge utile expérimentale devant pour l'essentiel être disponible en février-mars 1984. Un certain nombre de problèmes de calendrier se sont posés tant pour les sous-systèmes que pour la charge utile et l'on s'efforce tout particulièrement d'en réduire les effets. Le démarrage du programme des essais de systèmes à effectuer sur le modèle de vol reste fixé à juin 1984 et la livraison du satellite est toujours prévue pour le 31 janvier 1985.

Des négociations préliminaires ont été entamées au sujet de l'utilisation du véhicule Ariane 1 existant; elles seront terminées début 1984.

Sur le plan international aura lieu à Tokyo, du 12 au 16 décembre 1983, une réunion d'un Groupe consultatif interagences à laquelle participeront l'ESA, les Etats-Unis, l'URSS et le Japon. L'un des principaux objectifs de la réunion sera la recherche d'un accord sur la mise en oeuvre du concept dit de 'l'éclaireur' prévoyant la mise à disposition, par la mission russe Vega, de données mesurées sur les éphémérides de la comète dans le but d'améliorer le pointage de Giotto sur son noyau.

Olympus

Les examens des bases de référence de développement ont été effectués dans l'industrie pour près de la moitié des sous-systèmes en cause. Les examens restants, prévus pour le prochain trimestre, conduiront à l'examen de la base de référence de développement au niveau système que doit effectuer l'Agence.

La plupart des équipements du modèle de développement du sous-système de propulsion unifié ont été achevés et livrés prêts à être intégrés; des éléments du modèle de développement du réseau solaire ont été fabriqués et subissent actuellement les essais.

La fabrication des modèles de structure et thermique du véhicule spatial se poursuit en même temps que les préparatifs des essais 'système' qui doivent être exécutés sur ces modèles l'an prochain. Certains des équipements du modèle d'identification ont été construits après les examens de conception correspondants.

L'élaboration d'un plan d'ensemble pour l'utilisation d'Olympus et la mise en oeuvre du secteur sol est en cours. L'Union Européenne de Radiodiffusion et la RAI italienne ont demandé à utiliser la charge utile de radiodiffusion d'Olympus.

Spacelab

Le lancement de Spacelab-1 (SL-1) à bord de la Navette Columbia a eu lieu le 28 novembre dernier à 11 heures (heure locale) du Centre spatial Kennedy (KSC). Quatre heures après le lancement, l'équipage pénétrait dans le Spacelab dont tous les équipements étaient mis sous tension 6 h 40 après le lancement.

La mission a duré dix jours, elle a été prolongée d'un jour pour des raisons scientifiques; pendant tout ce temps, le système Spacelab a parfaitement fonctionné conformément aux spécifications, assurant le soutien de l'équipage et des expériences de façon tout à fait remarquable.

Seules deux anomalies de quelque importance ont été décelées, elles n'ont entraîné la perte d'aucune donnée d'expérience essentielle.

Tous les objectifs de vérification de SL-1 ont été atteints:
- *Les charges au lancement étaient dans les limites des prévisions;*
- *Le sas scientifique a fonctionné une vingtaine de fois sans problème;*
- *Les températures du module, du porte-instruments et du sas scientifique ont été maintenues dans les limites de chaud et de froid spécifiées;*
- *Tous les systèmes de régulation thermique (eau/fréon/électronique aérospatiale) se sont comportés comme prévu;*
- *Le sous-système de régénération de l'air a assuré le confort de l'équipage grâce au contrôle de la température, de la teneur en oxygène/gaz carbonique et de l'hygrométrie;*
- *Le sous-système d'alimentation en électricité a fonctionné comme prévu;*
- *Le sous-système de commande et de*

November and the results are now being analysed. Following this test, the spacecraft will be returned to the clean room at British Aerospace, Filton, for further software-development activity and antenna-pointing tests.

It is expected that the electrical-model programme will be completed in January 1984 following successful conclusion of the spacecraft system functional test.

Flight-model subsystem deliveries are now taking place, the structure subsystem being delivered to Filton by the end of November. Other subsystem deliveries will commence through January and February 1984, with the experiment payload due in February/March 1984. Some schedule problems have been experienced both in the subsystems and the payload areas and efforts are being concentrated on minimising these effects. The system-level test programme for the flight model is still planned to start in June 1984, and the spacecraft delivery date is still 31 January 1985.

Preliminary negotiations for use of the existing Ariane-1 vehicle have been initiated and will be completed in early 1984.

On the international scene, an Inter-Agency Consultative Group meeting between ESA, the US, the USSR and Japan will be held in Tokyo from 12 to 16 December 1983. One of the main items will be to seek agreement on the implementation of the so-called 'pathfinder concept' whereby the USSR Vega mission would provide measured comet-ephemeris data to improve the targetting of Giotto at the nucleus.

Olympus

Development baseline reviews have now been held in industry for nearly half of the subsystems involved. The remainder are planned to be held during the forthcoming quarter and will lead to the System Level Development Baseline Review to be conducted by the Agency.

Most of the equipment items for the propulsion development module of the combined propulsion subsystem have been completed and delivered, ready for integration, while elements of the solar-array development model have been built and are under test.

Fabrication of the spacecraft structure and thermal models is continuing, together with the preparations for the system tests on these models next year. Some items of equipment for the engineering model have been built following their respective design reviews.

Work is continuing on preparation of an overall plan for Olympus utilisation and ground-segment implementation. Use of the Olympus broadcast payload has been requested by the European Broadcasting Union (EBU) and the Italian RAI.

Spacelab

(see also pages 6 – 31 of this issue)

The Spacelab-1 (SL-1) launch took place on 28 November at 11.00 EST from Kennedy Space Center, Florida aboard the Shuttle-Orbiter Columbia. The crew entered Spacelab four hours after launch and Spacelab activation was completed after a mission elapsed time of 6 h 40 min.

During the subsequent ten days of the mission (original nine-day mission extended by one day for science reasons) the Spacelab system worked well within its specified operating range and supported both crew and experiments in a highly satisfactory manner.

Only two anomalies of any magnitude were reported. No essential experiment data losses occurred due to these anomalies.

All the Spacelab-1 verification goals were met. In particular:

- Launch loads were within those predicted.
- The Scientific Air Lock (SAL) operated at least 20 times without any problems.
- The temperatures of the module, pallet and SAL were within specification, at both the hot and cold extremes.
- All thermal-control systems (water/freon/avionics) worked as planned.

M. James Beggs, Administrateur de la NASA (au centre) et M. Erik Quistgaard, Directeur général de l'ESA (à droite), reçus par le Président Ronald Reagan à la Maison Blanche pour célébrer le succès de la mission Navette/Spacelab

US President Ronald Reagan, NASA Administrator James Beggs (centre), and ESA Director General Erik Quistgaard (right) at a White House reception to celebrate the Space Shuttle/Spacelab success

System overview consoles in the Spacelab Customer Management Room at the Payload Operations Control Center in Houston (seated L. Tedeman of ESA)

Salle de gestion 'clients' du Spacelab au Centre de Contrôle des Opérations Charge utile au Centre spatial Kennedy (on reconnait L. Tedeman de l'ESA, surveillant les consoles)

gestion des données a lui aussi fonctionné comme prévu à l'exception de l'un des sept éléments d'acquisition des données des expériences. L'acquisition et le stockage des données scientifiques ont fonctionné de façon remarquable. Comme l'on ne disposait que d'un seul TDRS, l'enregistreur de données à haut débit a été utilisé intensivement pour 'vider' les données à 32 Mbit/s; une défaillance temporaire de cet enregistreur a été réparée par l'équipage;
Aucune panne n'a nécessité le recours au calculateur de réserve ni à aucun équipement redondant;
Le logiciel Spacelab utilisé dans le calculateur des sous-systèmes et dans celui des expériences a fonctionné comme prévu;
Des corrections ont été apportées au logiciel des expériences pour pallier la défaillance de l'équipement d'acquisition (RAU) des expériences. En plus de ces corrections, des manoeuvres de commande d'orientation ont permis un fonctionnement réduit du RAU. L'une de ces corrections a provoqué une interruption de fonctionnement du calculateur des expériences qui a été réparée par l'équipage en moins de 30 mn.

– *On a constaté que les fuites du module étaient extrêmement faibles.*

Les équipements du Spacelab ont été mis hors tension le 7 décembre à 2 h 18 (heure locale) et l'équipage a quitté le Laboratoire pour se préparer à la rentrée dans l'atmosphère et à l'atterrissage.

La Navette Columbia a atterri avec Spacelab à la base Edwards de l'Armée de l'Air américaine le 8 décembre à 3 h 47 (heure locale) après avoir parcouru 6 millions de kilomètres au cours d'un vol de 10 jours très réussi.

Columbia et Spacelab ont ensuite été réexpédiés par train au KSC, le Spacelab sera ramené dans le bâtiment 'Opérations et Vérification' et les préparatifs du vol SL-3, prévu pour novembre 1984, commenceront.

Production ultérieure (FOP)

Les travaux du consortium chargé du Spacelab se poursuivent suivant un calendrier révisé selon lequel le montage et les essais de l'igloo et des équipements connexes précèderont l'intégration du module chez le contractant principal, ERNO.

L'intégration du module court a repris après un arrêt temporaire décidé par l'ESA en attendant que la NASA ait décidé comment – et jusqu'à quel point – la mousse Pyrell utilisée à l'intérieur du module pouvait être ignifugée. La livraison du module court à la NASA est fixée au 31 juillet 1984. La livraison du tout dernier article actuellement sous contrat est prévue pour le 1er juillet 1985. Les planchers support-expériences ont subi les derniers essais de recette et ont été livrés à la NASA. Ils sont toujours entreposés chez le contractant principal et seront utilisés pour le projet D-1.

La mise au point de la configuration Igloo/Porte-instruments est en cours. La Section 'Expériences' sera prête pour les formalités de recette par le client en décembre 1983.

Des problèmes de corrosion ont été décelés dans les câbles utilisés pour le Spacelab et l'IPS: la question est encore à l'étude.

En ce qui concerne l'IPS, le déroulement de la FOP est en grande partie fonction de la situation du calendrier du programme C/D. Pour limiter au minimum l'incidence des retards de la phase C/D sur les préparatifs par la NASA de la mission Spacelab-3, un calendrier révisé de livraison des matériels phase-C/D et FOP a été arrêté entre l'ESA et Dornier avec l'accord de la NASA.

Microgravité

Biorack

Une série d'examens critiques de conception au niveau équipements s'est déroulé de début septembre à fin novembre. Ils se sont traduits par le gel des conceptions et l'autorisation de fabriquer le matériel de vol pour les équipements de conditionnement thermique (congélateur-réfrigérateur, incubateurs et enceintes passives), la boîte à gants et les 14 expériences du Biorack. Toutefois les configurations des

- The air revitalisation subsystem provided for crew comfort with correct temperature PPO_2/CO_2 and humidity control.
- The electrical power-distribution subsystem worked as planned.
- The Command and Data-Management Subsystem (CDMS) worked as planned, with the exception of one of the seven experiment data-acquisition units (RAUs). The system for the acquisition and storage of scientific data performed remarkably well. Since only one TDRS was available, the High-Data-Rate Recorder (HDRR) was used extensively to dump data at 32 Mbit/s; one temporary malfunction of the HDRR was rectified by the crew.
- There was no reason to select the back-up computer or any other redundant equipment due to Spacelab.
- The Spacelab software running in the subsystem computer and the experiment computer also functioned as planned. Patches were made to the experiment computer software to work around the defective experiment RAU. Attitude control, together with these patches, enabled reduced operation of the RAU. One of the patches caused a 'trap and stop' in the experiment computer; this was recovered by normal crew actions in less than 30 min.
- Leakage from the Spacelab Module was extremely low.

Spacelab was deactivated at 2.18 EST on 7 December and the crew left the laboratory to prepare for re-entry and landing.

Columbia landed at Edwards Air Force Base, California on 8 December at 3.47 PST after a very successful ten day flight during which it travelled 4.6 million miles.

Columbia and Spacelab have subsequently been ferried back to KSC, where Spacelab will be returned to the O&C Building and preparations started for the Spacelab-3 flight in November 1984.

Follow-On Production
Work in the Spacelab Consortium is proceeding on a revised schedule whereby the Igloo-related assembly and testing precedes Module integration at the prime contractor (ERNO).

Integration of the Short Core Module is now continuing, after a temporary halt was directed by ESA awaiting a NASA decision about how and to what extent the pyrell foam used inside the Module should be treated against flammability. Delivery of the Short Core Module to NASA is scheduled for 31 July 1984. Delivery of the very last FOP item presently under contract is 1 July 1985.

The Module Experiment Floors have passed final acceptance and have been delivered to NASA. These floors remain at the premises of the prime contractor for use by the D-1 Project.

Build-up of the Igloo/Pallet configuration is in progress. The Experiment Segment will be ready for customer acceptance in December 1983.

Corrosion problems have been experienced with the harnesses used in both Spacelab and IPS, this matter is still under investigation.

IPS-FOP events are largely determined by the schedule situation in the Phase-C/D programme. To minimise the impact of C/D delays on NASA's Spacelab-2 mission preparation, a consolidated C/D and FOP hardware delivery schedule has been agreed between ESA and Dornier, with NASA's concurrence.

Microgravity

Biorack
A series of Critical Unit Design Reviews have been completed in the period between September and end-November, which have resulted in freezing of the designs and the giving of the go-ahead for the manufacture of the flight hardware for the thermal conditioning units (freezer-cooler, incubators and passive units), the glovebox and the 14 Biorack experiments. The designs of the Incubators and the Passive Units were, however, accepted subject to the implementation of some necessary design changes.

A contract for the integration of the mission-peculiar equipment (electrical harness and air ducts) into the Spacelab racks (flight and training models) has been placed with industry, while the negotiations for a contract for the integration of the different units in the racks have nearly been completed.

The schedule remains a problem of concern: the incubator acceptance date has had to be put back by two months, but it is expected that this delay can be recovered subsequently with an optimised Biorack integration and testing scheme. The Biorack schedule is just compatible with the revised Spacelab D-1 mission schedule (launch August 1985).

IPS

Mechanical assembly of the flight model is nearing completion, but the requisite system-level qualification testing will delay the delivery date further, to early July 1984. There are a number of serious design problems still being resolved by the prime contractor, which may force ESA/NASA into several unattractive compromises regarding availability of IPS hardware and software for preparation of the Spacelab-2 flight, scheduled for March 1985.

The operational life of all actuators on the first IPS is limited to the first flight, after which a major retrofit will be required. The Spacelab-2 flight date can still be supported through compromises of this nature.

Eureca

Four months into Phase-B (definition phase) of the Eureca project, the Programme Requirements Review started on 24 November as planned. This review will last until the end of January 1984, however, due to its interference with the delayed Spacelab launch activities. Termination of the Eureca Phase-B activities is now planned for the end of April 1984.

With the exception of the Automatic Gradient Heating Facility, development of which is to be discontinued for cost reasons, all other core payload facilities (five) eligible for the first flight of Eureca have commenced Phase-B definition activities.

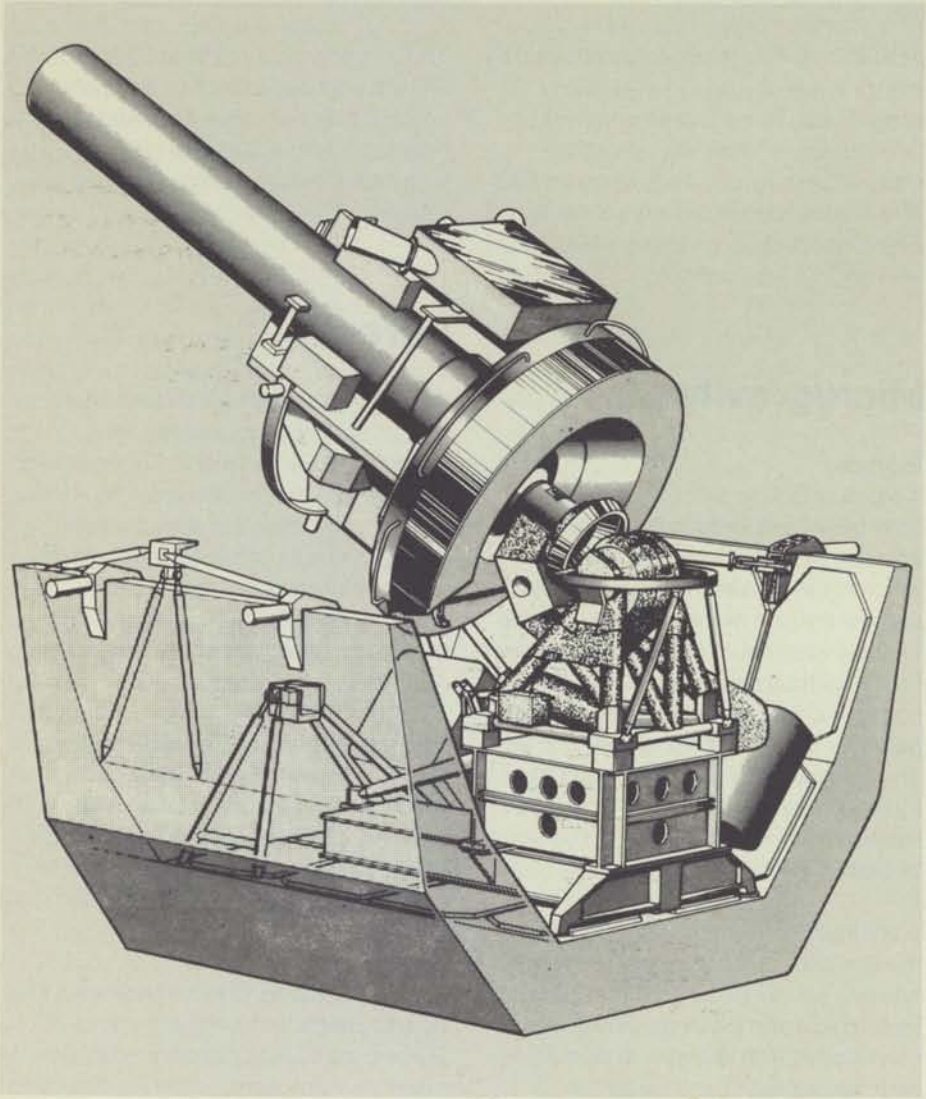
For the remainder of the experiments to be embarked on the first mission of Eureca, the selection peer groups have made their proposals to the Eureca *incubateurs et des enceintes passives ont été acceptées sous réserve de la mise en oeuvre de quelques changements de conception nécessaires.*

Un contrat pour l'intégration des équipements spécifiques à la mission (câblage électrique et conduits d'air) dans les bâtis du Spacelab (modèles de vol et d'entraînement) a été passé avec l'industrie; par ailleurs, les négociations en vue d'un contrat pour l'intégration des différents blocs d'équipements dans les bâtis sont presque terminées.

Le calendrier reste préoccupant; la date de recette des incubateurs a été reportée de deux mois mais il est probable que ce retard pourra être rattrapé en optimisant le programme d'essais et d'intégration du Biorack. Le calendrier du Biorack est tout juste compatible avec le calendrier révisé de D-1 (lancement en août 1985).

The Spacelab Instrument Pointing System (IPS)

Le Système de pointage d'instruments du Spacelab



IPS

Le montage mécanique du modèle de vol est presque achevé mais les essais de qualification nécessaires au niveau système retarderont encore la date de livraison jusqu'à début juillet 1984. Un certain nombre de problèmes de conception graves n'ont toujours pas été résolus par le contractant principal, Dornier System, ce qui contraint l'ESA et la NASA à accepter des compromis peu satisfaisants quant à la disponibilité des matériels et du logiciel de l'IPS pour la préparation du vol de Spacelab-2 fixé à mars 1985.

Il a été décidé de limiter la durée de vie opérationnelle de tous les actionneurs du premier IPS au premier vol, après quoi il faudra procéder à d'importantes adaptations. Sur cette base, la date de lancement de SL-2 peut encore être tenue.

Eureca

Quatre mois après le début de la phase-B du projet Eureca, l'examen des impératifs du programme a commencé comme prévu le 24 novembre. Cet examen durera jusqu'à fin janvier 1984 en raison du retard du lancement de Spacelab.

On prévoit aujourd'hui que les activités de phase-B d'Eureca seront terminées pour fin avril 1984.

A l'exception du four automatique à gradient qui sera abandonné pour des raisons financières, les activités de définition de phase-B ont commencé pour cinq autres installations du noyau de la charge utile susceptibles d'être retenues pour le premier vol d'Eureca.

En ce qui concerne le reste des expériences à embarquer sur la première mission d'Eureca, les groupes de sélection ont fait des propositions au Groupe de travail 'Charge utile d'Eureca'. Le Conseil directeur du Programme Spacelab devrait entériner ces recommandations vers fin janvier 1984. Les engagements de financement doivent être pris par les responsables des expériences d'ici fin mars 1984.

Les négociations concernant les accords sur l'intégration de la charge utile de la Navette et sur la revue de lancement sont en cours avec la NASA et l'on compte que des arrangements financiers satisfaisants pour les deux parties seront trouvés d'ici fin mars 1984. Le feu vert pour la phase-C/D du programme de développement d'Eureca doit être donné en juillet 1984, la date de lancement étant fixée pour octobre 1987.

Ariane

Développement complémentaire Ariane-2/3

Le programme de développement complémentaire Ariane-2/3 se trouve dans sa phase finale.

Toutes les études et essais systèmes ont été réalisés. Une ultime passe de calculs sera effectuée pour vérifier les valeurs des efforts généraux.

La qualification des différentes parties du lanceur est en cours d'achèvement avec la tenue des commissions de qualification

Payload Working Group. Endorsement of these recommendations by the Spacelab Programme Board is expected by the end of January 1984. Funding commitments by the experiment developers are required by the end of March 1984.

Shuttle Payload Integration and Launch Review Agreements discussions are in progress with NASA, and mutually satisfactory financial agreements are expected by the end of March 1984.

Programme go-ahead for Phase-C/D (main development phase) for Eureca is planned for July 1984, with a launch date in October 1987.

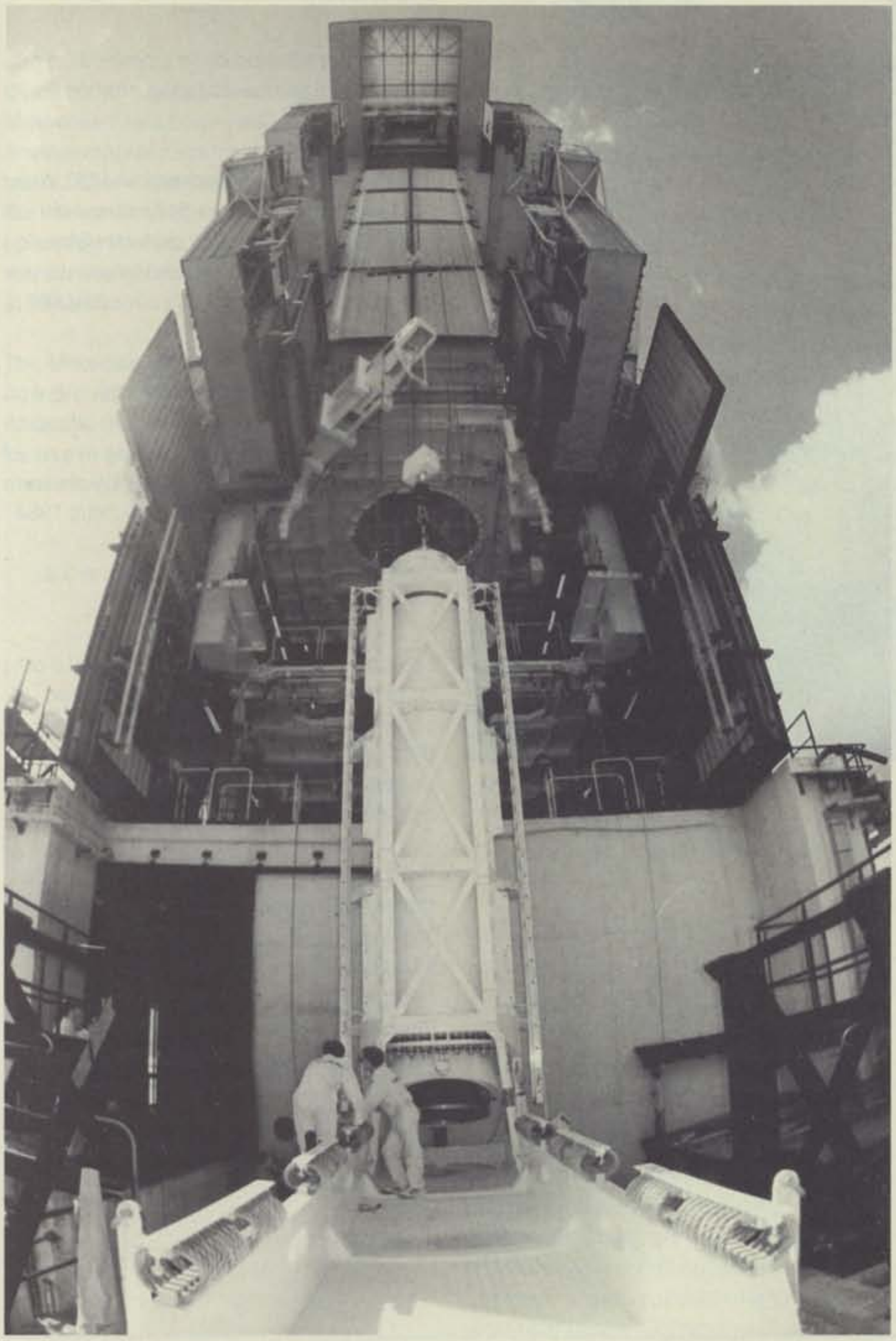
Ariane

Ariane-2/3 Follow-On Development
The Ariane-2/3 Follow-On Development programme is in its final phase.

All the system studies and tests have been completed. A final computer run will be made to verify the values of the general loads.

Essais d'érection des propulseurs d'appoint du lanceur Ariane-3, effectués sur le site d'ELA-1

Assembly tests with Ariane-3 strap-on boosters at the ELA-1 launch site



Qualification of the various parts of the launcher is nearing completion. The meetings of the qualification boards started in the last quarter of 1983 and will end after the last test of the third-stage propulsion system scheduled for mid-February 1984.

As the programme does not provide for a qualification flight, qualification will be certified on the basis of the results obtained from the ground tests. The last meeting of the Ground Qualification Board is planned for March 1984.

In the course of November 1983, a CSG facilities validation exercise was carried out in order to test their ability to attach the boosters to the structure of the first stage. The results obtained were very satisfactory.

The Flight Readiness Review (FRR) for the first Ariane-3 launcher has been scheduled so that the first launch in Ariane-3 configuration from ELA-1 can take place after the end of May 1984.

The first three launchers, intended for operational purposes, will however carry technological telemetry to provide additional data on the functioning of the various systems and equipment.

For the first time, the chamber pressure setting for the Viking engines (first and second stages) will be raised to 58.5 bar (instead of the 53.5 bar for Ariane-1) which, with the assistance of the solid-propellant boosters, will allow a payload of 250 kg to be placed in transfer orbit.

Assembly tests with Ariane-3 strap-on boosters at the ELA-1 launch site

Essais d'érection des propulseurs d'appoint du lanceur Ariane-3, effectués sur le site d'ELA-1

qui ont débuté au dernier trimestre 1983 et se termineront après le dernier essai de l'ensemble propulsif du troisième étage prévu mi-février 1984.

Le programme ne prévoyant pas de vol de qualification, celle-ci sera prononcée sur la base des résultats obtenus lors des essais au sol.

La dernière réunion de la Commission de Qualification au sol est programmée en mars 1984.

Au cours du mois de novembre 1983, une opération de validation des moyens du CSG s'est déroulée, afin de tester leur capacité à effectuer l'accrochage des propulseurs d'appoint à la structure du premier étage.

Les résultats obtenus ont été très satisfaisants.

La Revue d'Aptitude au Vol (RAV) du 1er lanceur Ariane-3 est prévue en mars 1984 de façon à permettre le premier lancement en configuration Ariane-3 à partir de l'ELA 1 dès fin mai 1984.

Les trois premiers lanceurs, destinés à des lancements opérationnels, comportent cependant une télémesure technologique destinée à donner des informations complémentaires sur le fonctionnement des différents systèmes et équipements.

Pour la première fois la pression foyer des moteurs Vikings (1er et 2ème étages) sera réglée pour le vol à 58,5 bars (au lieu de 53,5 pour Ariane-1) permettant avec l'appoint des propulseurs à poudre la mise en orbite de transfert d'une charge utile de 2580 kg.

Improved Antarctic Meteorological Data Collection – Meteosat Provides the Key

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A. Robson, Meteosat Exploitation Project, European Space Operations Centre (ESOC), Darmstadt, Germany

Since its launch in November 1977, Meteosat-1 has been relaying environmental data from remote sites to users. After experiments to determine the extremes of coverage of the data-collection system, operational systems were installed on the Antarctic continent in 1982/83.

The Meteosat data-collection system is now providing an important channel for Antarctic meteorological data destined for use in global weather analysis and medium-range forecasting.

Introduction

During the past decade there has been a growing demand for Antarctic synoptic surface meteorological and upper air reports to be rapidly disseminated throughout the Global Telecommunications System (GTS) of the World Meteorological Organisation (WMO). This has led to greater demands on the conventional HF radio-teleprinter circuits in an area of the World where radio reception is often subject to interference from the polar ionosphere, and frequently causes delayed data transmission or loss between Antarctic and meteorological centres on the neighbouring continents. Not much further improvement can be coaxed out of conventional HF communications systems and the development of the geostationary meteorological satellite with data-collection capability offers a solution to both the interference problem and to the timely delivery of synoptic reports at the main meteorological-analysis centres in Washington, Bracknell and Melbourne on the Main Trunk Network of the GTS.

The history of Antarctic meteorological communications is closely linked with changes of emphasis in Antarctic meteorology. There have been several distinct phases. Up until the International Geophysical Year (IGY) (1957–1958), Antarctic meteorology was mainly a matter of describing climatological features. An exception was the Antarctic Peninsula region where a meteorological network and forecast service was developed in the Falkland Islands and Dependencies in support of a thriving whaling industry. Communication was by HF radio morse transmissions. During the IGY, the network of stations was established by many countries and grew to cover the whole continent so that a larger communications network developed. During the 1960s, this network developed further as part of the Antarctic Treaty concept of data exchange. The countries and continents neighbouring the Antarctic needed the data to improve synoptic analyses and forecasts. New radio-teletype circuits and broadcasts were established, and links with the GTS were formalised. The main meteorological developments were associated with polar physical meteorology and with a better understanding of Antarctic weather systems as part of the Global Atmospheric Research Programme (GARP).

By the mid 1970s, hemispheric numerical models of the atmospheric circulation had developed into global models. This development culminated in the First GARP Global Experiment (FGGE) in 1979 when data from all regions of the globe was required by the main research and analysis centres. The largest concentration of computer power capable of handling global models is located in the northern hemisphere and Antarctic data must traverse a long communications chain into and through the GTS to the global-analysis centres.

The advent of polar-orbiting satellites in 1967 and geostationary meteorological satellites in 1975 (GOES) and 1977 (Meteosat), respectively, opened the way for reliable, rapid communications from remote areas.

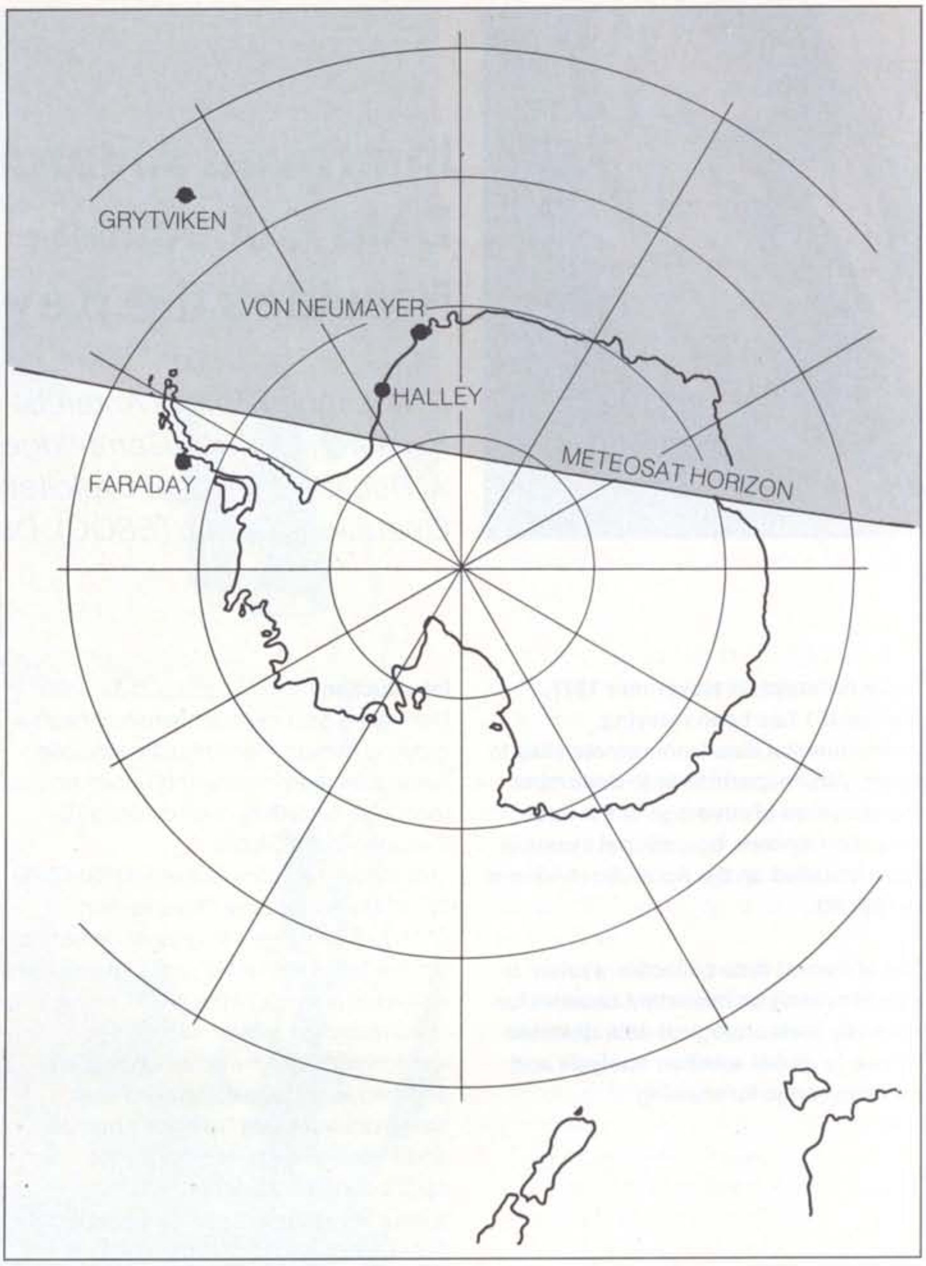


Figure 1 — Meteosat-1 Antarctic DCP coverage

Weather and climate* of the Antarctic

The Antarctic is the coldest continent. Its large total area and high altitude ensure that temperatures are roughly 10 to 30° colder than at comparable northern latitudes. At Vostock (78°S, 107°E), the mean annual temperature is −56°C and a record low temperature of −89°C has been experienced. Even mid-latitudes are affected; at South Georgia (54°S, 36°W), the mean annual temperature is +2°C compared with, say, Scarborough (54°N, 0°) where the annual average is 7° warmer. Temperature gradients between the equator and the poles generate energy that drives the atmospheric circulation. The gradient is greater in the southern hemisphere, making the circulation correspondingly more vigorous, and large-scale cyclonic disturbances (depressions) circulate eastwards around the Antarctic continent.

The height of the continent prevents all but a few depressions from penetrating the interior. Much of the moisture is deposited as snowfall in the coastal strip, where most bad weather occurs. The polar plateau has surprisingly little snowfall and is technically classed as a desert, even though it is an ice mass several kilometres thick! Depressions produce strong winds which lift loose snow from the surface. The most violent cases of drifting snow are caused by cold air draining off the plateau down steep valleys, producing what are called katabatic winds. At Cape Dension (67°S, 142°E), for example, the annual average wind speed is 37 knots (68 km/h), which can be compared with 9 knots (17 km/h) for a station near Bedford, England. The winds at the British Antarctic Survey (BAS) stations, Halley, Rothera and Signy are usually less severe, averaging 13 knots (24 km/h), though gusts of up to 97 knots (180 km/h) have been recorded. The combination of wind, low temperatures and blowing snow can be lethal. However, the weather is not all bad, and brilliant sunny days are fairly frequent in spring.

For nine months of the year, sea ice surrounds the continent. The amount of ice and its stability depend on the prevailing weather. The sea ice, in turn, influences the behaviour of weather as part of a large-scale atmosphere – ice – ocean interaction, which is not fully understood, but certainly has a role in determining climatic variations. Since 1944, the UK has been making regular surface meteorological observations which are valuable for climatic research. The Antarctic Peninsula acts as a barrier between the air mass over the South Pacific Ocean and the air flowing off the continent over the Weddell Sea. The Peninsula's climate depends on which air mass prevails. Large year-to-year variations in temperature and a great sensitivity to small changes in atmospheric circulation are the result.

To understand the impact that the Antarctic makes on global atmospheric circulation, vertical soundings of pressure, temperature, humidity and wind speed are made, up to an altitude of 30 km. BAS has a radiosonde station at Halley and, until recently, another one at Faraday. Both stations have been operated for more than 25 years, providing regular atmospheric soundings for use at major weather forecast centres and for WMO's World Climate Research Programme.

The development of Meteosat data links to the Antarctic

The Antarctic continent is at the limit of visibility for geostationary satellites. Soon after Meteosat-1 had been launched, BAS and the UK Meteorological Office, in

* Reprinted from booklet 'Research in the Antarctic', published in 1983 by the British Antarctic Survey.

collaboration with ESOC, arranged for the research ship 'Bransfield' to be fitted out with a Meteosat Data-Collection Platform (DCP), which had editing input facilities. The RRS Bransfield is the principal supply vessel serving British bases in the Antarctic and the annual voyage takes the ship to and beyond the Meteosat horizon.

The trials proved beyond doubt that regular reliable transmission of synoptic reports was possible, even when the satellite was on the visual horizon. Data were even received at Darmstadt when the ship was a half to one degree below the horizon. Thus there were grounds for believing that there would be successful communications to the GTS via Meteosat from Halley (75.5°S, 27°W). For several years, BAS had operated a meteorological collecting and broadcasting station at Grytviken (South Georgia), but it was clear by 1980 that no amount of effort was going to improve the 30% (approx.) success rate for data reaching Bracknell (HQ of the UK Met. Office) via the normal GTS.

The question was whether significantly better results could be gained by using DCPs and geostationary satellites. The evidence was that it would at least be better in summer, but there was no supportive evidence for year-round operations. There were also difficulties regarding sites (Fig. 1). At Grytviken the line of sight to Meteosat was barred by a mountain. Similarly at Faraday, the spine of the Antarctic Peninsula was an obstacle. Both these stations are in range of GOES East, and it is a fact, not commonly recognised, that the majority of Antarctic stations are within the range of geostationary meteorological satellites. In view of the poor data success rate, the growing need to make economies in HF radio collection and broadcasting, and because of the successful Bransfield experiment, BAS decided in 1981 to set up DCPs at Halley, Faraday and Grytviken as replacements for HF broadcast schedules.

Figure 2 — Halley DCP work station

The BAS Data-Collection-Platform System

Installation and performance

After discussions with the UK Meteorological Office, BAS approached a DCP supplier to develop a more flexible version of equipment being designed for use on ships. The BAS requirement was a radical step forward for it was proposed to collect and transmit a mixture of complete meteorological bulletins, which would consist of surface, upper-air and climatological data in WMO-coded format. The system consists of an Editing Visual Display Unit (VDU) (i.e. a computer terminal) with the DCP and a 300 baud printer connected in parallel to the output port. Complete meteorological bulletins, which may consist of reports from several stations, and upper air messages can be edited into separate bulletin blocks using the edit facility. The maximum DCP message length that can be transmitted in 1 min is about 640 characters long. It is absolutely essential to follow strict formatting rules so that data received at the Meteosat Ground Station in Darmstadt, Germany, can be automatically routed to the GTS terminal at the German Weather Service Centre at Offenbach.

All three proposed British stations were registered with ESOC in the hope that the antennas at Grytviken and Faraday could be located in a favourable position to see Meteosat, and on the off chance that Meteosat might be moved a few degrees further west to a more favourable position at a future date.

In the event, the failure of the DCP uplink channel on Meteosat-2 meant that neither Faraday nor Grytviken could use Meteosat-1, which was, by now, located at 10°E. It also meant that Halley was now on the very edge of the Meteosat-1 horizon and the whole enterprise began to appear to be a gamble. To resolve the problem, a supplier generously loaned a Mark-II DCP to BAS while the new Mark-III DCPs were being built and tested.

The trial system was installed at Halley by one of the authors in January 1982 (Figs. 2 and 3). There was a gloomy 24 h when ESOC reported nonreceipt of signal. This was followed by relief and a certain amount of smug satisfaction when they eventually reported that Halley was transmitting strong signals. Negotiations were then started between BAS and NESS (now NESDIS) in the USA to use GOES East for DCPs transmitting from Faraday and Grytviken. In April 1982, the BAS Meteorological Centre at Grytviken was forcibly closed as a result of the Falklands conflict. But by that time, Halley's (Station

Figure 3 — Halley Village DCP antenna

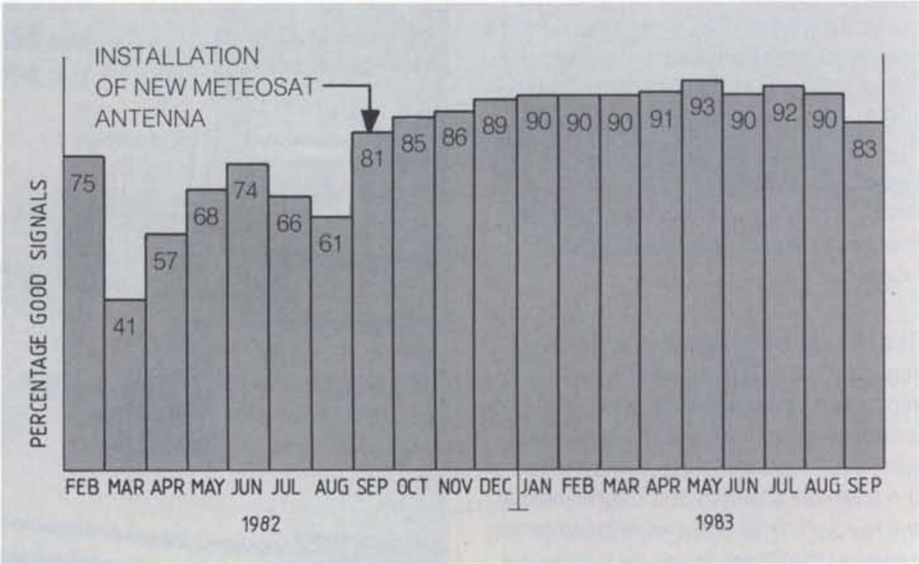


Figure 4 — Percentage of good signals received from Halley Village. (Pre-DCP installation figure ca. 30%)

89022) DCP was regularly sending its reports and those of the new German von Neumayer station (89002) direct to the GTS via Darmstadt and Offenbach.

These transmissions continued without interruption throughout 1982. A Mark-III DCP was substituted in January 1983 and the data flow has continued unabated, except when the DCP was accidentally switched off for a few days. All data are automatically sent on to Bracknell. The percentage of signals received at Darmstadt between February 1982 and October 1983 is given in Figure 4. From Figure 4, it can be seen that percentage reception is very much better than by the old meteorological communications network. More importantly, the new Meteosat-1 reception antenna made a significant improvement in the received signal, and for the first time data reception exceeded the 80% level, which is highly satisfactory for Antarctic data. Similar data levels have been achieved from Faraday into the GOES system.

In view of the good performance, the Georg von Neumayer station (70°S, 8°W), which is operated by the Alfred Wegener Institute for Polar Research, Bremerhaven, installed their own DCP, which has been operating since March 1983 (Fig. 5).

Practical aspects

The DCP system employed by BAS is part of a total weather observing system that must operate 24 h a day for both synoptic and climatological data acquisition and dissemination (Fig. 6). In 1984, a Synoptic and Climatological Automatic Weather Station and an Automatic Upper-Air Radio-Sonde and Wind-Finding System will be interfaced to the DCP with facilities for both direct input or interrupted input via the editing VDU. The DCP transmissions take place at 26 min past each hour which allows for overflow when normal bulletins exceed 640 characters, but normally it is not intended to transmit more than the eight 3-hourly synoptic report bulletins and a once-daily upper-air sounding. All the equipment is completely supported by spares at printed-circuit-board (PCB) level; in the case of the DCP, the VDU and printer, there is complete redundancy of equipment to ensure rapid replacement in the event of equipment failure. This is an accepted policy in BAS because there are no service engineers to call, or any replacement equipment until the once-yearly ship arrives!

Figure 5 — Georg von Neumayer station (photo courtesy of D. Enss)

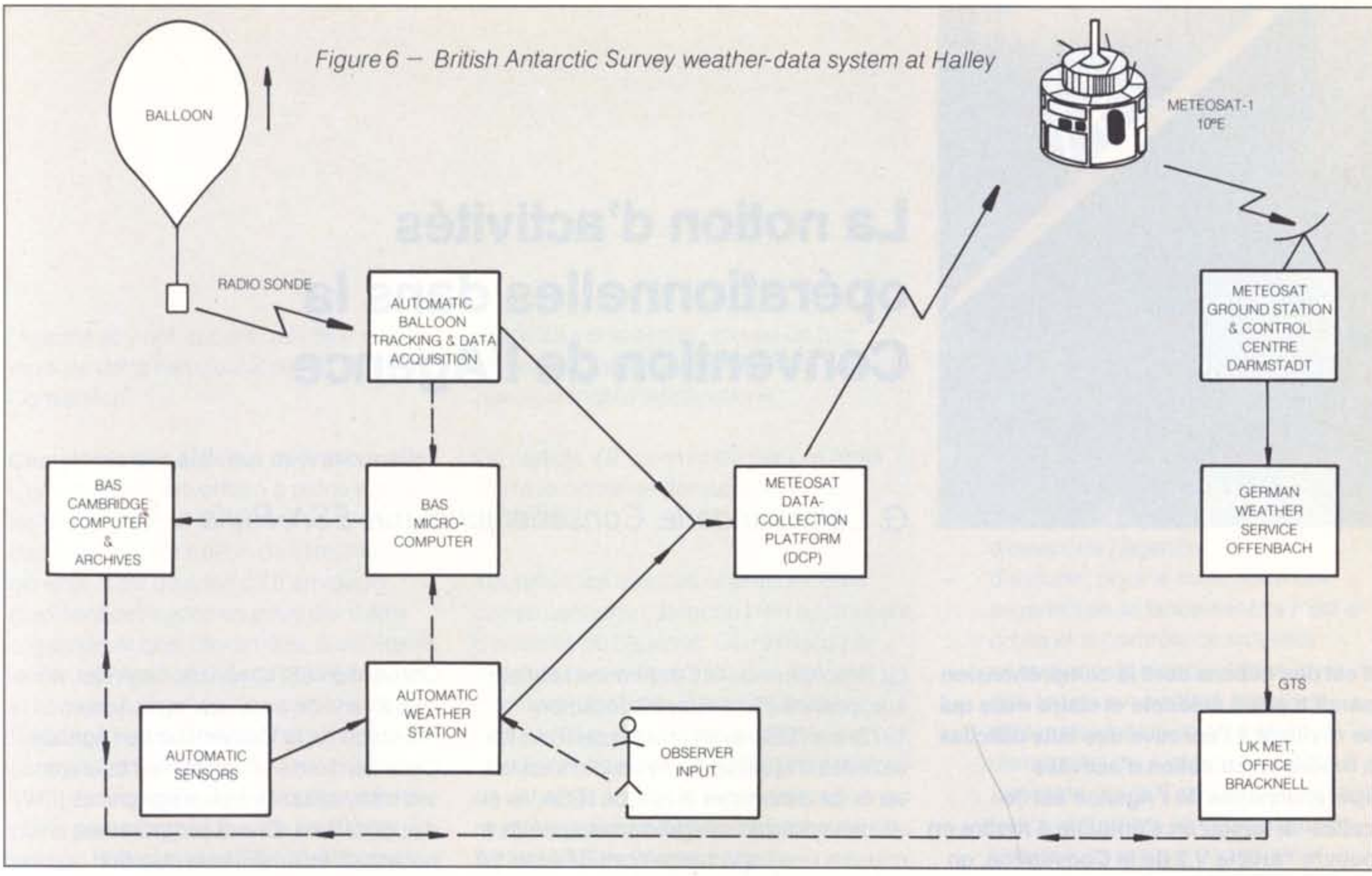


Figure 6 – British Antarctic Survey weather-data system at Halley

Conclusions and future developments
The use of editing VDUs linked to DCP for reporting bulletins of collected meteorological reports from Antarctica has proved a great success:

- The capital and operating costs of such a system are much less than those for conventional HF radio transmissions.
- Unskilled operators can use the system.
- It is reliable and free from radio interference, and
- It ensures that synoptic data enters the Main Trunk Network of the GTS at key locations.

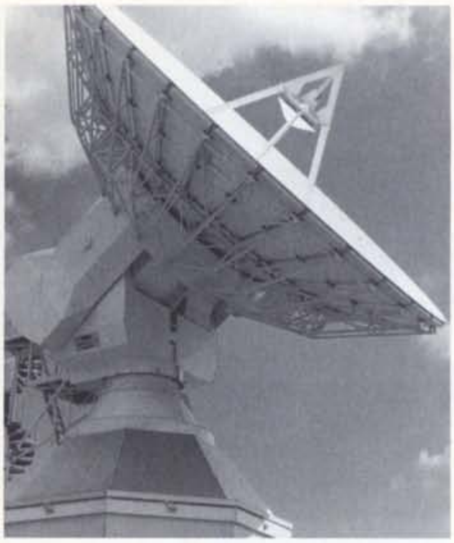
The pioneering work with Meteosat and then the use of GOES-E can be considered as a major breakthrough in obtaining regular and timely meteorological data from the Antarctic. It is confidently expected that there will be an increase in the number of DCPs operating in the region, and that the Data-Collection Systems of the geostationary meteorological satellites will become a primary channel for the Antarctic data.

One fact must be faced, however, in that Meteosat and its siblings do not give complete coverage of the polar region and its DCPs not lend themselves to widescale deployment for floating-buoy or iceberg studies. For such activities, Service Argos, the data-collection and positioning system using the NOAA series of Earth orbiters, is more appropriate. But even this has a drawback in that Antarctic data could be several hours old before being available to users in the northern hemisphere.

The way out of this problem would be to install a direct-reception station in the Antarctic for data relayed by NOAA satellites. This station, which would be in the Meteosat coverage area, would be able to receive the Argos DCP reports directly at the time of a NOAA satellite overpass (every 50 min when two NOAA satellites are operating). It would be able to receive DCP reports from platforms up to 2000 km from the station. The reports could then be compiled and formatted and entered into a Meteosat DCP for retransmission via Meteosat to the northern-hemisphere user.

Even position location for floating DCPs could be ensured by equipping them with receivers for the Omega VLF navigation system. In addition, the direct-reception station would also provide the Argos DCP data for local weather forecasting and aircraft operation activities in Antarctica.

Most important, however, would be the impact of more Antarctic data into the GTS and its availability for the global analyses being prepared in real time at the main numerical-analysis centres where the first products of a global analysis are completed within 4 h of the synoptic reporting time. An added attraction of such a combined system would be that a European-based research team studying, say, the impact of weather systems on the sea ice and on the circulation of the Weddell ocean gyre, would be observing events as they happen rather than in retrospect, and could thus modify ship or aircraft deployment to match experimental criteria. The thought of controlling an Antarctic field experiment from an office in Cambridge, where all relevant data have been received in real time using satellite communications, is very appealing – and cost effective!



La notion d'activités opérationnelles dans la Convention de l'Agence

G. Lafferranderie, Conseiller juridique, ESA, Paris

Il est des notions dont la compréhension paraît a priori évidente et claire mais qui se révèlent à l'épreuve des faits difficiles à maîtriser. La notion d'activités opérationnelles de l'Agence est de celles-là; lorsqu'on s'emploie à mettre en oeuvre l'article V.2 de la Convention, on s'aperçoit que les questions se multiplient. Il se produit des phénomènes de contamination avec d'autres notions et la frontière n'est pas toujours facile à tracer. Aussi faut-il en revenir à l'histoire pour tenter de dégager certains traits de cette notion d'activités opérationnelles dont on analysera ensuite les modalités de mise en oeuvre et son impact sur le fonctionnement de l'Agence.

La Résolution de la Conférence spatiale européenne (Bruxelles, 20 décembre 1972) sur l'ESA ayant mis l'accent sur les satellites d'application, le besoin s'est fait sentir de déterminer le rôle de l'ESA vis-à-vis des systèmes opérationnels appelés à prendre une importance considérable. Le premier exemple concret est intervenu lors de la discussion du programme Météosat et dès octobre 1972, le Secrétariat avait été invité à étudier l'impact résultant d'un rôle de l'Organisation dans le domaine de l'exploitation de Météosat en phase opérationnelle. Le projet de Convention du CERS/ESRO révisé contenait une première ouverture vers la possibilité de confier à l'Organisation un rôle en ce domaine (article V.2 du projet de Convention ESRO révisé). Ce projet, on le sait, a servi de base aux travaux de rédaction de la Convention de l'Agence. Cette dernière s'ouvre, et c'est là un de ses traits saillants, aux programmes d'applications. Or ces programmes posent en eux-mêmes la question fondamentale: où s'arrête le rôle d'une Organisation de recherche et de développement, doit-elle se désintéresser des satellites d'application une fois leur fonctionnement en orbite vérifié, doit-elle concevoir, construire et lancer ces satellites sans se préoccuper de leur avenir, de leur adoption et de leur filiation? Ces questions, les délégations n'ont pas manqué de les poser lors de l'élaboration de la Convention de

Figure 1 — Une vue de la Conférence spatiale européenne de Bruxelles (décembre 1972). De gauche à droite: Dr A. Hocker, Directeur général de l'ESRO; M T. Lefèvre, Président de la CSE; et M A. Stenmans, Secrétaire général de la Politique scientifique de Belgique

l'Agence et y ont apporté des éléments de réponse dans l'article V.2 de la Convention*.

Caractères des activités opérationnelles
L'encre de la Convention à peine sèche, les délégations se sont attelées à la tâche décrite dans l'allocution du Directeur général: 'il est déjà temps d'envisager comment ces systèmes pourraient être organisés et quel devrait être, à cet égard, le rôle de l'Agence... dans quelle mesure et comment l'Agence devrait-elle aider l'industrie européenne à s'assurer ces contrats?' (cf. Bulletin ESA, no. 1, juin 1975). Une groupe de travail était mis en place par le Conseil lors de sa 10ème session (7/8 octobre 1976) et élaborait alors des projets de Résolutions qui furent soumis au Conseil réuni au niveau ministériel en février 1977. Le Conseil ministériel adopta une Résolution intitulée 'l'Agence et les systèmes opérationnels' qui vient compléter et éclairer l'article V.2 (cf. Volume I des Textes fondamentaux de l'Agence).

1. **Les activités opérationnelles constituent des activités de l'Agence,** exécutées sous sa responsabilité, au même titre que les activités obligatoires ou les programmes facultatifs. Bien sûr elles ont leurs caractères propres.

Il est en effet significatif que ces activités figurent dans l'article V de la Convention intitulé 'Activités et programmes de l'Agence'. Les activités et programmes de l'Agence sont le reflet de sa mission définie à l'article II: 'L'Agence a pour mission d'assurer et de développer... 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... *et pour des systèmes spatiaux opérationnels d'applications.*'

Or, l'article V.2 commence par ces mots 'Dans le domaine des applications spatiales...'.

Toutefois, les activités opérationnelles constituent une catégorie bien particulière d'activités de l'Agence. On relèvera par exemple que ni l'article XI (sur les fonctions du Conseil) n'en traite ni l'article XIII qui définit les modalités de contributions aux activités et programmes de l'Agence. La seule autre disposition qui se réfère aux activités opérationnelles est l'article VII.2 de l'Annexe I de la Convention ('Privilèges et immunités') pour précisément ne pas faire bénéficier les activités opérationnelles automatiquement des privilèges fiscaux octroyés aux activités entreprises dans le domaine de la recherche et de la technologie spatiales et des applications spatiales. Il appartient au Conseil d'étendre chaque fois à une activité opérationnelle le bénéfice des articles V et VI de l'Annexe I. On constate que les activités exécutées au titre de l'article IX de la Convention se trouvent dans la même situation, des activités entreprises en dehors de l'Agence mais conformes à sa mission. Ainsi commencent à se dessiner les contours des activités opérationnelles:

Des activités qui se situent dans le prolongement naturel des activités de recherche et de développement de l'Agence, des activités conformes à la mission de l'Agence, *définies, entreprises à l'extérieur* de l'Agence et qui ne sont pas financées, en principe, par des contributions des Etats membres. Ce dernier point est confirmé par l'article V.2 qui fait mention d'organismes d'exploitation intéressés ou d'utilisateurs intéressés. Les activités opérationnelles sont des activités demandées par un organisme extérieur; ce dernier définira la prestation qu'il attend de l'Agence.

L'article V.2 ne définit pas l'activité opérationnelle; il en donne une liste, non exhaustive. La capacité d'intervention de l'Agence est très large. Il peut s'agir:
- de mise à disposition d'installations que l'organisme d'exploitation juge utiles, essentiellement les moyens de poursuite et contrôle et les moyens d'essais de l'Agence;
- d'assurer, pour le compte de ces organismes, le lancement, la mise en orbite et le contrôle de satellites opérationnels d'applications, c'est-à-dire fournir un système complet;
- d'assurer toute autre activité demandée, sous réserve qu'elle soit acceptée par le Conseil. Entrent sous le couvert de cet alinéa les activités de consultance qui connaissent un développement certain.

2. **Mais l'Agence intervient de façon supplétive.** L'Agence '*peut*', 'le cas échéant', assurer des activités opérationnelles. Cette répétition souligne les limites d'intervention de l'Agence. L'Agence ne se saisit pas elle-même, elle répond à une demande externe. Ce n'est pas son rôle premier d'exécuter des activités opérationnelles. Elle doit être tournée en priorité vers l'exécution des activités obligatoires et des programmes facultatifs parce qu'ils répondent à sa mission fondamentale, parce qu'ils sont financés par les contributions des Etats membres. Ses forces, ses ressources doivent s'appliquer en premier lieu à ces activités et programmes définis par les Etats membres. Les signataires de la Convention de l'Agence ont expressément voulu qu'au-delà de la recherche et du développement, les organismes d'exploitation de satellites opérationnels d'application prennent pleinement leur responsabilité et assurent le financement et l'exploitation des satellites répondant à leurs besoins.

Toutefois, ils ont voulu éviter l'écueil de l'absence momentanée d'un organisme d'exploitation responsable, éviter une dispersion des efforts, des duplications d'installations, un gaspillage de ressources en Europe. Pour réduire ces

* Il faut aussi mentionner la Résolution no. 5 de l'Acte final de la Conférence des Plénipotentiaires pour l'établissement d'une Agence spatiale européenne: 'Considère que les programmes de l'Agence spatiale européenne doivent faciliter la réalisation des systèmes opérationnels qui seraient acceptables pour les utilisateurs et exploités par eux.'

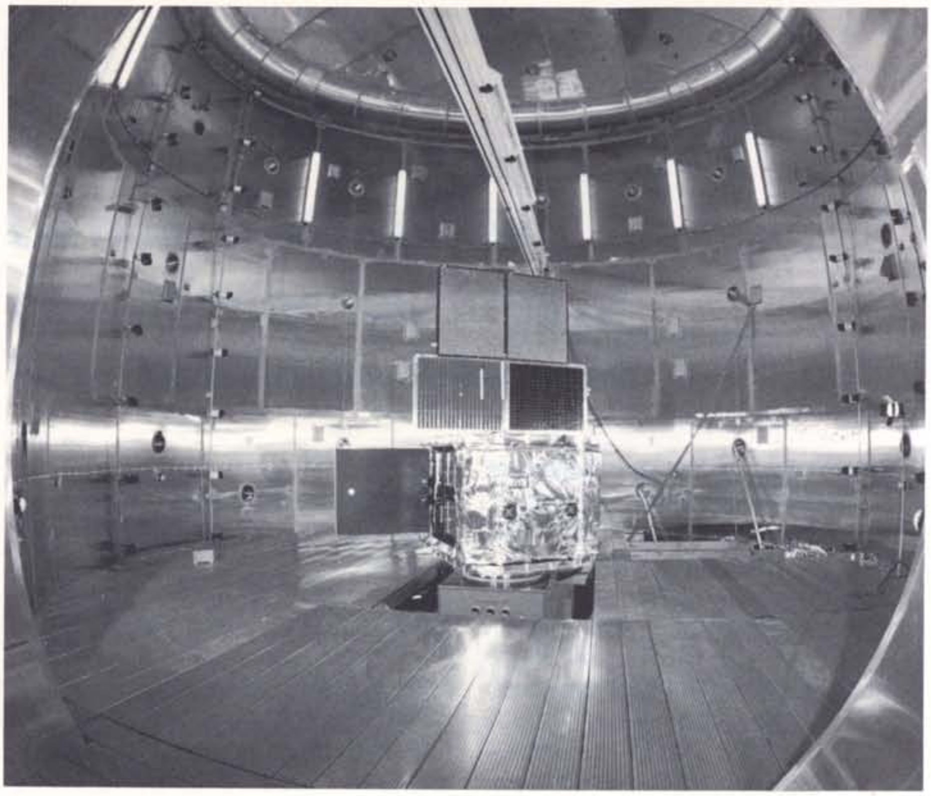


Figure 2 — Modèle de qualification du satellite Exosat dans la chambre d'essais dynamiques

risques, ils ont pris conscience de la nécessité de donner ainsi à l'Agence la capacité juridique de répondre et donc de sauvegarder finalement les investissements et les efforts consentis au niveau de la recherche et du développement. L'Agence constitue ainsi une structure capable d'apporter une réponse à une situation qu'on espère provisoire en matière de satellites d'applications opérationnels, de défaut de structure appropriée.

Le préambule de la Résolution 'L'Agence et les systèmes opérationnels' adopté par le Conseil au niveau des Ministres en février 1977 résume ces diverses idées: l'Agence a pour mission d'aider à créer et à gérer les systèmes spatiaux opérationnels européens. Les activités opérationnelles permettent à l'Agence de mieux définir ses programmes en fonction des besoins des utilisateurs. Elles lui permettent aussi de mieux exploiter ses capacités et ses investissements.

L'Agence n'entreprend de telles activités que si elle peut le faire sans interférence avec l'exécution efficace des tâches principales pour lesquelles elle a été créée.

3. On a déjà vu que le problème se pose parfois de distinguer entre cette notion d'**activités opérationnelles** et des notions voisines:

- **activités d'assistance** aux Etats membres – article IX.1 et IX.2
- **activités de coopération** avec des Etats non membres, des organisations ou des institutions internationales (article XIV.1).

Les Etats membres ont non pas une faculté, comme dans l'article V.2, mais un accès de droit aux installations de l'Agence pour les besoins de leur propre programme: 'l'Agence met ses installations à la disposition...'. La seule réserve est la priorité donnée aux activités et programmes de l'Agence en cas de conflit d'utilisation d'installations de l'Agence.

L'Agence peut aussi être amenée à apporter son aide à un Etat membre pour un projet qu'il entreprend et qui se situe en dehors des activités et programmes de l'article V (y compris en dehors de l'article V.2), mais toujours dans le cadre de la mission de l'Agence (article II).

La coopération, pour sa part, suppose un objectif commun et la définition de responsabilités précises de chaque partenaire en vue de sa réalisation.

L'article V.2 n'exclut pas que l'organisme d'exploitation intéressé soit une Organisation ou une institution internationale compétente en matière de satellites opérationnels d'applications; mais c'est l'Agence qui conduit et exécute l'activité opérationnelle.

L'article V.2 ne définit donc pas la notion d'activités opérationnelles mais se contente de dresser une liste; toutefois, en combinant cet article et la Résolution de février 1977, on peut arriver à dessiner les contours de cette notion. Ces contours vont se préciser en examinant les modalités de mise en oeuvre et son impact sur le fonctionnement de l'Agence.

Les modalités de mise en oeuvre de l'article V.2

1. Les relations contractuelles entre l'Agence et l'utilisateur

Le Conseil définit les conditions d'exécution par l'Agence de la demande présentée; on ne parle pas de règles détaillées d'application (comme pour l'article III) ou de règlement (comme pour l'article XIII). Aussi n'existe-t-il pas de règlement et le Conseil se prononce-t-il cas par cas. Seule la Résolution du Conseil au niveau des Ministres de février 1977 est venue apporter quelques compléments. Le projet de règlement financier ESA, en cours d'approbation, fait une brève allusion à ce problème dans son article 32.

Une phase exploratoire se déroule entre l'Agence et l'organisme intéressé avant la présentation de la demande au Conseil; évaluation de l'effort demandé, capacité technique de réponse, etc. Le Conseil se prononce sur la base de l'article V.2 ainsi que sur celle de l'article VII.2 de l'Annexe I de la Convention. Un contrat (ou un Accord) est négocié et conclu entre l'Agence et l'organisme en question, un contrat particulier puisqu'ici c'est l'Agence qui est appelée à fournir une prestation, à rendre un service et non plus comme pour ses programmes, à demander à un industriel de lui délivrer un produit ou fournir un service. Aussi les clauses et conditions générales des contrats ne peuvent-elles être appliquées telles quelles et il a fallu élaborer des clauses spécifiques.

L'utilisateur sera le plus souvent un organisme extérieur, cf. la NASA pour l'acquisition d'un deuxième Spacelab, des

Administrations nationales ou des Organisations internationales (Inmarsat, Eutelsat). L'utilisateur peut être aussi, fait exceptionnel, un autre programme de l'Agence. C'est ainsi que la série de promotion* a été construite comme activité opérationnelle et fournit des services de lancement à des clients dont certains sont des programmes de satellites de l'Agence elle-même. Si des contrats ont pu être conclus avec des entités extérieures à l'Agence, il ne lui était pas possible, dans ce dernier exemple, de contracter avec elle-même, les programmes clients n'ayant pas de personnalité juridique. De ce fait, les relations 'contractuelles' ne pouvaient être qu'incomplètes. Cet utilisateur, l'Agence parfois, aide à sa création: tel est le cas de l'Organisation Eumetsat.

2. En **matière financière,** l'article V.2 pose le principe que les coûts exposés par l'Agence sont supportés par l'utilisateur intéressé. Ce principe est loin de se suffire. La Résolution de février 1977 apporte des éléments complémentaires. Les frais internes de l'Agence seront limités autant que cela sera possible; une politique d'imputation sera définie (effort qui n'a pu encore aboutir). L'objectif est qu'aucun engagement financier ne doit en découler pour un Etat membre sans son accord exprès. En d'autres mots, l'Agence doit être transparente et l'opération 'blanche' pour les Etats membres au niveau de leurs engagements financiers, l'Agence ne 'faisant ni perte ni profit'.

* ESA/C/XXIV/Res. 3 (Final) du 26 avril 1978.

Toutefois, le Conseil n'a pas exclu que certaines dépenses puissent rester à la charge de l'Agence 'notamment en vue de promouvoir la constitution et la mise en route des groupements d'utilisateurs'.

Certains Etats membres peuvent ainsi convenir de prendre en charge une quote-part des frais encourus, de 'subventionner' l'utilisateur en quelque sorte. Le Conseil peut décider de ne pas appliquer une imputation totale des coûts encourus à des fins de promotion. Dans ce cas activités opérationnelles et activités promotionnelles se rencontrent.

Cette possibilité a été utilisée à diverses reprises. On citera:
- la Déclaration sur la phase 3 bis du programme de satellites de télécommunications,
- la Résolution 'Inmarsat' en date du 20 mai 1980 (ESA/C/XL/Res. 1),
- la Résolution 'Eumetsat' du 9 décembre 1982 [ESA/C/LVI/Res. 2. (Final)].

3. En matière de **politique industrielle,** l'Agence est invitée à définir et à mettre en oeuvre une politique permettant aux Etats membres qui ont contribué au développement d'un programme spatial d'être associés équitablement aux activités opérationnelles ultérieures résultant de ce programme, en tenant compte de toute contrainte commerciale impliquée. Objectif difficile à atteindre, l'Agence n'étant pas directement responsable de la définition de l'activité opérationnelle. L'Annexe V de la Convention ne s'applique pas aux activités opérationnelles et les contrats correspondants ne sont pas présentés à l'IPC.

4. Des **clauses juridiques spécifiques** doivent être élaborées en matière de responsabilités pour dommages (on peut se référer sur certains points à la Résolution ESA/C/XXII/Res. 3 du 13 décembre 1977), de droits de propriété intellectuelle, accès aux résultats techniques et leur utilisation par l'Agence pour ses propres fins, de propriété de biens, d'impôts et taxes.

Conclusion
Il reste encore bien des réflexions suscitées par cette notion d'activités opérationnelles, bien des domaines encore relativement peu explorés et qui révèlent toute la richesse et l'intérêt de cette notion originale de la Convention de l'Agence. Les réponses aux questions fondamentales identifiées par le Directeur général dans son allocution de 1975 s'élaborent progressivement au fur et à mesure de l'action de l'Agence. Cette notion d'activités opérationnelles se construit tous les jours sous nos yeux; elle n'est pas une notion figée mais bien vivante.

Figure 3 — Première réunion du Conseil ESA au niveau interministériel (Paris, 14-15 février 1977)

OTS Enters Sixth Year of Service

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At the time of launch in May 1978, two of the major objectives for OTS were to test, under orbital conditions, equipment, techniques and design philosophies that would be used in the later operational European Communications Satellite (ECS) programme. In addition, it was to provide pre-operational satellite telecommunications capacity to assist Eutelsat and their customers with the development of ground-segment facilities and procedures for the ECS system. The design philosophy and operational flexibility of OTS have allowed all of these objectives to be achieved and, moreover, have allowed highly satisfactory performance to be continued well into a sixth year, despite the originally planned three-year lifetime.

Historical background

To demonstrate the feasibility of a European-developed communications satellite and to provide the PTTs with a means of gaining experience in the use of a satellite for regional communications, ESA (then ESRO) decided in early 1972 to embark upon the development of an experimental satellite to serve as an orbital test bed.

Development of this satellite, called OTS (Orbital Test Satellite) began in 1972 with the award of three parallel study contracts (Phase-A) to three competing European consortia. These were then narrowed to two for definition studies (Phase-B) in 1973, and finally to a single contract with the award of the main development contract (Phase-C/D) to the MESH Consortium, with British Aerospace Dynamics Group (then Hawker Siddeley Dynamics) as prime contractor.

OTS was initially planned for launch in December 1976 from Eastern Test Range (USA) on a Delta-2914. When the more powerful Delta-3914 became available to international users in mid-1974 it was decided to switch. The additional satellite mass then allowed meant that greater redundancy in the payload was possible and that additional propellant could be carried to extend OTS's lifetime. The effect of changing launchers, however, was to delay the launch date to mid-1977. OTS was finally launched on 13 September 1977, but was destroyed when the launch vehicle exploded early in the flight.

Fortunately, the OTS programme included the components for a second, back-up spacecraft. This second satellite, now known as OTS-2, was launched successfully on 11 May 1978 and reached its operating location at 10°E two weeks later.

The satellite is owned and operated by ESA on behalf of its participating Member States. A joint management structure was set up between ESA and the Interim Eutelsat organisation to operate and control OTS in orbit, whereby Eutelsat is responsible for scheduling and controlling all communications traffic through OTS (experimental and pre-operational) for itself and for its customers, in preparation for the European Communications Satellites (ECS) system. ESA is responsible for the satellite's maintenance and operation in orbit, for the periodic performance measurements on the communications payload, and for its Orbital Test Programme. Both ESA and Eutelsat use OTS for ad-hoc demonstrations.

Design philosophy

When OTS-2 was launched in May 1978, the primary goals for the planned three-year mission were to validate the hardware and communications techniques intended for ECS and to allow future users of ECS to gain experience in operating a combined satellite/ground segment telecommunications system.

OTS was designed to be as close as possible, subject to the mass constraints of the Delta-3914 launcher, to the configuration then envisaged for the larger ECS satellites. Befitting its experimental nature, however, OTS

Figure 1 — Launch of OTS-2 from Cape Canaveral at 22.59 GMT on 11 May 1978

carries two competing technologies in a number of subsystem areas for in-orbit performance evaluation. Examples are the use of both dual linear and circularly polarised antennas and the use of two different makes of travelling-wave tubes, nutation dampers, Earth sensors, and momentum wheels.

The initial validation goals for OTS were fully realised during its first three years in orbit. It has now entered its sixth year of service, and has proved far more useful than originally anticipated. This extra lifetime is the result of the possibility to load some five year's worth of hydrazine into the on-board tanks at launch, combined with the conservative design, test and redundancy implementation philosophies, and the built-in operational flexibility. Moreover, since most of the equipment items on OTS were designed to be compatible with the requirements of the later ECS system, they were qualified for a seven-year orbital lifetime.

The redundancy philosophy employed in the design of OTS was based upon two basic premises:

- as much redundancy as possible was to be incorporated in all active subsystems (the reliability of passive subsystems was to be ensured through the use of generous design margins and verification through extensive qualification testing)
- wherever feasible, functionally redundant units and/or modes of operation were to be used, to minimise the likelihood of an undetected design error endangering the mission.

The latter premise was also a result of the intention to use OTS to test the in-orbit performance of as many alternate items of equipment as possible, before freezing the design of the operational ECS satellites to follow, which would not then need such a high degree of functional redundancy.

A further design guideline for OTS was to incorporate on-board means to detect, and correct, automatically any failures that might occur during on-station operation and which might otherwise endanger the mission. Certain power-subsystem failures, for example, would result in automatic switch-off of all nonessential loads, whilst failures in the attitude control system would result in automatic switch-over to redundant units. All of these automatic functions were implemented such that they could be inhibited, or their actions reset, by ground command.

In-orbit results

OTS is now well into its sixth year of on-station operation. It has been used jointly by ESA and various PTT members of Eutelsat. ESA has conducted its Orbital Test Programme (OTP) and performed a number of service demonstrations, and the PTTs have used it for testing various communications techniques, for ensuring the compatibility of Earth-station and satellite links, to demonstrate a pre-operational traffic capability, and for their own service demonstrations.

The OTP test results, without exception, confirmed the soundness of the design baseline for the ECS satellites and their derivatives. In several areas, information obtained from OTS has made it possible to incorporate certain design/operational improvements into the ECS baseline.

Operations

Table 1 lists a number of the more important, specific lessons learned from anomalies experienced on OTS. In addition, a number of general lessons have been reinforced:

- Use of automatic on-board fault detection and correction circuitry has been shown to be of great benefit, both in preventing transient outages and in protecting the satellite's 'health'.
- The need for ground override control over any automatic onboard function has been confirmed.
- The advantage of incorporating functionally redundant equipment relying on dissimilar technologies has been demonstrated.
- The inherent flexibility of a three-axis stabilised spacecraft has been endorsed, both by being able to repoint antenna beams in previously unplanned directions for various demonstration purposes and by the ability to 'solar sail' (see below).

In view of its experimental nature, OTS was designed with a comparatively high degree of inherent operational flexibility. A number of alternate or backup modes

Table 1 — Notable 'lessons learned' from OTS

Subsystem	Observed performance	Investigation conclusions	Actions taken on OTS	Modifications for ECS
Repeater	One TWTA failed after a few months in orbit.	Probable crack/void in potting, allowing high-voltage arc to trigger automatic overcurrent protection logic to switch off tube supply.		Additional quality monitoring procedures and more rigorous radiographic inspection.
	TWTAs have, on several isolated occasions, spontaneously switched themselves off. Performance is subsequently nominal when they are switched back on by ground command.	One TWTA found to be sensitive to dynamic overdrive. Another appears overly sensitive to random EMI transients.	Ground stations have been advised against exposing sensitive channel to dynamic overdrive conditions.	All TWTAs tested for dynamic overdrive capability. Auto-restart circuit incorporated.
Attitude-Control Subsystem (ACS)	One IRES sensor exhibited short-term spurious outputs at certain times of year, repeatably every day.	An internal temperature-sensing circuit was found to oscillate when the temperature reached a certain value. When the temperature was several hundredths of a degree above or below that value, no oscillations occurred. Around equinox periods, this temperature occurs twice per day, at repeatable and predictable times.	This IRES is now inhibited during these periods, and functionally redundant IRES is used.	Redesign of IRES for ECS has deleted oscillation-susceptible circuit. Electronic equipment now tested for performance during temperature transitions, not merely at high- and low-temperature extremes.
	Both IRESs displayed an effect whereby the apparent Earth's centre varied in position when any one of four detectors was inhibited, as is done to avoid Moon or Sun blinding.	IR horizon profile of Earth varies considerably more than previous models of atmospheric radiance profile would have indicated. Local meteorological conditions at horizon positions can cause significant effects, depending upon sensor's spectral responsivity/bandpass.	Software developed to detect sudden shift of null when one detector is inhibited and automatically telecommand compensating bias signals.	Ground software as for OTS, plus modification to IR filter bandwidth to minimise effect.
Reaction-Control Subsystem (RCS)	Cross-axis disturbance torques sometimes observed when north-south station-keeping thrusters are fired.	'Plume-impingement' torques on rotating solar array greater than previously predicted by idealised theoretical models. Torques are sinusoidal and repeatable, depending upon solar-array position.	Station-keeping manoeuvres broken down into smaller increments interspersed with momentum-unloading manoeuvre. Station-keeping manoeuvres planned to occur at preferred array positions wherever possible.	Same as for OTS. Additional torques taken into account in propellant budget.
	Attitude transient disturbances and overshoots sometimes larger than expected during station-keeping or momentum-unloading manoeuvres.	Gas generation occurs inside RCS which can cause missing pulses in a train or sputtering during a train. Effect varies in magnitude between thrusters. Magnitude of effect is directly proportional to the length of time that a thruster has been unused.	Manoeuvres performed more frequently. 'Priming' of thrusters by initially commanding very small pulses to expel gas.	Same as for OTS plus changes to ACS electronics to minimise effects of any missing pulses.
Thermal-Control Subsystem	Average spacecraft temperature increasing at a somewhat higher rate than predicted.	Increase of absorptivity of thermal surfaces under UV and particulate radiation, greater than predicted by preflight test programme.	Modification of operations procedures for heaters to reduce overall and local satellite temperatures.	Thermal design/analyses cater for higher alpha degradation than assumed for OTS. Thermal prediction uncertainties explicitly taken into account in determining qualification acceptance temperatures for equipment.
Power Subsystem	One BAPTA (Bearing And Power Transfer Assembly) on a solar-array wing showed disturbance-torque anomalies.	Preload on bearings can apparently be too low under certain conditions.	Operation of that BAPTA in a high-pulse mode, where torque anomalies are insignificant.	Manufacturing and test modifications instituted.

Figure 2 — Demonstration of direct television broadcasting/teleconferencing via OTS in progress

were incorporated, each capable of performing similar functions to the primary modes. In addition, there was a high degree of control authority required from the ground to modify parameters of the onboard subsystems by telecommand (e.g. array step sizes, thruster pulse lengths and duty cycles, repeater gains, thermal heater dissipation, etc.). These design features were instrumental in allowing OTS to cope with various anomalies or failures experienced in orbit, and in enabling it to be used, in many instances, for purposes and in ways not foreseen initially.

Nevertheless, this complexity had its own drawbacks, in that it put a sometimes excessive workload on the ground controllers. For operational satellites, it would seem prudent to strive to minimise the requirements on the spacecraft controllers, either by simplification/automation of satellite subsystem functions or by automating standard command sequences at the ground control centre where feasible, or both.

OTS's flexibility has also allowed it to be used to develop a number of novel in-orbit operations techniques.

Solar sailing
The major external torque that tends to disturb the attitude of a satellite in geostationary orbit is due to 'solar pressure', when the spacecraft's centre of pressure and centre of mass do not exactly coincide.

The solar arrays on a conventional three-axis-stabilised satellite generally represent the greatest cross-sectional area perpendicular to the satellite-Sun line, and also constitute the areas furthest away from the satellite's geometric centre. Because they are designed to be as light as possible, they exhibit varying degrees of bending and distortion in orbit, according to the season. They are therefore the major cause of variations in centre of pressure, and hence disturbance torques.

Recognising that the solar arrays are the major source of attitude disturbances, Dr. U. Renner of ESA reasoned that it should be possible to use the arrays themselves to counteract the disturbance torques (a detailed report on the technique can be found in ESA Journal No. 1, 1979). He has developed an algorithm, based only upon measurements of roll attitude error taken four times per day, from which the array manoeuvres needed to maintain the satellite's attitude within specification (without the use of thrusters) can be determined.

Controlling attitude in this manner has several advantages:
- small savings in propellant, and a large reduction in the number of thruster pulses required;
- the smooth nature of the control torques produced eliminates excitation of nutation, which might cause additional transient attitude errors;
- perhaps most significant, the procedure constrains yaw attitude error, as well as roll, to values well below that obtainable from the passive yaw control inherent in a biased momentum control system.

The only penalty that this method incurrs is a small (about 3%) loss in power, at some times of the day. Since all such satellites are designed with power margins greater than this, at least until near end-of-life, this is a small price to pay.

The solar-sailing technique has now been used operationally on OTS for more than two years, during which time no control-thruster firing has been needed to maintain satellite attitude during normal mode control.

Solar-array degradation
As expected, the output from OTS's solar arrays has degraded with time, due to their exposure to space radiation. Surprisingly, however, the degradation has been considerably less than expected based upon the best information available on the radiation environment prior to launch. Data from one array section, instrumented to allow periodic short-circuit current measurements to be made, also show a much lower decrease than expected. An instrument flown on OTS to measure the change in transistor parameters when exposed to the radiation in geostationary orbit also shows considerably less degradation than anticipated.

Investigations are now under way to correlate this data with solar activity during the time OTS has been in orbit. If this period is found not to have been unusually benign, it might be concluded that existing models of radiation in the geostationary orbit are unduly pessimistic. Such a finding could result in significant savings for future satellites.

High-precision station-keeping
Communications satellites typically need to be maintained on-station to within ±0.1 deg. In the future, with more and

more satellites vying for geostationary-orbit positions, it may be necessary to tighten station-keeping tolerances significantly. An experiment was therefore performed on OTS whereby the station-keeping deadband was gradually reduced in several stages.

This experiment showed that it was perfectly feasible, with satellites with similar area/mass ratios to OTS (0.03 m^2/kg), to station-keep to within $\pm$0.035 deg, without using significant additional propellant.

'Listening-in'
OTS carries a 12 GHz downlink beacon to provide propagation statistics under varying seasonal weather conditions. During ground testing prior to launch, it was discovered that the frequency of the beacon's cavity-controlled Impatt diode oscillator changed transiently by a few kilohertz when the satellite was vibrated slightly. As such changes were well within the allowable frequency variations for propagation measurements, this phenomenon did not lead to any pre-launch modifications.

Once OTS was in orbit, an experiment was performed in which the beacon signal was mixed down to 136 MHz, phase demodulated, amplified, and then recorded. When the tape was played back it was discovered that one could clearly hear the whine of the momentum wheel (varying in pitch as speed changed), the pulses as thrusters were fired, and the latching valves within the reaction control subsystem. This microphonic characteristic of the beacon generator (only an amusing oddity at the time of this initial experiment) was later put to good use when one of the OTS thrusters failed to operate. Telemetry data were insufficient to determine whether this was due to failure of the electronic thruster driver circuit, flow control valve, or thruster itself. Tapes of the demodulated beacon signal clearly showed the audible 'click' of the valve solenoid operating when commanded, and so it was possible to conclude that the failure was in the thruster itself!

Demonstrations
OTS has been used a great deal since its launch by both ESA and Eutelsat to demonstrate the capabilities of satellite communications to a wide range of potential users of space communication links. The extended lifetime has allowed OTS to be used to develop and test a number of communications and spacecraft-related techniques that were not fully foreseen at the time of its launch. It has also been possible to employ OTS for demonstrations at many additional conferences and symposia, generating interest and confidence in potential new users of follow-on operational communications-satellite systems. More than 170 such demonstrations have been made during the five years of operation.

The effect of these demonstrations has been dramatic. The great demand for transponders on the ECS satellites, particularly for TV distribution, can in part be credited to these demonstrations. In addition, they have contributed to Eutelsat's decision to ask ESA to include special multiservice transponders on ECS flight models F2–F5.

End-of Service (EOS) tests
A number of additional payload and platform tests have been identified which will provide further very useful information, but which could not be performed while the satellite was being used for pre-operational telecommunications purposes. They either require an extended interruption in communications, or could be of potential danger to the satellite itself. It is planned to conduct these tests early in 1984, when OTS's telecommunications capacity is no longer required by Eutelsat.

A number of payload tests will be made, mainly intended to collect performance data for comparison with performances observed during the early part of the mission. Antenna mapping tests will be performed, where solar-sailing manoeuvres will be used to change spacecraft attitude, so avoiding extra fuel consumption.

An important platform test still to be conducted is a solar-sailing exercise using the redundant momentum wheel. Given nominal performance during this two-week test, other tests with a low risk factor will be executed at the same time, such as bearing and power-transfer assembly (BAPTA) tests, extreme pitch bias, 'thruster 19' burn attempt (this thruster failed to operate after some years in orbit), and excitation of array resonances. Two further potentially more risky attitude-control tests are then foreseen: 'Open loop recovery from Emergency Sun-Acquisition Mode' and 'Flat Spin Recovery'. Another test concerns verification of hydrazine thruster performance following tank depletion and a check on thruster performance at low pressure.

Following these tests, OTS is intended to be operated in a 'hibernation' mode for some 18 months, to obtain long-life information on the behaviour of its subsystems.

Finally, a 'graveyard-orbit' manoeuvre is planned, consisting of a pair of east-west thrusts of sufficient magnitude to bring the satellite outside the 'tube' used for active geosynchronous spacecraft into a new (initially) circular higher orbit. The satellite will then be turned off and it will drift around the Earth at a rate of a few degrees/day.

Conclusion
The final de-orbiting of OTS will bring to an end a mission which has been successful far beyond the hopes and expectations which existed at the time of its launch. OTS has, furthermore, demonstrated unequivocally the benefit of such a pilot-mission experimental programme to verify in orbit the hardware and techniques intended for later operational systems.

Broadcasting of Radio Programmes by Satellite Direct to Portable/Vehicle Receivers

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The rapid economic development in the Third World demands improved radio services with affordable and appropriate national programmes. In Africa, only 20% of the population in some countries has radio coverage. Networks of low-power VHF/FM transmitters have been identified as the best conventional approach to improved coverage, but this is likely to be slow and to lead to maintenance problems.

By contrast, sound broadcasting by satellite direct to portable receivers could provide total national coverage speedily and with zero maintenance. Studies of this possibility since 1977 led to an ITU* report in 1982 which confirms its technical feasibility. The satellite technology is proven and the necessary additions to the portable receiver will not add greatly to its cost and complexity. Satellites of the same size as ESA's L-Sat/Olympus could provide direct sound broadcasting at similar cost to ground networks. Such large satellites could broadcast 20 channels or more to be shared by the countries in any one region.

* International Telecommunications Union
** World Administrative Radio Conference 1979

At WARC '79**, the World agreed that further work should be done to aid decision making at WARC '85/'88 on the allocation of a suitable frequency band. If a positive decision is taken in 1985, the Conference in 1988 will choose a specific frequency band. European broadcasters requested consideration of a UHF satellite sound-broadcast service, but the near-equatorial countries would be the first to benefit. The enthusiasm of these Third World countries could be crucial in the campaign at the forthcoming Conferences for winning a frequency allocation for improved radio broadcasting, which could be so important to their economic development.

The need

In recent years, the link between telecommunications investment and the rate of economic development of a country has become more widely appreciated. Some have suggested that sound-radio broadcasting is as important as the telephone service. It has also been pointed out that radio programmes are relatively simple and cheap for broadcasters to produce, unlike television programmes. This makes the ideal of indigenous radio-programme production a realistic goal.

It is difficult to find reliable data for Africa. African countries with low and average GNP per capita have only five or six radio receivers per 100 people, compared to 74 per 100 for Europe or North America. Why so few? Part of the reason must surely be the poor radio coverage of many countries (Table 1).

Most radio broadcasting in Africa is still based on short- and medium-wave transmissions and problems with propagation instability, interference and noise limit the efficient use of these bands. For these reasons, it was agreed a few years ago that VHF/FM is the most useful transmission mode for improving radio broadcasting in Africa. Networks of low-power transmitters can provide the highest quality, interference-free broadcasting service, particularly in those rural areas not already being served. Installation of these transmitters is proceeding in many countries, but it is clear that it will take years before complete coverage can be achieved.

Such terrestrial networks have two serious drawbacks, resulting both from the number of installations involved and their inaccessibility in many cases. Each transmitter requires feeding with programmes and certainly satellite distribution is an elegant solution here.

Table 1 — Radio-broadcast coverage in Africa

Country	Population, %	Area, %
Cameroon	80	65
Ethiopia	20	25
Kenya	65	40
Lesotho	70	70
Rwanda	n/a	20
Tanzania (mainland)	20	20
Togo	70	70
Upper Volta	20	12
Zambia	50	40
Zimbabwe	95	n/a

The problem of maintaining such a network remains. For example, it has been estimated that 30 such transmitters would be required to cover Kenya, and even this seems unlikely to provide full coverage. For many administrations, maintenance would be a major problem.

In contrast, direct sound broadcasting by satellite to portable receivers could provide total coverage of a country, with the maintenance problem being confined to the earth station feeding the programme to the satellite.

Technical feasibility
The Agency started work on direct sound broadcasting by satellite in 1977. From the outset, it was assumed that reception with a portable radio or in a vehicle was essential and it was soon established that a UHF frequency around 1 GHz would be the best choice. Direct-broadcast satellites transmitting in the 12 GHz frequency band are able to transmit radio programmes very efficiently, but only to fixed receivers with rather large antennas.

The ESA studies showed that the technology for both the satellite and the receiver involved design techniques that were well understood and could be used with predictable costs. The main area for international argument has been the link margin required for satisfactory quality. More and more satellite power is required as the receiver moves north and south of latitude 40°, and the geostationary satellite is lower in the sky. The problem is particularly serious in urban areas, and the French broadcaster TDF has made tests in the Paris streets of reception from a beacon transmitting from the top of the Eiffel Tower. Such difficulties clearly do not concern Africa and the satellite power needed would be acceptably low. The European Broadcasting Union (EBU) has made other studies covering the need for bandwidth and the general planning of the service.

The results of the ESA and TDF work were passed via the EBU to the International Radio Consultative Committee (CCIR), which also received contributions from the USA. The most recent result was the publication of CCIR Report 955 in 1982. Its conclusion was that this service was indeed feasible, certainly in rural areas. The portable or vehicle receiver can have an antenna with a beam about 120° wide, which would be more than sufficient to pick up the signal. With such a receiver antenna, the satellite RF power needed to cover an area about 1000 km in diameter is between 100 and 200 W. At a frequency of 1.5 GHz, such coverage can be provided by a satellite antenna about 9 m in diameter, and this is the most unusual part of the satellite. A similar antenna has already been proven in space on NASA's ATS-6 satellite, used in the 1970's for experimental educational TV transmissions to India and North America. Of course, such a large antenna raises particular problems. To fit into the limited space available within the launcher, it must be folded to the size of a large suitcase. This has already been achieved by several companies and further technical progress will no doubt be made.

The portable and vehicle receivers
The receiver concept that has been assumed in the ESA work is essentially the same as the VHF/FM transistor portable in production in many parts of the World, with the simple addition of a printed-circuit antenna built into the top of the case and a UHF/VHF converter to adapt the satellite signal to something compatible with existing receiver designs. If these features were built into a mass-produced receiver, the cost impact would be small.

The vehicle receiver is relatively easy to install, with a flat antenna that can be mounted on the roof of the car or truck cab. Two antennas may be necessary to overcome signal fading due to multipath effects.

If radio receivers are, for example, to be distributed to the rural population of Kenya, so that the coverage would be the same as it is now in urban areas, the number of sets involved would be 2.8 million. Thus it is important that these

Table 2 — Radio receivers in Kenya

	Urban areas	Rural areas	Total
Population (millions)	1.9	13.4	15.3
Radio sets (thousands)	420	120	540
Density of sets (per 100 people)	22	1	–

Figure 1 — Yagi printed antenna for portable receivers (can be printed on receiver case)

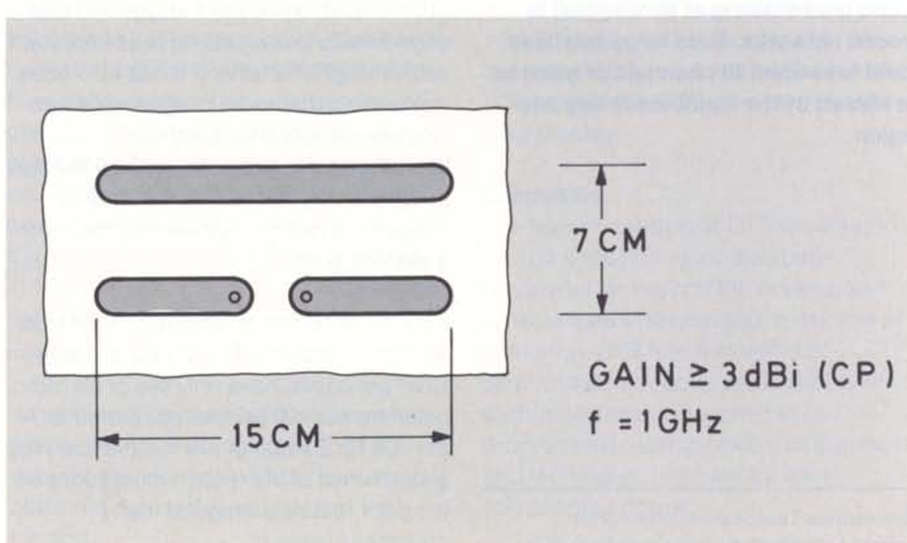
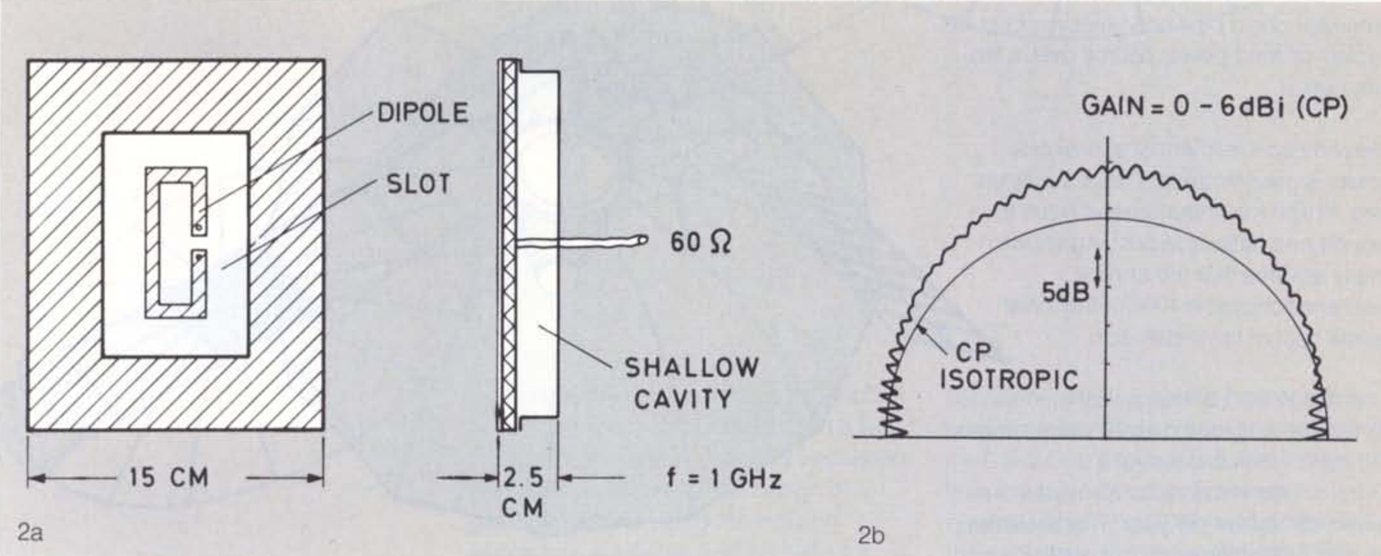


Figure 2 – Slot dipole antenna for car reception
a. General layout
b. Typical radiation diagram



satellite receivers be neither more costly nor more complicated than conventional receivers.

International developments – WARC '79 and after
The sound-broadcast satellite service was discussed at WARC '79. The Conference acknowledged that a service in the frequency band 0.5–2 GHz would provide a service to portables that was impossible in the other bands allocated to the Broadcasting Satellite Service (BSS). It was considered that further studies were necessary before a suitable frequency allocation for operational systems could be agreed. The particular problem of sharing with terrestrial services was highlighted.

At WARC '79, there were proposals from several Administrations, including a number of Third-World countries. These suggested the use of the 1429–1525 GHz band, but it was pointed out that the radio-astronomy service has an allocation in a lower neighbouring band. The Conference therefore encouraged experiments in this service, implying that a few hundred kHz in the upper part of the 1429–1525 MHz band might be suitable (see Resolution No. 505). The CCIR was to continue its studies into the technical characteristics of the system, and into band-sharing with terrestrial services.

WARC '79 resolved that the next WARC (to be ORB-85) should consider the results of all new study work and 'take appropriate decisions regarding allocation of a suitable frequency band'.

Following WARC '79 the CCIR has conducted some studies, the results of which are given in Report No. 955. Technical feasibility is discussed, but little work on sharing with other services appears to have been done to date.

Economics – terrestrial versus satellite transmission
In discussing the economics of any proposal, the two main factors are always:
– Is it more economic than the alternative?
– Is it affordable anyway?

The second question is difficult to answer and certainly impossible for us to resolve here so we limit ourselves to comparing terrestrial and satellite transmission. At the beginning, we talked about the introduction of networks of low-power VHF/FM transmitters, and this is the terrestrial technology that we assume, since it is currently recommended and since it can provide a service quality that is as good as direct satellite broadcasting, as long as enough transmitters are provided.

We can use Kenya as our example once again. It has been estimated that 30 VHF/FM transmitters could provide 100% coverage of Kenya. Each transmitter might have a power of 50 W and theoretically cover an area about 100 km in diameter, using an antenna mast 50 m high. We say 'theoretically', as in practice it is likely that transmitters would vary in power and coverage. In the United Kingdom, VHF radio transmitters range from 10 W right up to 100 kW in a few cases. So 100% coverage of Kenya with only 30 transmitters is probably optimistic. The United Kingdom is roughly the same area as Kenya and about 100 transmitters are needed to provide near 100% coverage of the UK.

The capital cost of the 50 W transmitter would be about 150 thousand US dollars, including something for a solar power supply which would be needed in many rural locations. The solar power supply is important, since it seems that provision of power to remote sites by other methods is likely to be both unreliable and expensive. One estimate made for ESA showed that the cost of a diesel-driven 250 W

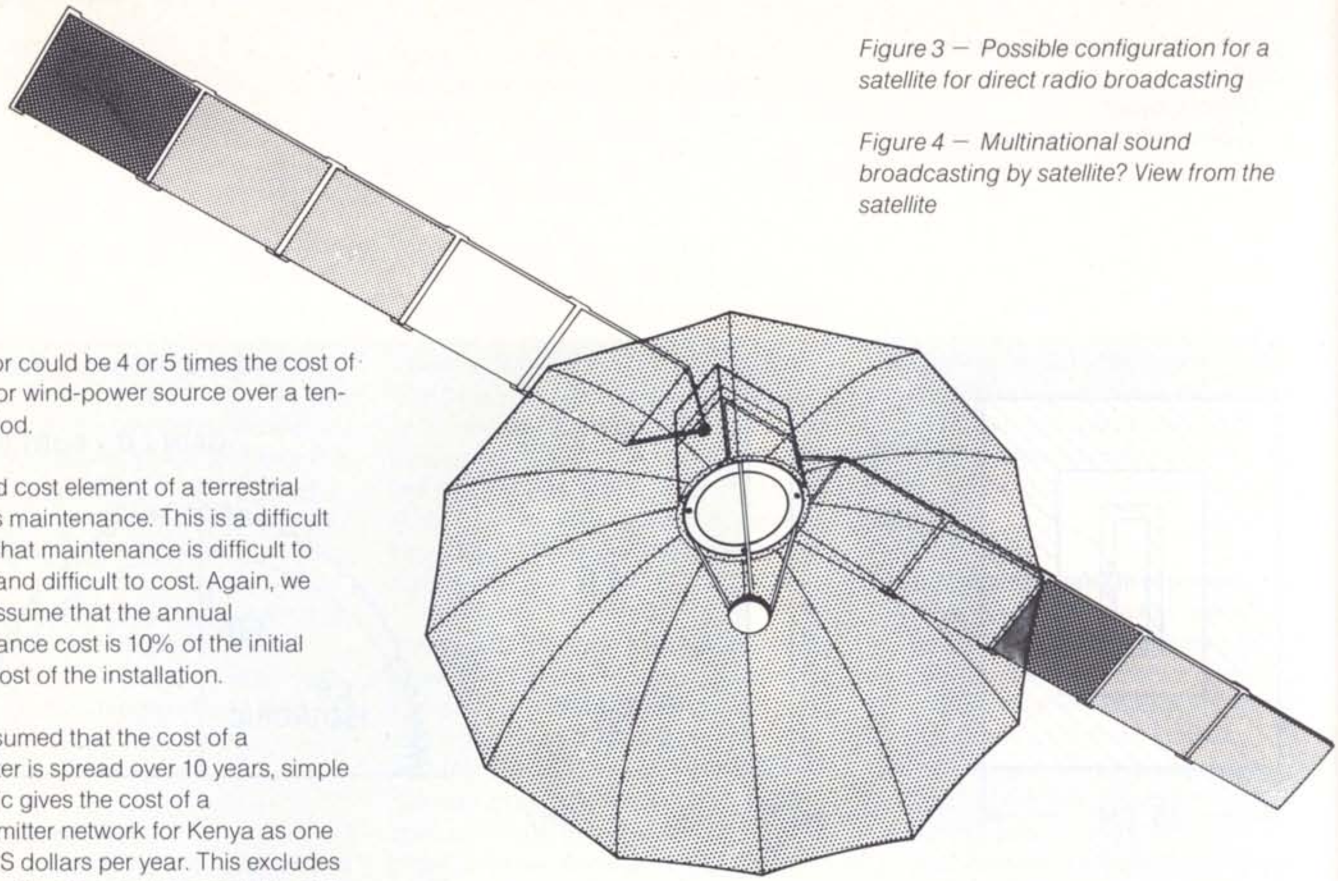


Figure 3 — Possible configuration for a satellite for direct radio broadcasting

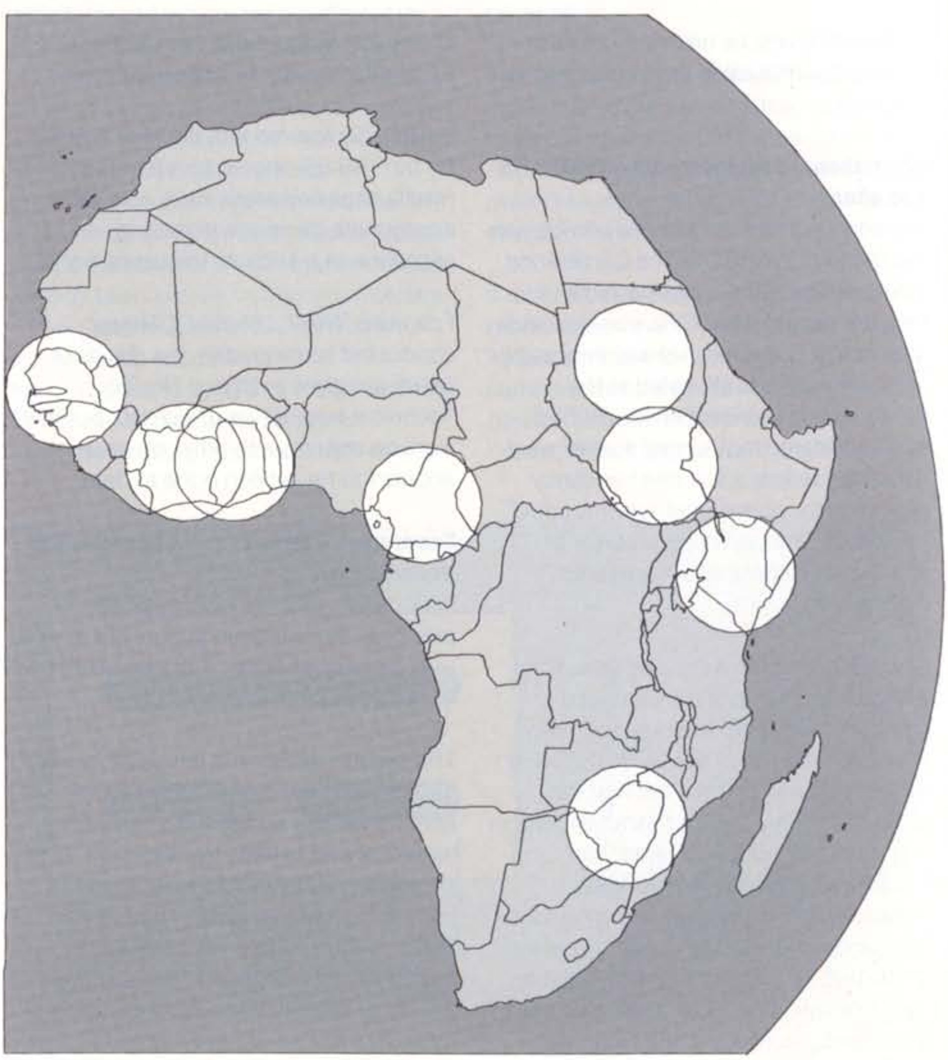


Figure 4 — Multinational sound broadcasting by satellite? View from the satellite

generator could be 4 or 5 times the cost of a solar- or wind-power source over a ten-year period.

A second cost element of a terrestrial system is maintenance. This is a difficult area, in that maintenance is difficult to provide and difficult to cost. Again, we simply assume that the annual maintenance cost is 10% of the initial capital cost of the installation.

If it is assumed that the cost of a transmitter is spread over 10 years, simple arithmetic gives the cost of a 30-transmitter network for Kenya as one million US dollars per year. This excludes the cost of feeding each transmitter, and of course the programmes. It seems that the broadcasting budget of most countries is between 0.1% and 0.5% of the gross national product, so that many countries might indeed be able to spend $1M per year on such a transmission system.

A satellite system that will be cost-competitive with this terrestrial approach will feature some quite large satellites. It was said earlier that an antenna of 10 m diameter or more was required and a channel RF power of between 100 and 200 W to illuminate an area 1000 km in diameter.

The mass and power requirements of the antenna and repeater making up the satellite payload are such that the smaller and currently most typical sizes of satellites are only able to provide a few broadcasting channels. Hence these small satellites are unlikely to be cost-competitive with terrestrial distribution. The most attractive approach is to use larger satellite designs of the size already being built in Europe and the USA, chiefly for direct-TV broadcasting and for Intelsat.

These larger satellites could be designed to carry up to twenty broadcasting channels, and recent Canadian studies have confirmed the feasibility of this

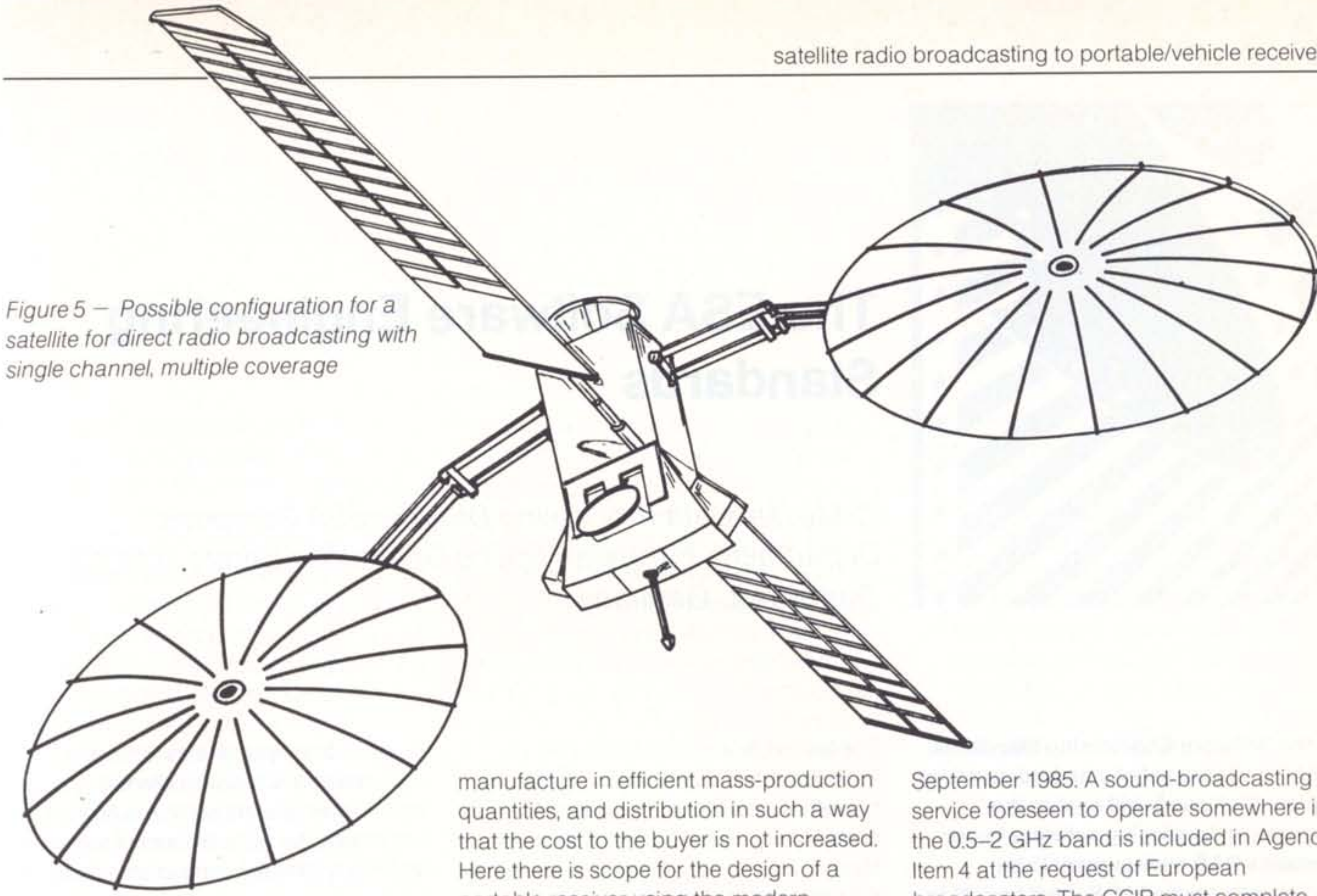


Figure 5 – Possible configuration for a satellite for direct radio broadcasting with single channel, multiple coverage

approach with channel RF powers of more than 100 W. The annual channel cost for such systems is certainly competitive with terrestrial distribution.

Another alternative is to build a multipurpose satellite of similar large size to carry a number of payloads providing different services. Examples of such multipurpose satellites are Arabsat, Insat and ESA's L-Sat/Olympus. Sound broadcasting might then share the cost of the satellite with trunk telecommunication services. Such multipurpose satellites offer the possibility of tariff policies favouring the development of new services.

Satellites can not only be cost-competitive with ground transmitters, but can also provide immediate full coverage, in contrast to a laboriously-built and maintained ground network, and can provide excellent, reliable reception. This will be demonstrated operationally with direct-broadcast satellites in Europe and elsewhere from 1986 onwards.

A review of problems – What now?
There are problems that must be solved to realise full coverage of the population. The necessary number of receivers must be deployed. The answer could be local manufacture in efficient mass-production quantities, and distribution in such a way that the cost to the buyer is not increased. Here there is scope for the design of a portable receiver using the modern technology available, and perhaps for external financing of the setting up of the venture.

The spreading of these portables will only occur if the satellites are in orbit transmitting programmes. Progress is already being made with programme production, but a considerable institutional problem exists in financing the provision of the satellites and sharing their capacity between the different countries if they provide only sound-broadcast services (a two-satellite system could provide 20, 30 or more programmes). This is a major challenge in international collaboration between many countries, but it is a major opportunity for those concerned with the funding of economic-development activities.

However, satellites can only be designed and launched if international agreement is reached as to what frequency band should be allocated for the service. *This is the most immediate and pressing problem.*

Preparations for the next WARC (ORB-85)
The ITU Administrative Council has fixed the date for the first session of the 'Conference Relating to the Use of the Geostationary Satellite Orbit and to the Planning of Space Services utilising it'. This Conference is known simply as ORB-85, and is scheduled for August–September 1985. A sound-broadcasting service foreseen to operate somewhere in the 0.5–2 GHz band is included in Agenda Item 4 at the request of European broadcasters. The CCIR must complete the necessary studies by October 1984. It must be made clear that the task of this first session of ORB-85 is not to allocate the frequency band for the sound-broadcasting serve. Rather, its task will be to define the need for such an allocation, the technical feasibility of the service, and the effect such a service would have on other services (satellite or terrestrial) and on the use of the geostationary orbit.

If the results of ORB-85 are favourable, it is anticipated that the allocation of a band around 1 GHz for direct broadcasting by satellite to portable receivers or vehicles could be agreed at the second session of the Conference, to be held in the second half of 1988.

Because of the technical difficulties anticipated in providing this service to the higher latitude countries, it seems that the Third World would benefit first. The enthusiasm of these Third-World countries could be crucial in the campaign before and during the forthcoming conferences, at which majority voting is required. A successful result would lead to improved sound-radio broadcasting, which could be very important to the Third World's economic development.

The ESA Software Engineering Standards

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In the Software Engineering Standards, ESA now has a set of standard practices which, if followed, will enable the process of developing software in our complex R&D environment to be judiciously controlled. For full benefit to be obtained, these standards should be applied systematically on all projects involving software.

The factors that lead to successful implementation of software projects are nowadays well known to software practitioners, as are those that lead to failures. A thorough analysis of numerous past projects and investigation of the causes of success or failure, based on thirty years of experience with computers and software development, has fostered a new engineering discipline, called 'software engineering'.

Although still far from achieving the maturity of other engineering branches, the development of which started more than a century ago with the birth of the industrial revolution, software engineering has progressed considerably in the last few years. This progress has been encouraged by the development of sophisticated software systems in several major industrial fields. A primary role has been played by the aerospace industry, with its advanced software applications.

In ESA we have a wide variety of different software applications: real-time applications for spacecraft control, mathematical computations for mission analysis and for orbit and attitude determination, modelling applications for various satellite subsystems (power distribution, thermal, structural, communication), simulation of space and ground segments and of payloads, software embedded in station and communications-network equipment, on-board software for satellite and payload control and processing of scientific data acquired from the payload, software for checkout of satellite and payload, software for archiving and retrieval of scientific and applications data, and administrative software. Different organisational units within the Agency are responsible for these classes of software and many different computers are used to support these various applications. In addition, a large part of the software produced at ESA is developed by external contractors, each of them having their own methods for software development. These three factors, the division of responsibility for software, the different hardware and different methodologies from different companies, and the varied nature of the applications, have generated a strong need for some standardised manner of software production. The ESA Board for Software Standardisation and Control (BSSC), made up of senior staff from ESOC and ESTEC, has been making a serious effort to answer this need.

Two aspects of software development were considered when developing the Standards – the product itself and the process of producing it:

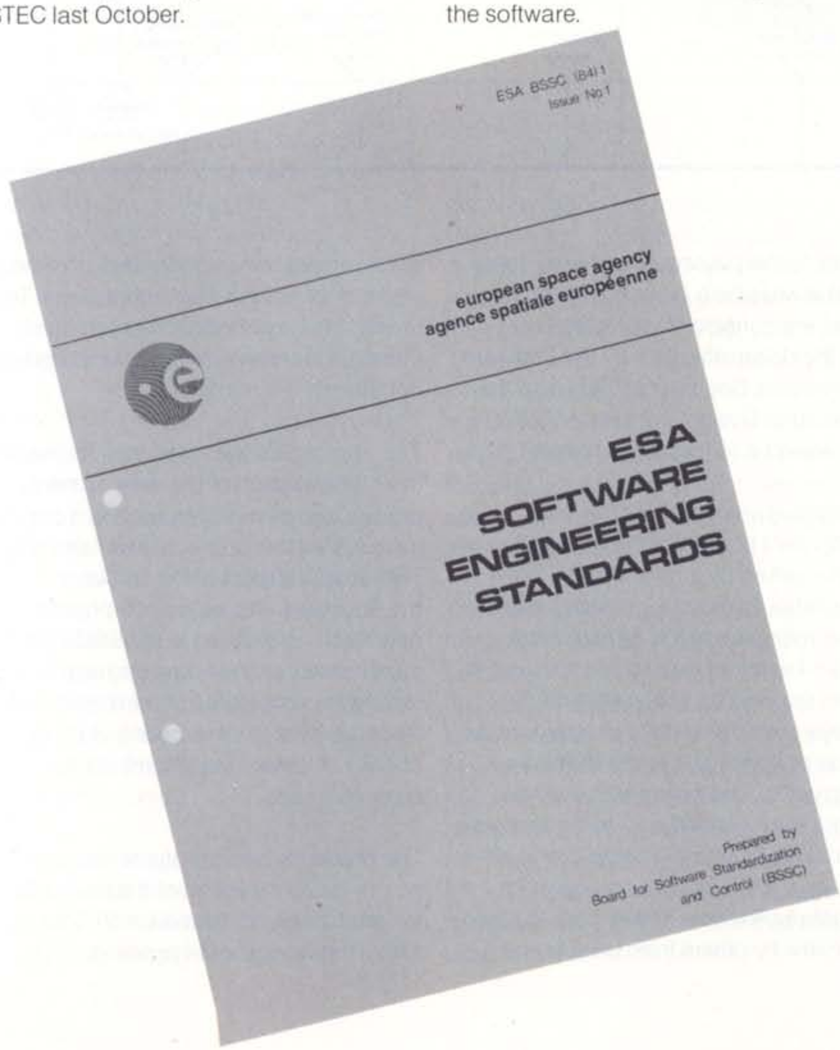
- *The Product:* This covers how the software should be specified, how it should be designed, how it should be coded, how it should be documented, how it should be tested, accepted, operated, maintained, and which qualities it should have in order to meet the specified requirements.
- *The Process:* This covers those actions that have to be taken from a managerial point of view in order to complete the work on schedule, within the agreed budget and in order to guarantee that the product actually meets the requirements.

Despite the considerable differences in the software to be produced, there are strong common denominators between all software-development tasks. These common denominators have been encapsulated in the ESA Software Engineering Standards (ESES). A draft version of the Standards issued in October 1982 was distributed widely within the Agency, and outside, to all industries currently involved in the Agency's activities. The draft was discussed extensively with internal and external experts. A number of useful suggestions were collected, analysed by the BSSC and incorporated in the final Handbook, which is about to be issued.

In general, a good degree of consensus has been reached with industry on ESES, and this was further confirmed at the Software Engineering Seminar held at ESTEC last October.

The Standards are in line with the state-of-the-art of software engineering. The practices recommended are widely accepted and are already past the research stage. The BSSC has carefully avoided recommending anything that has not yet been thoroughly tested, both inside and outside the Agency, with positive results. The terminology used, which is normally one of the indicators of a discipline's maturity, fully conforms to the IEEE Standard Glossary of Software Engineering Terminology. The BSSC document on quality assurance is also directly derived from an IEEE Standard.

The Standards are to be used for any software project in ESA, be it an internal development or contracted outside. All tender actions that contain software as a deliverable item should refer to the Handbook as a basis for the provision of the software.



The standard practices are subdivided into three classes:

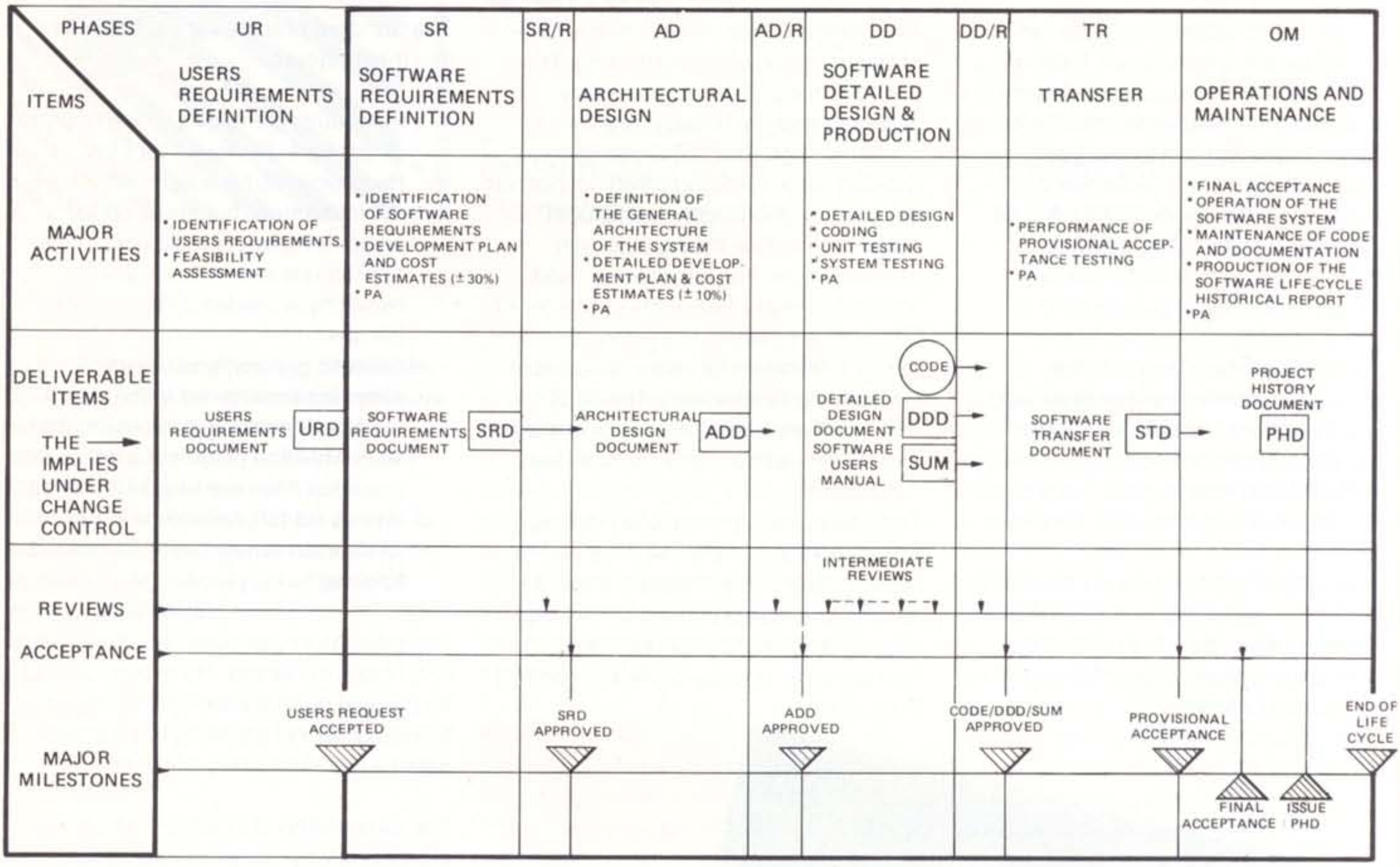
- *Mandatory standards*, which apply to all software developed for ESA.
- *Recommended practices*, which are not mandatory, but are strongly recommended. A justification to the appropriate level in the Agency's hierarchy is needed if they are not followed.
- *Guidelines*, constituted by all the other items contained in the Standards, excluding the mandatory standards and recommended practices. They are to be considered only as useful practices, and no justification is required if they are not followed.

The mandatory practices have been kept very limited in number. No waivers should be granted on these items since they are fundamental; not following them would mean a high probability of failure.

The recommended practices are also, in principle, always to be followed unless there are very strong grounds for not doing so. Typical exceptions could be additions to an existing system for which some other standards were followed, or hardware constraints that would make adherence impossible. These grounds should be clearly identified and the management responsible for the project should be fully aware of the consequences of granting, or not granting, the waiver.

The ESA Software Engineering Standards are founded on the software life-cycle concept (Fig. 1). The software development project is split into distinct phases, each with defined activities and defined items to be released at the end of the phase. It is to be noted that the ESES assume the software to be always composed of code *and* the related documentation (as soon as there are maintenance requirements, nondocumented code is useless!). The phases of the life cycle are:

Figure 1 – Software life-cycle management scheme



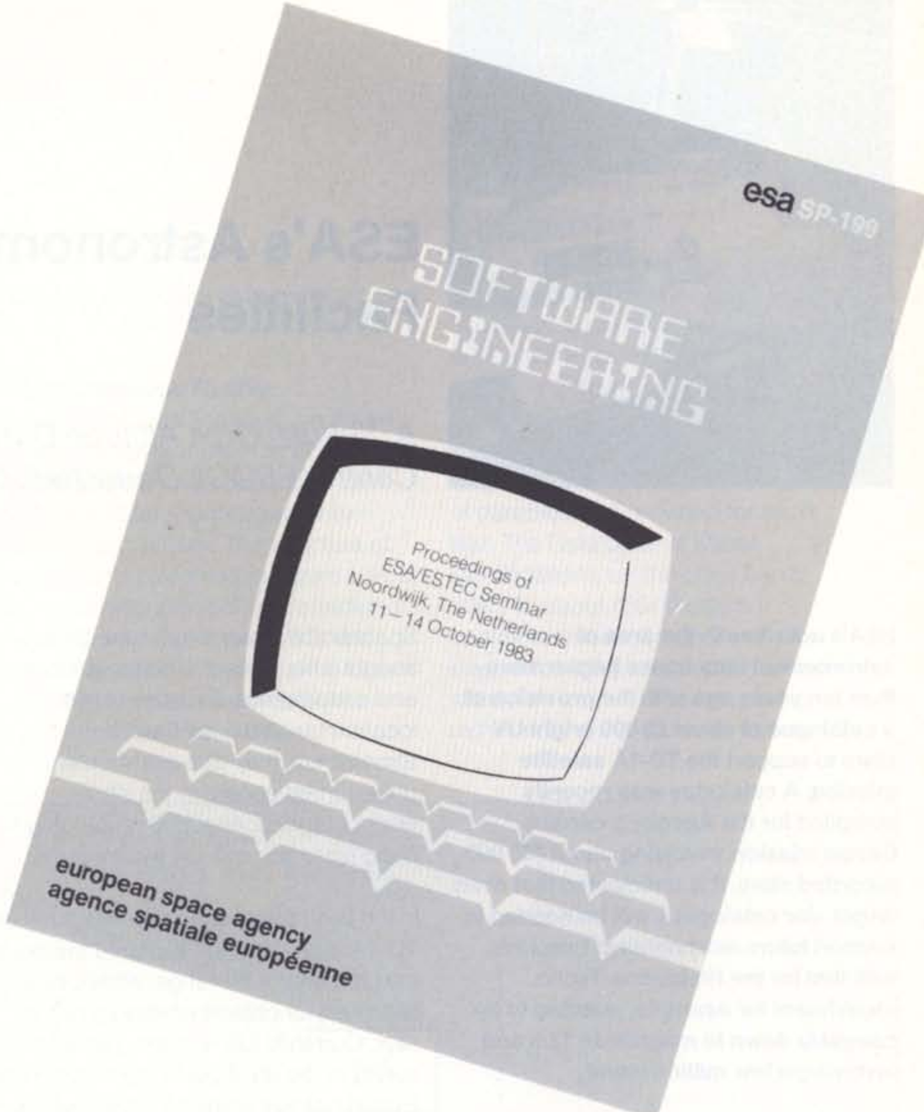
- definition of the software requirements (normally preceded by a written definition of the user needs)
- architectural design of the system to be implemented
- detailed design, coding and testing of the system
- transfer of the system to operations
- operation and maintenance of the software.

Software development is an intellectual activity and it is almost impossible to reduce it to a purely sequential series of activities, particularly in the first two phases (definition of the requirements and the architectural design). As in any creative process, there are iterations (i.e. trials), verifications and trade-offs to be made before the definition of the requirements and the top-level design can be finalised. Nevertheless, in order to proceed in an orderly and methodical manner to the subsequent phases, there should always be a point where the two phases are considered complete, i.e. when the deliverable items – the Software Requirements Document (SRD) and the Architectural Design Document (ADD) – are reviewed and formally approved.

The conclusion of each of the development phases of the life cycle is always marked by a review of the items produced in the phase. In these reviews, various members of the development team and external experts are required to discuss and verify the correctness of the steps undertaken and to eliminate, as early as possible, any errors that may have crept in. The power of the review methodology – which should be seen as constructive help to the project, or in other words as a 'peer review', and never as destructive criticism – stems from the fact that review by others from outside the development team is more likely to detect errors than are the developers alone. The review can be conducted quickly, and therefore inexpensively, if the appropriate documents are made available.

The approval of the outputs is the major milestone of each of the development phases and the next phase should only commence after this approval has been given. This crucial aspect of the software development, also called the 'phased approach', is stressed in the ESES. Several disasters in previous projects have resulted from a global commitment for the whole development without including check points for assessment of the progress made.

The phase reviews constitute decision points for continuation of the work and for establishing the conditions under which the work should proceed.



Another important aspect underlined in the ESES is that, once the software has been validated at module, subsystem and system levels, it should still undergo acceptance tests to ascertain the correctness of the final product before it is made operational. The purpose is to ascertain that it performs according to the requirements specified in the Software Requirements Document. It is worth underlining that this mechanism of concluding one phase with a formal document that forms the input to the following phase, ensures a smooth transition from definition of requirements, to top-level design, to detailed design, to code and to testing. It is relatively easy then in the 'transfer phase', to verify the system's performance against the requirements, after which the system goes into operation.

Operations should always be described in a Software User's Manual (SUM).

The ESES stress the importance of software maintenance. ESA has some operational software that needs to be maintained for several years. Consequently, the maintenance-phase costs may eventually exceed the software's development costs. It is therefore important to produce and maintain proper software documentation.

The ESES also recommend production of a Project-History Document. This document, to be kept in a database, should summarise all the important aspects of a project. The collection of historical data on ESA projects will enable the management to take advantage of past experience and possibly to avoid repeating errors, and it will constitute an excellent basis for estimating for future projects. This document is to be produced by Agency staff and not by the contractors involved.

In general, the emphasis in the ESES is on the managerial aspects of software production. The life-cycle concept, and consequently the phased approach, the documentation requested and the reviews, all help to provide visibility of the development process. This visibility is essential to allow management to make the right decisions at the right moments. The methodology shown in the ESES is, in this sense, quite general and there should not be complaints arising from lack of visibility if the methodology has been followed. Managerial effort is required to apply it systematically on each project, but the tool is there.

The ESES give the project manager the freedom to enforce more stringent standards to satisfy the specific requirements of a particular project. The ESES request the choosing of the design methodology that best suits the project's needs and the establishment of detailed design and coding standards. The latter are often machine- and application-dependent and are always language-dependent; the ESES require that they be established for each project.

Conclusion
In the Software Engineering Standards, ESA now has a set of standard practices which, if followed, will enable the process of developing software in the complex R&D environment to be kept under control. This is a major Agency achievement, but for full benefit to be achieved the management of the Agency should, through the established hierarchy, ensure that these standards are applied systematically on all projects involving software.

ESA's Astronomical Data-Base Facilities

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ESA's activities in the area of astronomical data bases began more than ten years ago with the provision of a catalogue of about 26 000 bright UV stars to support the TD-1A satellite mission. A catalogue was recently compiled for the Agency's current Exosat mission, involving about 435 000 recorded stars. It is anticipated that even larger star catalogues will be needed to support future astronomical missions, with that for the Hipparcos/Tycho experiment for example, needing to be complete down to magnitude 12.5 and involving a few million stars!

The ESA Star Catalogue Facility is well suited for the generation of the necessary operational catalogues from the input catalogues supplied by external institutes, while the 'celestial-cube' method would guarantee rapid data access. The ESA X-Ray Data Base, an extremely versatile tool for the retrieval or recording of X-ray source data, could be used to handle other kinds of celestial objects, such as infrared or radio sources.

Spaceborne observatories are becoming sought-after research tools in astronomy and astrophysics. Because of their location far above the Earth's atmosphere, they give astronomers unperturbed access to the whole electromagnetic spectrum, extending from radio up to gamma-ray wavelengths.

In the past, astronomic satellites such as TD-1A and ANS have explored the sky in the ultraviolet (UV) range, while Cos-B has searched for objects emitting gamma-rays. Currently IUE is making an all-sky survey in the UV, IRAS in the infrared and Exosat has just started to investigate X-ray sources. In future years, Hipparcos will measure the position of stars with an unprecedented accuracy and ISO will make in-depth studies of infrared sources previously discovered by IRAS.

As observers expect to use these observatories just like ground observatories, the control centre that commands the spacecraft has to provide more facilities than are required just to operate it. Centralised astronomical data bases clearly belong to this category of additional facilities. The guest observer who comes to the control centre to prepare his experiment and assess the first collected measurements can use these data bases to retrieve information quickly about the celestial objects that he wants to observe or about the objects emitting in other radiation bands which would fall within the field of view of the instrument during the observation.

On the spacecraft side, the platform will generally be equipped with high-performance star sensors in order to meet the stringent requirements on instrument pointing accuracy. These sensors must provide the spacecraft attitude-control system with the necessary inertial references. Accurate and complete star catalogues are hence required by the control centre to support these sensors.

DEFINITIONS

Visual magnitude: In astronomy, the brightness of a celestial object is defined in terms of magnitude. This unit was invented in the second century BC by the Greek astronomer Hipparcos, who compiled the first catalogue of stars visible to the naked eye. To quantify the brightness of the stars, he assigned a number ranging from 1 for the brightest to 6 for the faintest. As human sensory organs respond roughly linearly to the logarithm of the strength of external stimuli – Fechner's law – it follows that this magnitude scale, still in use today, should be logarithmic in nature. In fact, a star of magnitude one is 2.5 times brighter than a star of magnitude two, which in turn is 2.5 times brighter than a star of magnitude three, and so on.

Spectral type: The spectral type reflects the surface temperature of a star. It also gives an indication of the distribution of the radiated energy as a function of wavelength. If the stars are ordered in classes of decreasing temperature, the following letters are assigned to the corresponding spectral types: O B A F G K M R N S.

The initial development of astronomical data-base facilities was started at ESOC more than ten years ago, for the TD-1A mission. At that time a catalogue of about 26 000 bright UV stars was compiled and graphics-oriented handling tools were developed for star-identification and attitude-determination purposes. Recently, a new impulse has been given to such activities by the Exosat project.

In preparation for the Exosat mission, an X-Ray Data Base Facility was developed for the community of X-ray astronomers and a star catalogue was compiled to support Exosat's star tracker. The procurement of a more general software package called the 'Star Catalogue Facility' was also initiated in preparation for the Agency's future astronomical missions.

The Star Catalogue Facility

The Star Catalogue Facility is a software package that gives a user the possibility to create a specific star catalogue from general star catalogues provided by astronomical institutes. The structure of the package is presented in Figure 1. Four different catalogue levels are considered:

- The Source Catalogues (SC) are those received in their original form on magnetic tape from outside institutes. The size of these catalogues depends on the number of objects recorded and on the amount of data provided for each object. The Yale Catalogue of Bright Stars, for example, contains only 9110 stars, which are all brighter than magnitude 6.5. An impressive number of parameters is provided for each star. The Catalogue of Stellar Identifications, on the other hand, refers to about 435 000 stars. It contains almost all stars down to magnitude 9.5, plus selected fainter stars. The amount of data per star is rather limited, but the main feature of

OF TERMS

Proper motion: Although stars may be considered in a first approximation to be fixed points on the celestial sphere, they have their own motion in space. From photographic plates of the same region of the sky, but taken at widely differing times (several decades), one can observe small displacements in the positions of some stars with respect to their neighbours. The proper motion is generally very small – less than 1 arcsec per year – but it needs to be taken into account to compute the current position of stars from the position given in the catalogue. The catalogued position refers to a fixed time, or 'epoch', usually the year 1900, 1950 or 2000.

Instrumental magnitude: This magnitude quantifies the brightness of a star as 'seen' by an optical detector. As the sensor placed at the focal plane of the instrument may not have the same sensitivity as the retina of the human eye, the magnitude of the observed object may also be different. For prediction purposes, a rough estimate of the instrumental magnitude can be derived from the visual magnitude, the spectral type of the object, and the response curve of the detector.

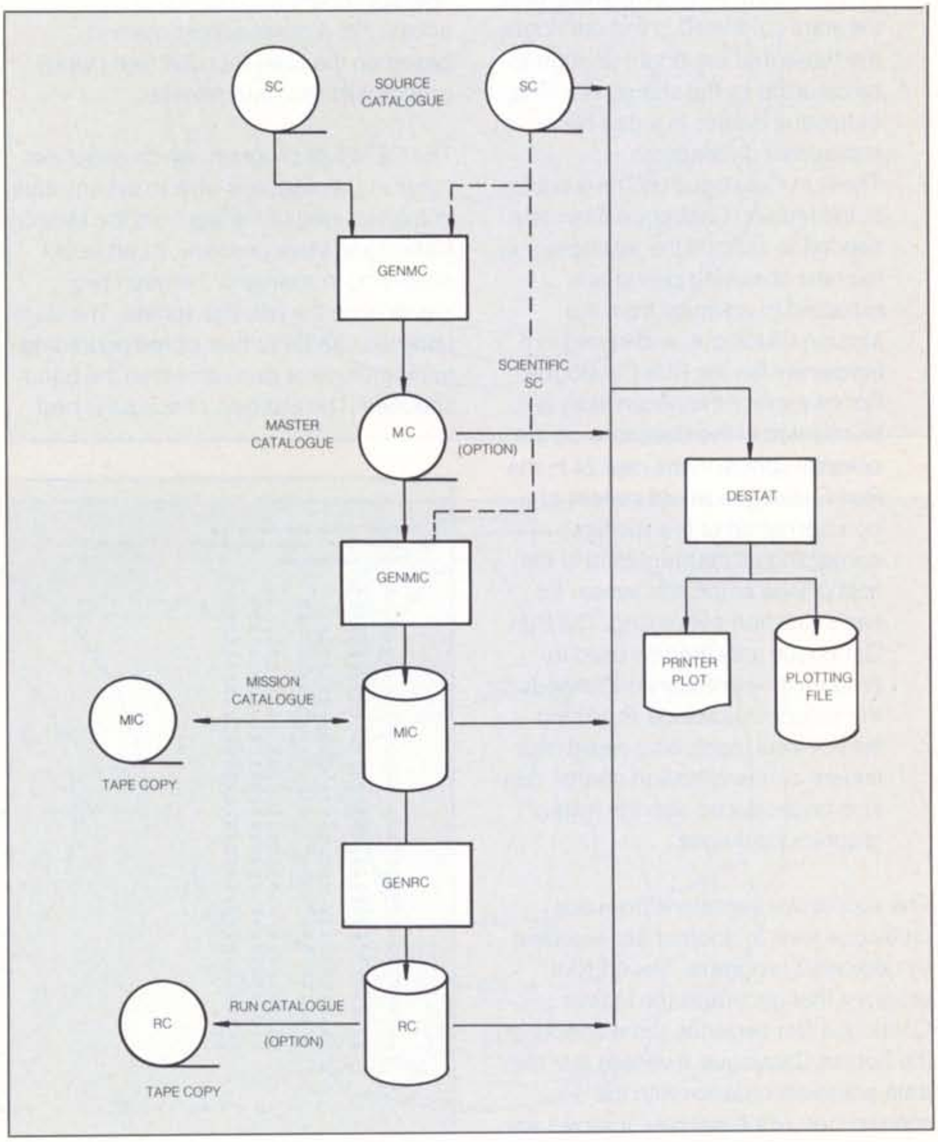


Figure 1 – Concept of the Star Catalogue Facility

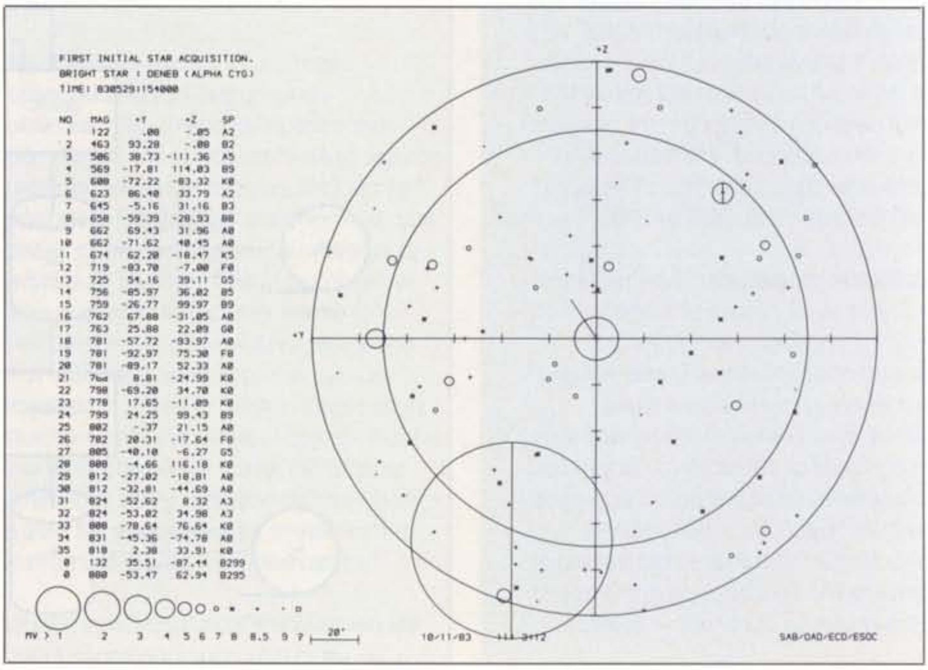
this catalogue lies in the references to specialised catalogues from which further information may be retrieved.
- The Master Catalogue (MC) is a copy of a source catalogue (perhaps with some corrections to a few of the star parameters or including data taken from another source catalogue) and is intended to cover the needs of several potential missions. It also resides on magnetic tape.
- The Mission Catalogue (MIC) is generated from the Master Catalogue (with possible additional information taken from another source catalogue) to cover the needs of a particular mission. For example, the stars contained in this catalogue are those that are bright enough to be detected by the star sensor. This catalogue resides in a disk file to ensure fast data access.
- The Run Catalogue (RC) is a subset of the Mission Catalogue. Star data needed to support the star sensor in the next observing period are extracted in advance from the Mission Catalogue and stored in a temporary file, the Run Catalogue. For example, if the observatory is to be oriented in five directions on the celestial sphere in the next 24 h, the Run Catalogue would consist of a concatenation of five subfiles containing all the stars lying in the field of view of the star sensor for each direction of pointing. The Run Catalogue may then be used to prepare the necessary commands for the sensor in advance. Predicted field-of-view maps, also called 'star finders' or 'identification charts', may also be produced with the help of graphics packages.

The successive transitions from one catalogue level to another are executed by dedicated programs. The GENMC program that generates the Master Catalogue first performs some checks on the Source Catalogue. It verifies that the data are in accordance with the specification of the supplier. It allows also for deletion, insertion or correction of star data. If two Source Catalogues are used, parts of the star records from one catalogue may be replaced by corresponding values from the other.

The GENMIC program which generates the Mission Catalogue can assume all tasks included in the previous program. In addition, the following features are available: computation of the instrumental magnitude, selection of stars in a given magnitude range, computation of the star positions for a given epoch and in a given system of coordinates. The stars are sorted according to their positions on the celestial sphere and stored on a direct-access file. A novel access method based on the celestial cube (see below) guarantees fast data retrieval.

The GENRUN program, which generates the Run Catalogue, is able to extract stars in a given area of the sky from the Mission Catalogue. More precisely, it can select stars lying in a circle or between two parallels on the celestial sphere. The stars retrieved can be further stored according to magnitude or azimuth within the band specified. The first type of access is best suited to support a spacecraft in pointing mode, whilst the latter is applicable when the spacecraft is in scanning mode, i.e. the telescope is sweeping a band across the sky.

In addition to these transition programs, the 'Star Catalogue Facility' provides the DESDAT program, which can produce descriptions, statistics and perform auxiliary computation functions on any catalogue level. The program can, for instance, list and sort stars according to a set of criteria defined by the user; it can also produce histograms or compute correlations between selected star parameters. Star maps for a given area of the sky may also be produced. Figure 2 is an example of a map used to support the Exosat mission. It shows all the stars in a circular, 2° radius field of view, which corresponds to the field of view of the star sensor plus a small margin. The star in the centre of the field of view is Deneb, the brightest star in the constellation of the Swan and the first star acquired by Exosat. Nonstellar objects are represented schematically by a circle with a vertical diameter drawn in, the diameter being proportional to the apparent size of the



NO	MAG	+Y	+Z	SP
1	122	.00	-.05	A2
2	463	93.20	-.00	B2
3	506	30.73	-111.36	A5
4	569	-17.81	114.03	B9
5	600	-72.22	-83.32	K0
6	623	86.40	33.79	A2
7	645	-5.16	31.16	B3
8	658	-59.39	-20.93	B8
9	662	69.43	31.96	A0
10	662	-71.62	40.45	A0
11	674	62.20	-18.47	K5
12	719	-83.70	-7.00	F0
13	725	54.16	39.11	G5
14	756	-85.97	36.02	B5
15	759	-26.77	99.97	B9
16	762	67.88	-31.05	A0
17	763	25.88	22.09	G0
18	781	-57.72	-93.97	A0
19	781	-92.97	75.30	F8
20	781	-89.17	52.33	A0
21	7bd	8.81	-24.99	K0
22	798	-69.20	34.70	K0
23	778	17.65	-11.09	K0
24	799	24.25	99.43	B9
25	802	-.37	21.15	A0
26	782	20.31	-17.64	F8
27	805	-40.10	-6.27	G5
28	808	-4.66	116.18	K0
29	812	-27.02	-18.81	A0
30	812	-32.81	-44.69	A0
31	824	-52.62	8.32	A3
32	824	-53.02	34.98	A3
33	808	-78.64	76.64	K0
34	831	-45.36	-74.78	A0
35	818	2.38	33.91	K0
0	132	35.51	-87.44	8299
0	800	-53.47	62.94	8295

Figure 2 — A predicted field-of-view map

object. The Pelican Nebula (also called I5067-70) and another smaller diffuse nebula are also shown. The *y*- and *z*-reference axes are those associated with the field of view of the star sensor. The arrow in the centre indicates the direction of the celestial north. This is useful if the user wishes to compare this map with a conventional star atlas. The instrumental magnitudes are recorded in units of 0.01, the local coordinates in arcmins and the spectral type is represented by two characters.

The celestial cube

As we have seen, the retrieval of all objects lying around a given point on the celestial sphere is the most frequent form of access to an astronomical data base. One way to implement it would be to take every object in the data base in turn and to check whether it satisfies the request. Because of the very large number of objects, this method would be very inefficient. One feels intuitively that it would be better for objects belonging to the same region on the sphere to be stored near each other in the file, so that only part of the data base would need to be scanned through. The problem then is to divide the celestial sphere into areas of roughly equal size. Identical areas can be obtained by projecting a regular polyhedron onto the surface of the sphere. Of the five regular (also called 'platonic') polyhedra (tetra-, hexa-, octa-, dodeca- and icosa-hedron), the hexahedron (alias cube) has been selected because of the trivial trigonometric formulation involved. The projection of the cube onto the celestial sphere is called the 'celestial cube'. Each face of the cube may then be further subdivided into smaller zones by drawing a grid of *n* lines and *n* columns. These zones are numbered from 1 to $6 \times n \times n$. When the data base is generated, each object is attributed the number of the zone it belongs to. All objects with the same zone number are stored in consecutive locations in the file and a directory is set up to indicate where the first object in each zone is stored.

To retrieve data on all objects in a given region of the sky, it is necessary first to find out which zones are overlapped by that region and then to extract all objects from these few zones via the directory. Only these objects are then checked to see if they lie in the region of interest.

A representation of the celestial cube is shown in Figure 3. Five of the six faces can be distinguished, as well as the grid's construction. The circle centred on S overlaps zones (2,2), (2,3), (3,2) and (3,3) of the $+y$ face. To establish which zones are overlapped by a band, or part of a

Figure 3 — The celestial cube

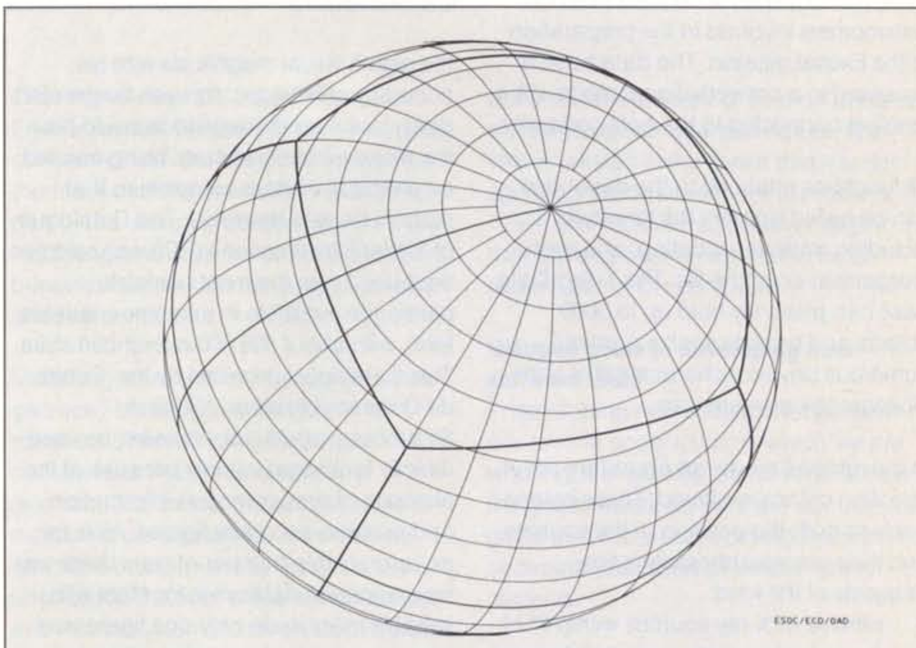


Figure 4 — Partitions on the celestial cube

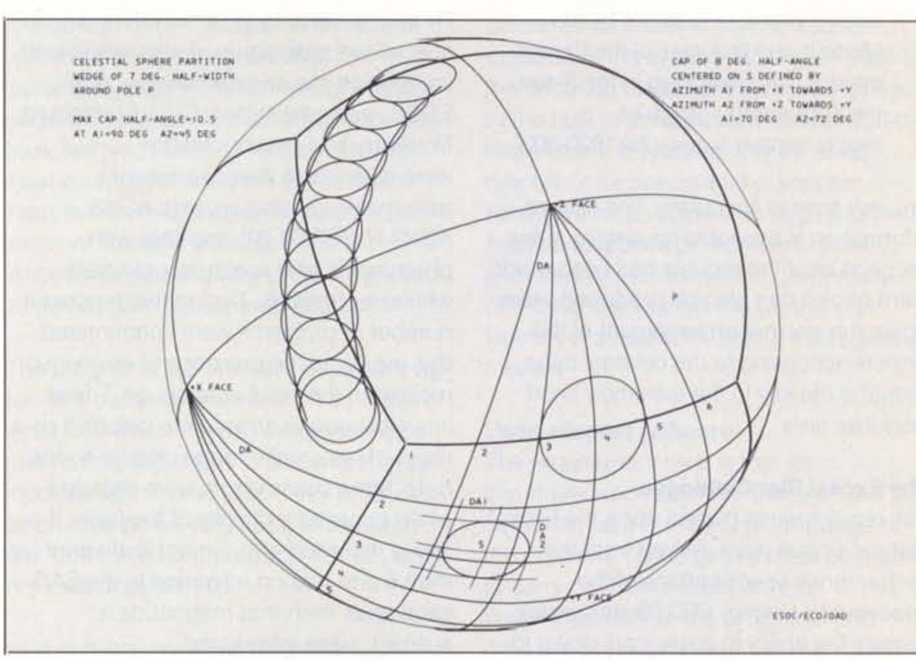
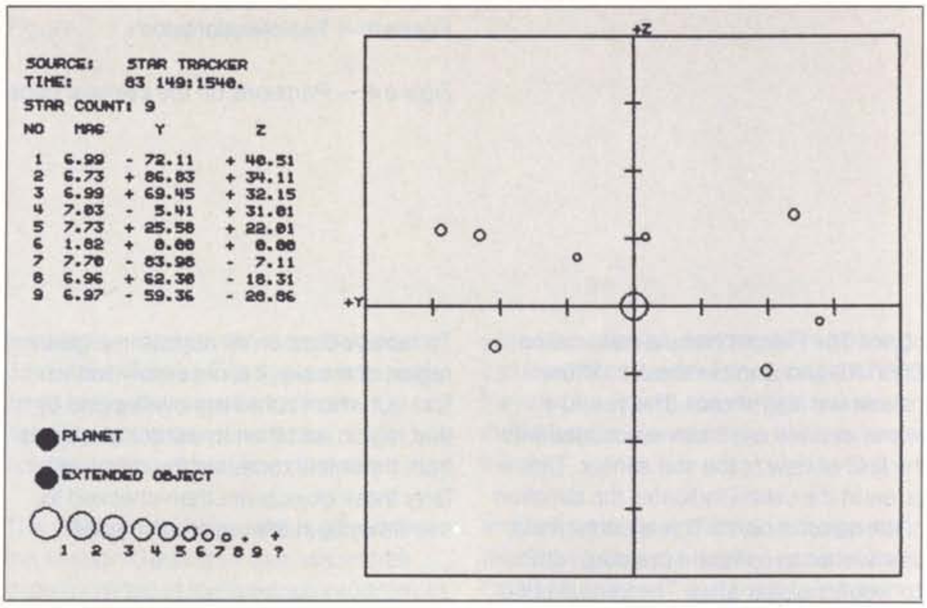


Figure 5 – The first star image detected by the Exosat star sensor



band, one first defines a pattern of partially overlapping circles which covers that band. One can then easily define the overlapped zones for each of these circles.

The X-Ray Data-Base Facility

This facility was developed at ESOC in response to a specific request from the astronomers involved in the preparation of the Exosat mission. The data base is accessed in a conversational mode, via a terminal connected to the host computer.

All functions attached to the data base can be called up from the terminal, including retrieval, updating, and even reorganisation of the file. The X-Ray Data Base can presently hold up to 5000 objects and provide each's position, numerous physical characteristics and bibliographical references.

In the retrieval mode, an abundant set of selection criteria is offered. These criteria apply to both the position of the sources and their physical characteristics. Requests of the kind:

- retrieve all X-ray sources within 5° of the galactic centre and identified as globular clusters or Seyfert galaxies
- retrieve all X-ray sources near the ecliptic plane, occultable by the Moon in the first year of the Exosat mission, and radiating in the X-ray medium-energy range or
- simply retrieve source '3A1820-303'

are very easy to formulate. The desired information is available for display a few seconds after the request has been made. Hard copies can also be produced. Here again the internal arrangement of the objects according to the celestial cube format is the key to the extremely short response time.

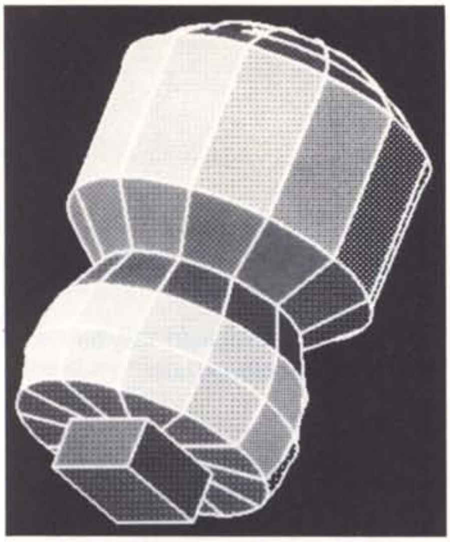
The Exosat Star Catalogue

The requirements placed upon the Exosat star catalogue were derived from the performance specifications of the spacecraft's Sodern SED 03 star sensor, namely the ability to track stars down to the eighth visual magnitude with an accuracy of 3 arcsec. As even fainter stars down to the tenth magnitude could bias the measurements of stars being tracked, a catalogue of stars complete to that magnitude was desirable. The Catalogue of Stellar Identifications (CSI) was selected because it was the most complete catalogue available in machine-readable form, with about 435 000 referenced stars. This Catalogue, provided by the 'Centre de Données Stellaires' (CDS) in Strasbourg, could not, however, be used directly for Exosat, mainly because of the absence of proper-motion information and position-accuracy figures. Also, for an appreciable number of stars there was no magnitude data while for stars with variable magnitude only one figure was given, corresponding to the maximum, minimum or average brightness.

By taking advantage of the references to specialised catalogues, it was possible to improve on the original catalogue at ESOC, with advice from CDS, Strasbourg. Positions and proper motions were taken from the most recent astrometric catalogues (e.g. AGK3, AGK3-R, PERTH-70), together with photometric and spectroscopic data whenever possible. During this process a number of problems were encountered, due mainly to the presence of erroneous records in the input catalogues. Trivial input-catalogue errors were detected as a result of systematic range checks on the data. More subtle errors were detected when plausibility checks of the form: 'If a star is recorded with a magnitude brighter than 6 and has no reference to the SAO catalogue, then that magnitude is suspect', were introduced.

From the experience gained in the compilation of the Exosat catalogue, one can only confirm that error-free catalogues do not yet exist, although major improvements have been observed since the introduction of automated data processing in astronomy. The considerable effort invested in the compilation of the Exosat star catalogue was, however, highly worthwhile. During the first five months of the Exosat mission, the star sensor was requested to acquire and track about 600 stars. In that period the acquisition failed in only five cases, each time because the star was in reality much fainter – by about one order of magnitude – than expected. Figure 5 shows the very first constellation of stars detected by the sensor on the 29 May 1983. It can be compared with the predicted pattern of stars shown in Figure 2 and centred on Deneb.

The Exosat catalogue is already being used to prepare for another mission, namely the Giotto spacecraft's encounter with comet Halley in 1986. Star maps of the type shown in Figure 2 are being produced to show the comet's position with respect to background stars as it sweeps across the sky and to show the star background as seen by the spacecraft during its cometary approach.



MANIP and MINIP: New Modelling Tools for the Thermal Engineer

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In developing new tools for the thermal engineer we have as our ultimate goal a fully interactive engineering computing environment in which all communication with the software will be in engineering terms. Strong emphasis will be placed on high-speed interactive graphics for problem specification, verification and results interpretation. The MANIP system is a big step towards this goal. The MINIP system, developed as a prototype for MANIP, is already in use as a pre-processor for the existing analysis tools and demonstrates the techniques and principles of MANIP.

The engineers in ESTEC's Thermal and Environmental Control Section are mainly concerned with the design of spacecraft thermal-control systems. An important part of the design process is the modelling and analysis of the system's behaviour under various simulated orbit and test conditions.

Modelling starts with a description of the geometry of the spacecraft and the materials of which the geometry is constructed. From this we derive a mathematical model (essentially a set of mathematical equations) on which we can base calculations to carry out the simulation. The final stage is the analysis and interpretation of the results of these calculations.

The engineer relies heavily on the use of various computer programs for several steps of the modelling process. In particular, large computer programs are used for parts of the mathematical model: view factors, which represent radiative heat exchanges between surfaces and heat rates, which represent inputs from external sources, such as the Sun. Another large computer program is used to perform the actual simulations.

The programs that we have at present all run in a batch environment. They require input files which have to be prepared by means of a text editor in a format that is inconvenient for the user. They produce, as standard, very large output files with few facilities for data reduction. Last, but not least, they are old.

As a consequence, the engineer spends a considerable amount of time on tasks of a purely computer-oriented nature. This time is wasted in the sense that it is not spent on the treatment of the problem. There is an additional disadvantage in that the engineer is required to be an expert user of the computer.

Ultimate goals in developing new software tools

In developing new software tools, there are several goals towards which we are working. It should be borne in mind that the goals described here are our ultimate goals and the present developments necessarily fall short of them in some respects.

Interactivity

We need a software system that is interactive in all tasks; a working definition of interactivity here is that no action required of the system takes more than a few seconds to deliver the result. Applied to the task of simulation, it is clear that this requirement is feasible only for small models or for specialised computer hardware when applied to large models. Applied to graphical representations of geometrical models and to graphically displayed calculation results, it is quite feasible at present for all but the largest models.

User-adapted software

The requirement here is that all communication between the user and the computer be in the natural language of the problem. The engineer must be able to carry out his function without knowledge of how the programs and data are organised within the computer.

This is in sharp contrast to the existing situation, but with a little care it is already achievable.

Structured problem description

We want the mathematical description of the problem to represent physical reality as closely as possible. This means that we wish our description of the problem (i.e. our model) to have an organisation that reflects the organisation of the object being modelled. Failure to achieve this will introduce extra difficulties, for example when minor changes in the object (design improvements) require major changes in the model.

Future software should strongly encourage such natural and well-structured problem descriptions, putting an end to the monolithic models that are commonplace today in thermal analysis.

High-speed interactive colour graphics

It is an old but nonetheless apt cliché that a picture is worth a thousand words, or in our case a thousand numbers, a reflection of the eye's power for dealing with pictures rather than long lists of numbers. Often the user is only interested in a few numbers within a large data set. When this large amount of data is presented in the form of a picture, especially when colours are used to convey meaning, it is much easier to detect anomalies and to focus attention on the particular numbers of interest. This can be applied not only to the interpretation of the results of calculations and tests, but also to the construction and verification of problem descriptions.

It must be stressed, however, that graphics facilities are only useful if they are both fast and convenient. The feasibility of combining these two features is already proven by state-of-the-art graphical display systems.

Interactive design

When mathematical modelling is employed as part of the design process, we can distinguish three distinct tasks:

- definition of the model
- calculations based on that model
- interpretation of the results of the calculations.

On the basis of the results of a calculation, changes are made to the model, fresh calculations are carried out, and the new results compared to the old.

One of the most desirable features of modelling is to be able to experiment with the effects of changes to the design through modifications to the model. When the modelling process is divided into distinct tasks, as we have at the moment, this becomes time-consuming and laborious. In an integrated analysis tool, the boundaries between these tasks are reduced in significance. It should be possible for the engineer to see the effects of design modifications more or less immediately. This means that we can make repeated modifications to the definition of the model while observing the effects in the results of the calculations. One example would be changing the thermal design (e.g. an emissivity) while watching the effects on the calculated temperatures, displayed as colours on a drawing of the spacecraft.

Documentation

Future systems must maintain automatically a fully detailed record of all stages of model development and the simulations carried out. This is required in order that the development may be retraced and appraised later.

MANIP

Of the two connected developments described in this article, MANIP is by far the larger: it represents a major stride towards achieving the goals outlined above. While it falls short of these ultimate goals in some respects, it represents a significant advance in the state-of-the-art of engineering computing. The timetable for the MANIP project is shown in Table 1. The total manpower required to obtain the first release will be in excess of ten man years.

Description of the system

The MANIP system is envisaged as taking the form of an interactive 'operating system' for thermal-engineering modelling, superimposed on the real operating system of the computer. It satisfies some of our most important requirements, namely: the user requires no knowledge of the computer, data storage or program structure and all communication with MANIP is in the real-world terms of the engineer's problem.

Modelling and simulation tasks are supported by a scientific database with three important properties: its internal structure is completely invisible to the user; it uses real-world terms to describe objects; it permits the definition of data items as functions instead of as constants. As a consequence of this last capability, MANIP will support the analysis

Table 1 — MANIP timetable

August 1982	User requirements issued
January 1983	Phase 1: Final software specification and architectural design begin
End 1983	Phase 1 complete
January 1984	Detailed design and implementation commence
End 1985	User trials
End 1986	Final acceptance

of objects that have variable geometry – indeed anything can be variable within a MANIP model.

The database will also be largely responsible for the automatic documentation and history functions. In addition, it will allow the creation and use of libraries of submodels: this will allow rapid conceptual studies through the assembly of standard components from libraries for quick analyses. MANIP will make it very easy to study the same model in a range of different environments and subject to different conditions and events, with automatic comparison of the calculation results as a function of the changing conditions.

The system relies heavily upon high-speed, interactive, colour graphics for model creation, modification, verification, for the processing of results of calculations, and for the reduction of the results from multiple calculations.

MANIP is not restricted to the current technique of spacecraft thermal modelling as typified by the SINDA program. The inclusion of suitable algorithm libraries and a minor reconfiguration of the database would allow the use of different techniques, such as finite-element thermal analysis. Indeed the possibilities of combined analysis are not excluded by the design of MANIP.

MINIP

During the preparation of the user requirements for MANIP, a number of issues arose which might have materially affected the project. They centred mainly around the desirability and feasibility of using interactive computing for engineering problems of this nature and the applicability of high-speed graphics as specified for MANIP.

It was decided to parallel the early stages of the MANIP project with an in-house project with considerably more restricted specification. This miniature MANIP, from which we derive the name MINIP (Mini-MANIP), would at the same time fulfil certain other requirements: it would bring some of the benefits of MANIP to the thermal engineers in ESTEC two years earlier; it would allow evolution in the MANIP requirements through experience before the MANIP project progressed too far. Specifically, it has allowed an evaluation of the style of the man/machine interface that was envisaged for MANIP.

Development of the system

The development of the MINIP system started in September 1982 and the first release was in service in the Thermal Environmental Control Section at ESTEC in June 1983. The system has undergone considerable development since that date. By October 1983, a total of approximately eight man months had been spent on the development.

The development strategy, which we have called Interactive Prototyping, is roughly illustrated in Figure 1. Such a strategy has (in common with all development methods) its strong and its weak points. Its major advantage is that the end users can significantly influence the specification of the system and will ultimately get something that they really want. A disadvantage, if it must be reckoned so, is that the specification is never frozen unless a deadline is imposed. Furthermore, it is not a reasonable process to apply to a large team. In our circumstances neither disadvantage applies.

One of the interesting consequences of this development method applied to this project is that features originally regarded as highly desirable have eventually been discarded completely, while others regarded as 'frills' have become indispensable aids to the engineer.

The first release of MINIP has been implemented on a Hewlett-Packard 9845C desktop computer equipped with a large internal memory, a colour-graphics display and a floppy-disc memory system.

Scope of the system

MINIP is restricted to the role of a pre-processor for the viewfactor calculation programs (i.e. VWHEAT or LOHARP). It is concerned with the creation and manipulation of geometrical models and the description of the physical properties of the materials of which the models are constructed. MINIP produces (apart from documentation and graphics, etc.) a correct and suitably formatted data file for input to these programs.

A version of MINIP is planned which will use the original model combined with

Figure 1 — Illustration of development method

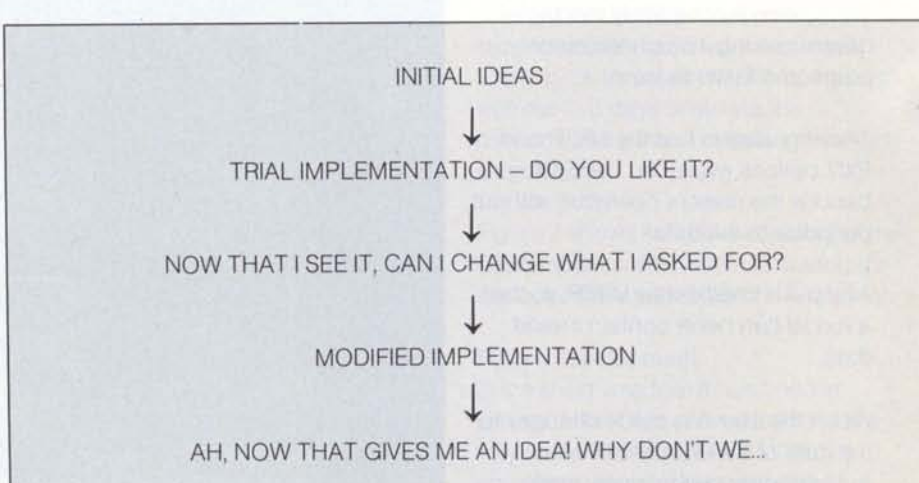


Figure 2 — Display and menu of the Graphical Editor

analysis results to generate graphical representations of the model behaviour, for example showing temperatures as colours.

Description of the system
MINIP is a single, highly interactive computer program for the construction, verification, manipulation and documentation of geometrical models. It incorporates a database whose internal organisation is completely invisible to the user: he refers only to a particular version (called a 'mark') of a particular model.

MINIP makes use of relatively high-speed colour-graphics displays for several functions: to prompt the user for the definition of surfaces; to verify the geometry; to produce high-quality semi-realistic displays of the model; to access the data of the model by means of a graphical editor.

We can make a number of key statements concerning the style of the man/machine interface:

- The user does not have to know anything about the computer, except how to turn it on and the single command necessary to run MINIP.
- Nothing the user can enter at the terminal can crash MINIP.
- The system is completely menu-driven, making it much less error-prone and faster to learn.
- The user always has the HELP and EXIT options available. The EXIT cancels the present operation without prejudice to the data.
- All input is checked by MINIP, so that a model can never contain invalid data.
- When the user has made changes to the data of a model, MINIP will automatically create a new mark. This means that the user can never accidentally destroy the contents of a model. This also means that the history of the model is always available. It should be noted that this does not cause data redundancy, since the database shares common data between marks.

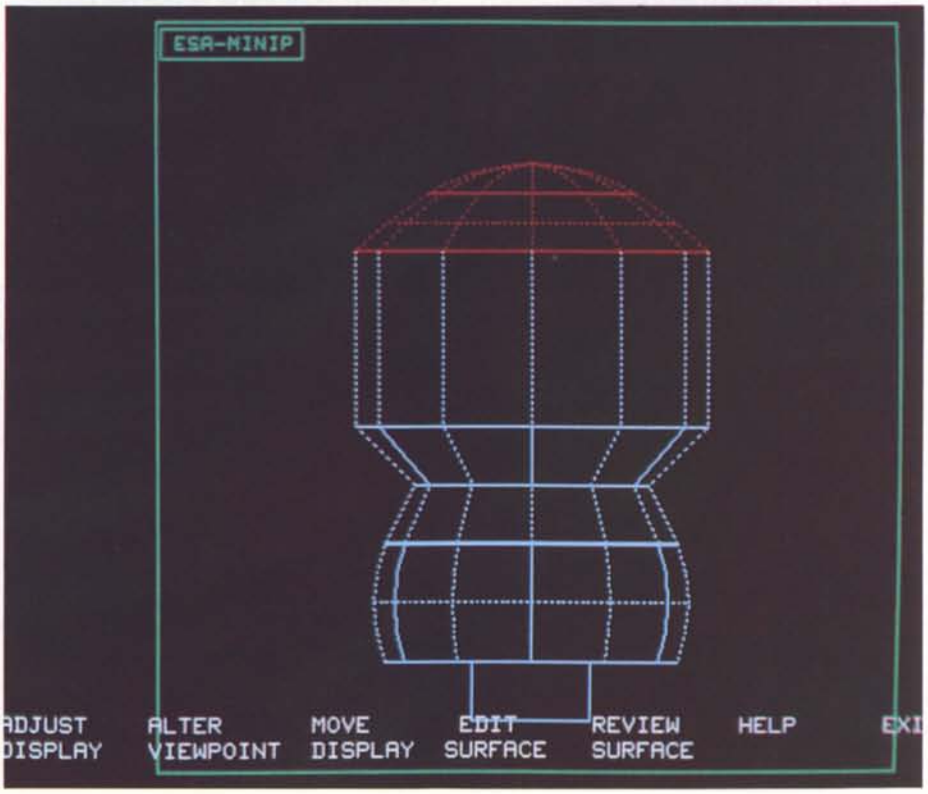
Additional capabilities of the system include the automatic production of a full report of the contents of a mark in a readable, titled, paginated, dated A4 format.

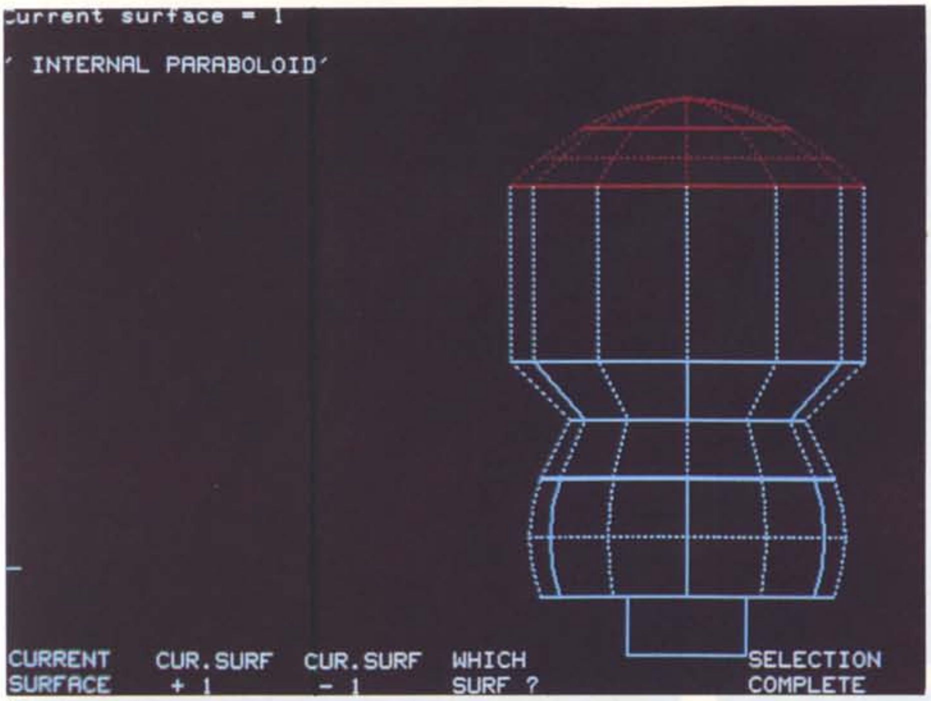
Using the system
Since MINIP is primarily a graphics-oriented system, its use is best illustrated through examples of screen displays. Figure 2 shows a side view of a simple demonstration model containing seven surfaces. The menu in this case is that of the graphical editor. With the hardware on which we developed this prototype system, the menu labels correspond to keys just below the screen: choosing from the menu is simply a matter of pushing the appropriate button. Note the two options 'HELP' and 'EXIT' discussed earlier.

The surface at the top of the screen is in a different colour from that used to draw the others. This difference identifies it as the 'current surface' in the model.

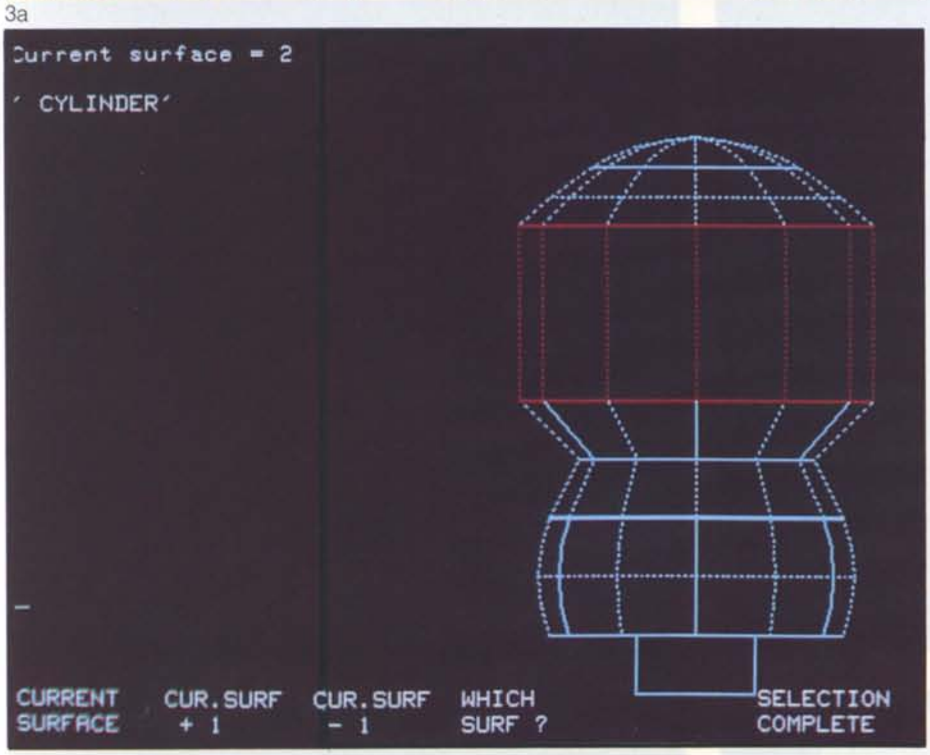
All actions on the data are carried out on the current surface. The colours used to draw the object can be changed by the user to suit his own taste.

Selecting the option 'CHANGE SURFACES' gives the display and menu of Figure 3a. This permits the user to select a different surface as current; for example 'CURR.SURF + 1' would step forward to the second surface as shown in Figure 3b. Repeated application of this stepping process allows the user to access, by graphical means, any part of the model without the need to know the number or name of the surface and without documentation of the model.

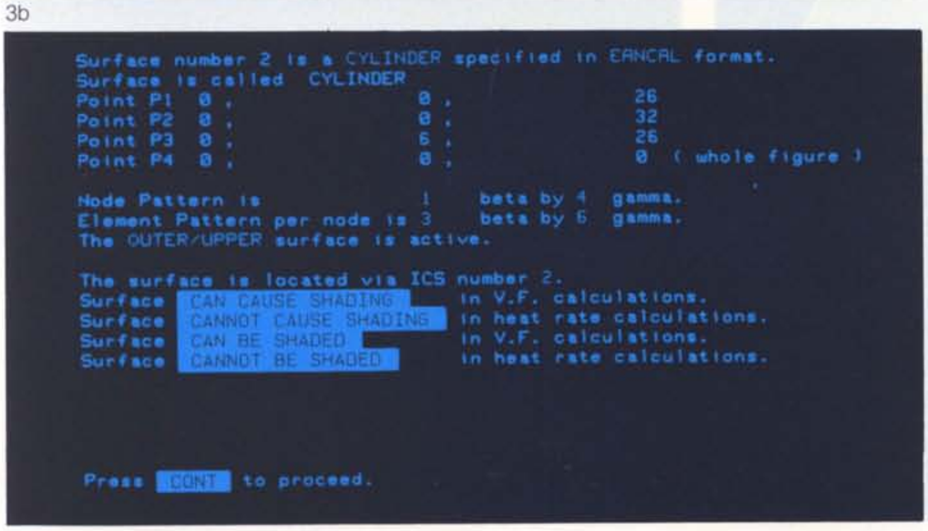




3a



3b



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Figures 3a,b — The 'change-current-surface' facility

Figure 4 — Review of numerical specification of the 'current surface'

Choosing 'SELECTION COMPLETE' returns the user to the graphical editor menu of Figure 2, where it is possible to obtain a review of the numerical specification of the current surface (Fig. 4). Under 'MOVE DISPLAY' we can manipulate the image in a variety of ways, each operation taking a few seconds, to obtain the views of Figure 5.

The use of solid filling to obtain a semi-realistic view of the object is illustrated in Figure 5c.

A common error in the creation of geometrical models results from wrongly specifying which is the thermally active face of the surface. This fault is often only detected after considerable calculation has been done on the models. Figure 6 shows how MINIP has been used to trap such an error. In this case the user has assigned different colours to the thermally active (green) and thermally inactive (red) faces.

The faults where the surfaces are inverted or where holes appear are indicated by the red patches in this display of the external model of the Hipparcos spacecraft. This particular error took 5 min to discover with MINIP, compared with the 2–3 days taken via the conventional path of checking heat-rate calculations.

Figure 7 shows two different views of the Giotto spacecraft model, illustrating the exploded-view capability of the system.

Future development

In the short time that it has been in service, MINIP has proved itself to be a very useful tool for ESTEC's thermal engineers. As a consequence, the development will be taken further.

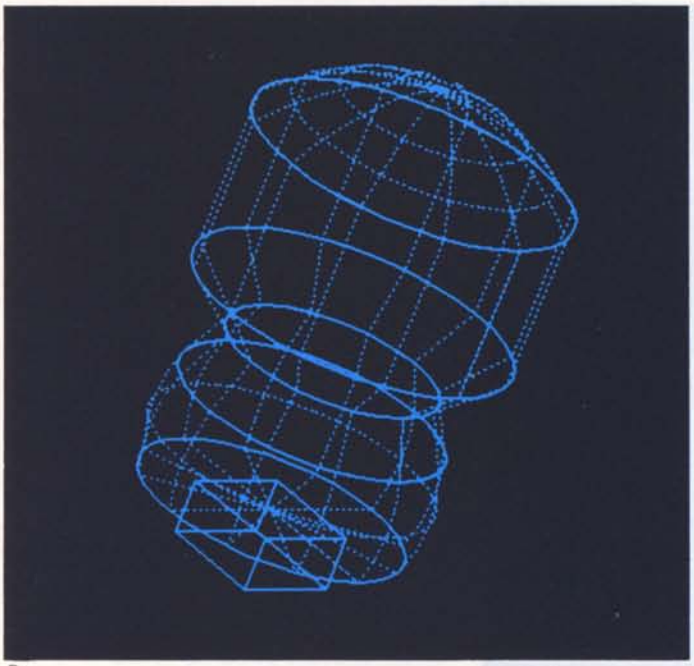
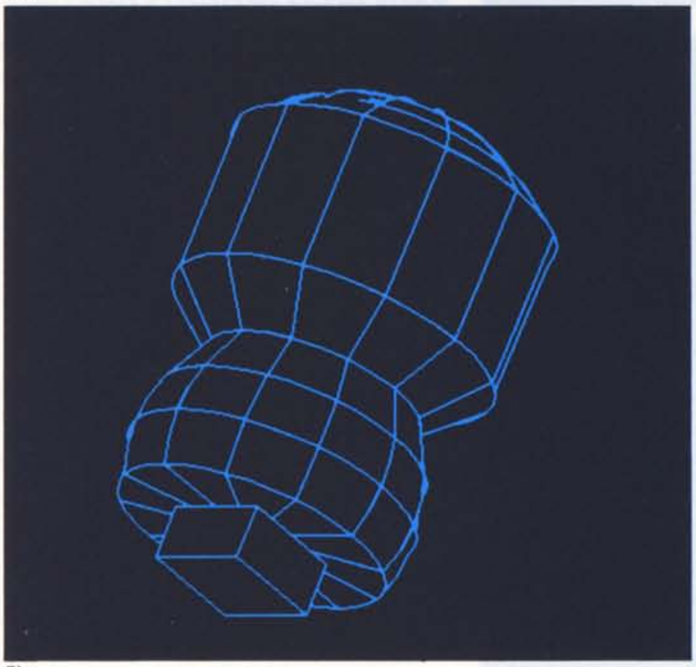

5a

Figure 5a — Graphical presentations: wire-frame drawing

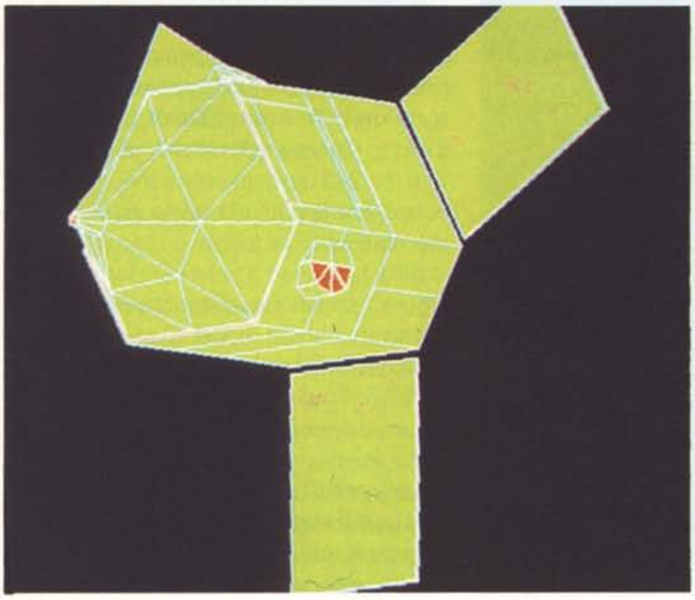
Figure 5b — Elimination of hidden lines

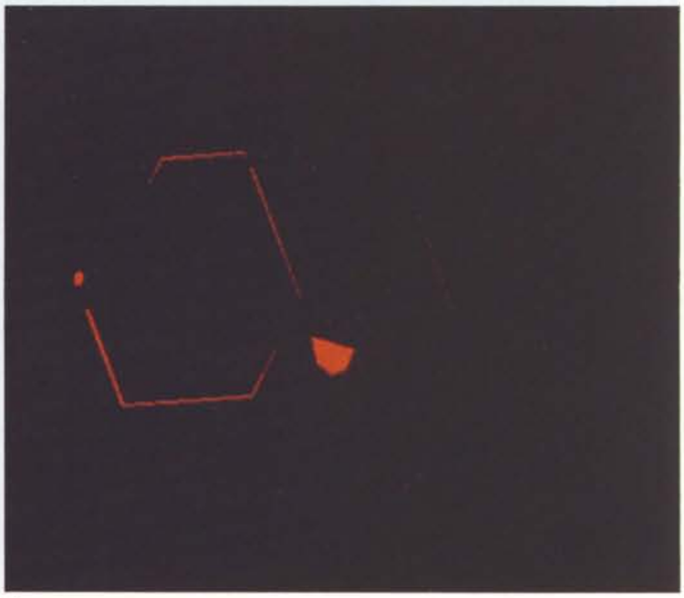
Figure 5c — Solid fill with shading according to a light source

Figures 6a,b — Errors in the geometrical model. (a) The thermally active faces are shown in green, while the thermally inactive faces are in red. (b) A view of the inactive faces only (none should be visible in a correct geometry). The small 'noisy' red areas are due to display-device inaccuracies

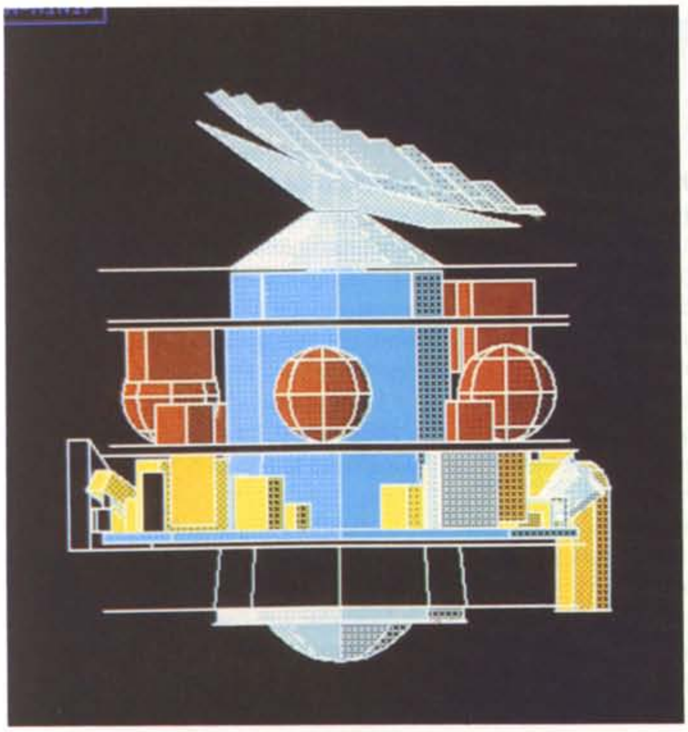

5b


5c


6a


6b

Figures 7a,b — Two views of the internal thermal model of the Giotto spacecraft



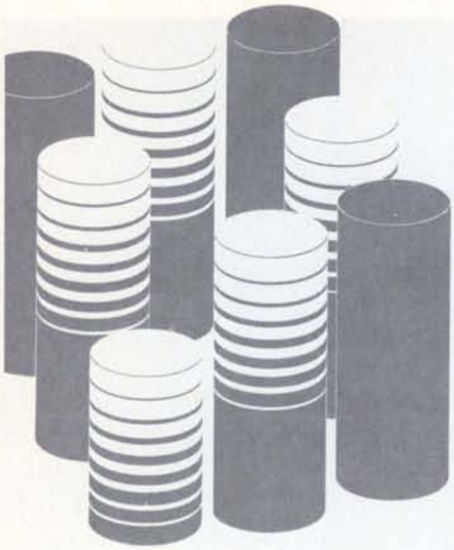
7a

7b

Summary

MINIP is a fully interactive 'user-adapted' front-end processor for the existing calculation and analysis programs. It is already in use, with development still continuing, and it serves to demonstrate and test the ideas being incorporated in MANIP.

MANIP will be a fully interactive system for model creation, maintenance, simulation definition and results analysis, with a limited capability for interactive simulation execution. It might fairly be described as a revolution in thermal-analysis computing and will be available at ESTEC in late 1985.



The Outlook for World Space Expenditure

G. Dondi, Directorate of Administration, ESA, Paris
M. Toussaint, Eurospace, Paris

Space expenditure, like many other economic and physical phenomena, seems to follow recurring patterns. After the 'Moon race' of the sixties and the 'telecommunications explosion' of the seventies, will a 'space-industrialisation boom' follow at the end of the eighties? A global assessment of space-expenditure trends is attempted, to put into perspective:

- **the role of the European space effort within the global effort**
- **a ranging of space expenditure compared with other types of expenditure financed mainly by public spending (military expenditure, R&D expenditure, etc.).**

Global space expenditure
Space expenditure may be classified according to two main criteria:

- *the source of funding*
  - expenditure covered by institutional budgets (e.g. NASA, ESA, CNES, etc.),
  - expenditure covered by commercial procurements:
    - space segment (satellites and launchers)
    - ground segment.
- the *final utilisation* of the funds
  - expenditure for civilian applications
  - expenditure for military applications.

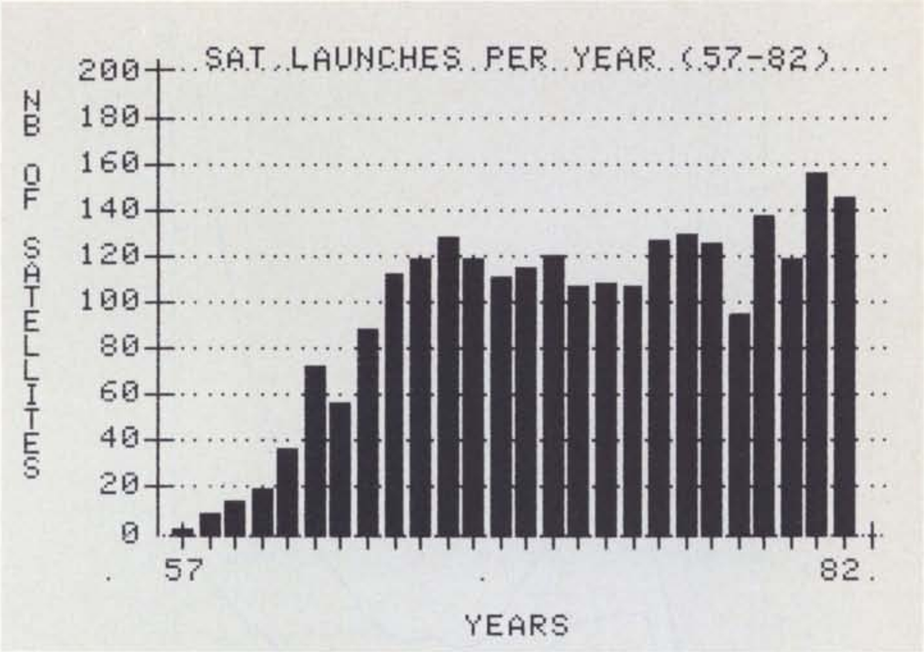
Institutional versus commercial space expenditure
Institutional space expenditure
The expected institutional space expenditures for 1983 are shown in Table 1, which summarises the authorised budgets for:

- NASA, DOD, DOE and other small institutions in the USA
- the USSR's space activities (of which more than 75% are said to be military)
- NASDA, ISAS and other smaller institutions in Japan

Table 1 – Expenditures of the space organisations in 1983 in MAU (1 MAU = ± 1 US$)

Country	Organisation		Expenditure MAU	Value as % of World total
USA	NASA	6122 M$ (41.3% of the total)		
	DOD	8502 M$ (57.3% of the total)		
	Others	215 M$ (1.4% of the total)		
	Total	14 839 M$ (i.e. 17 060 MAU)		42.6%
USSR	Defence: more than 75% of total, est. at		20 700	51.7%
Japan	NASDA: 85% of total		538	1.3%
Canada			130	0.35%
India			100	0.25%
Europe	ESA programmes		810	(2.0%)
	National programmes		730	(1.8%)
	Total (civil only)		1 540	3.8%
Total			40 068 MAU	100%
		rounded	40 000 MAU	

Figure 1 — Satellites launched between 1957 and 1982



- the Ministry of Communications and other Departments in charge of space activities in Canada
- ISRO in India
- ESA and the national space institutions in Europe.

The total amounts to some 40 000 MAU, 1540 of which is European (this represents 3.8% of the World total, and 7.6% of the US total). The USA and USSR space expenditures together represent 94.3% of the World total.

For comparison purposes, World space expenditure in 1981 amounted to 26 085 MAU, 1110.5 of which was European (601 MAU for ESA), i.e. 4.25% of the World total and 11.8% of the US total (9360 MAU).

In spite of an increase of 39% in European expenditure between 1981 and 1983 (in current money), the relative position of Europe vis-à-vis the two superpowers, and in particular vis-à-vis the USA, has thus been slightly degraded. This is not due to the increases in the military space expenditure only: compared with the NASA authorised budget, Europe's institutional space expenditures will represent 21.9% of the total in 1983, compared with 23.7% in 1981.

Commercial space expenditure

In a document published by Eurospace in 1977, the forecasted World communications satellites market was summarised as indicated in Table 2.

Globally, for the 1976–1985 period, the expected market amounted to 4900 MUS$, i.e. an average of 490 MUS$ per year. The associated earth-terminal part was, at the same time, evaluated at an average of 400 M$ per year worldwide, and the launcher market at some 500 M$ per year. Communications were considered to represent by far the largest element of the commercial market.

Table 2 — Projected communications satellite market

	1977 Forecast (1976–1985)		1983 Observations (1982–1985)		
	Total (M$)	Av./year (M$/y)	Satellites (to be) launched	Market Total (M$)	Av./year (M$/y)
Intelsat	1400	140	12	500	125
US Domestic & Canada	1000	100	39	1600	400
Asia & Australia	400	40	10	360	90
Third World	1060	106	4	140	35
International Systems	700	70	2	80	20
Europe	340	34	7	400	100
Total	4900	490	74	3080	770

Today, these forecasts have certainly been confirmed. Communications satellites still represent the largest portion of the commercial market, with an average annual value (based on the years 1982–1985) of 770 M$ (Table 2).

The earth-terminal market is estimated at some 650 M$ per year, and the launcher market (for which communications satellites represent the majority of customers), at 800 M$ per year.

In 1983, global space expenditure was of the order of 42 B$, of which about 2.2 B$ (roughly 5%) represented commercial expenditure and the remainder institutional expenditure.

To provide an idea of the outcome of these expenditures, Figure 1 shows the number of launches per year throughout the World. As an order-of-magnitude guide:

- the USSR launches about 100 spacecraft per year (i.e. two per week)
- the USA launches about 25 spacecraft per year
- the remainder of the World between 8 and 16 spacecraft per year.

Civilian versus military space expenditure

Military space activities are largely concentrated in the USSR and the USA. Figure 2 shows distribution trends for US space expenditure by civilian institutions (NASA, NOAA, etc.) and by the US Department of Defence. It can be seen that:

- civilian expenditure peaked in 1968/1969, when it was about twice the military total
- military expenditure is currently about 50% greater than the civilian total.

This trend reversal is even more pronounced if one considers the same curves adjusted for inflation. About 35 to 40% of the USA's launches are for military purposes.

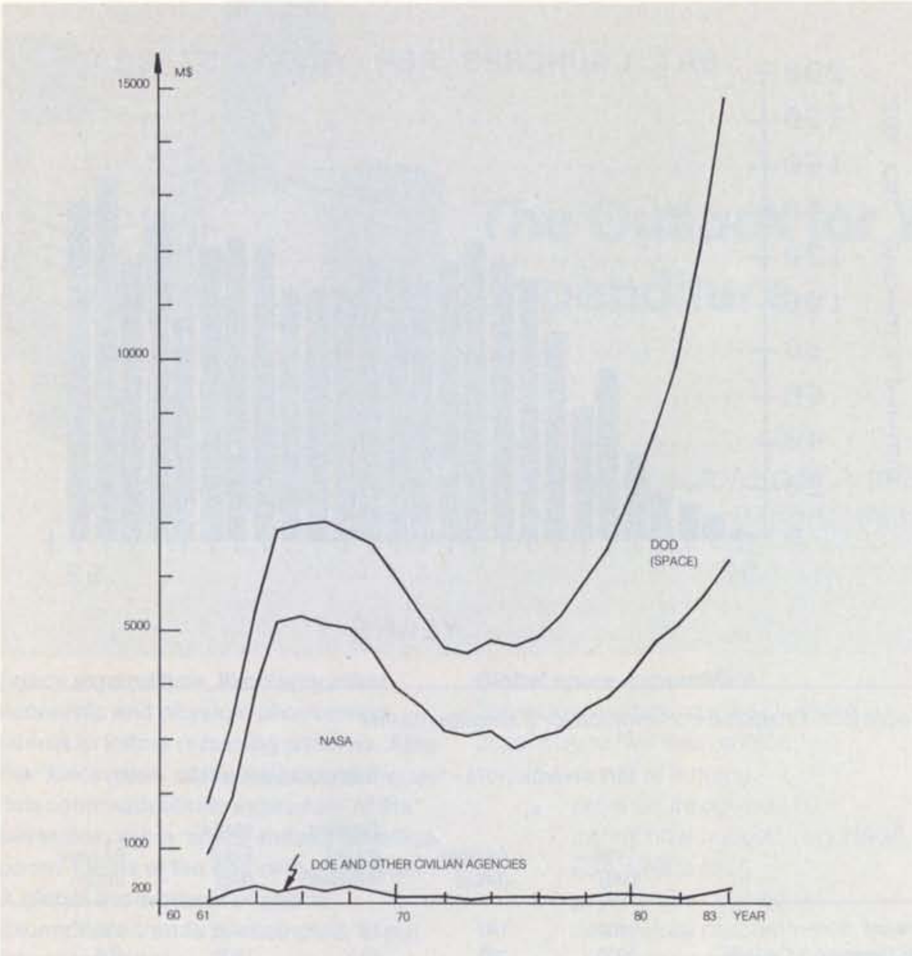


Figure 2 — Space expenditure in the USA in the sixties, seventies and early eighties

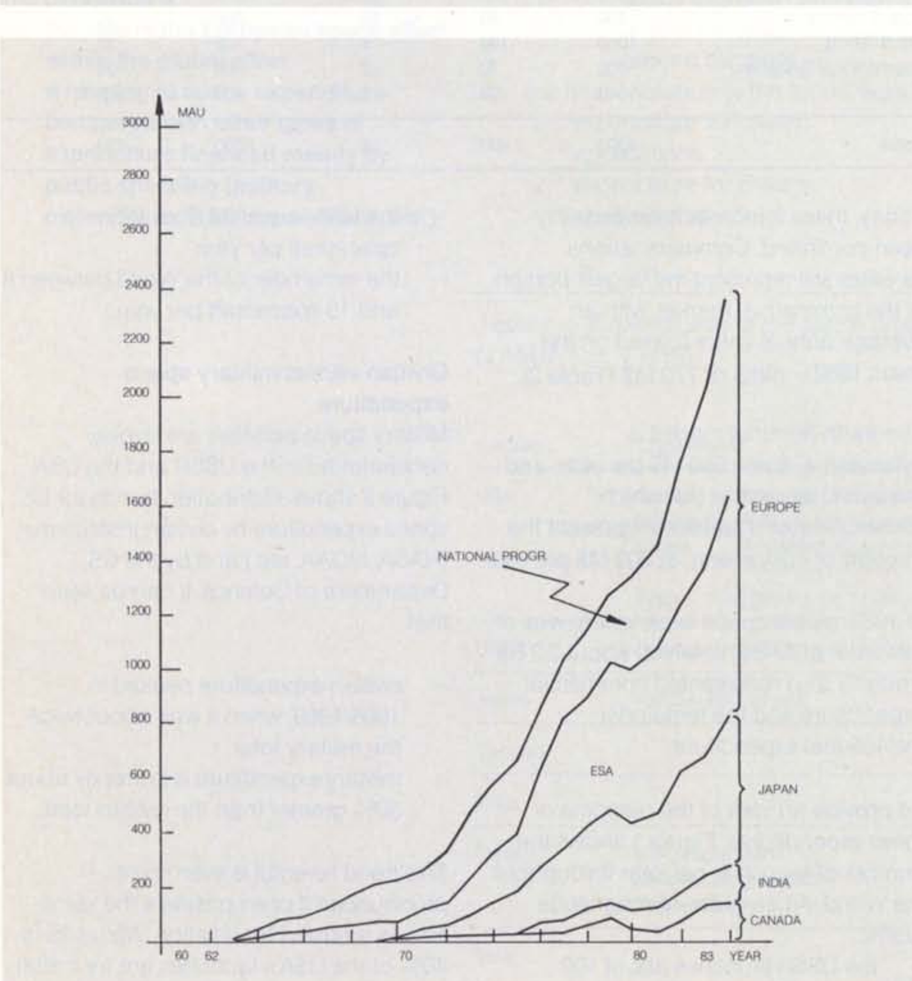


Figure 3 — Space expenditure in the western World (excl. USA) in the sixties, seventies and early eighties (1 AU= ± 1 US$)

Turning to the USSR's military space expenditure, it is estimated that it represents more than 13 B$ per year (out of a total annual space expenditure of 18 B$ per 1983 data). About 70% of the USSR's launches are considered to be for military purposes.

In comparing the figures for the two countries, two different interpretations have been put forward:

– according to the first viewpoint, the figures firstly provide an indication of the relative effort expended by the two countries on military space applications, and secondly of the forseeable return obtained;

– according to the second point of view, even if there is a difference in deployed effort, the results obtained are not that different; in other words, due to the advanced technology used by the USA, a distinctly lower number of spacecraft are necessary to perform a similar type of programme.

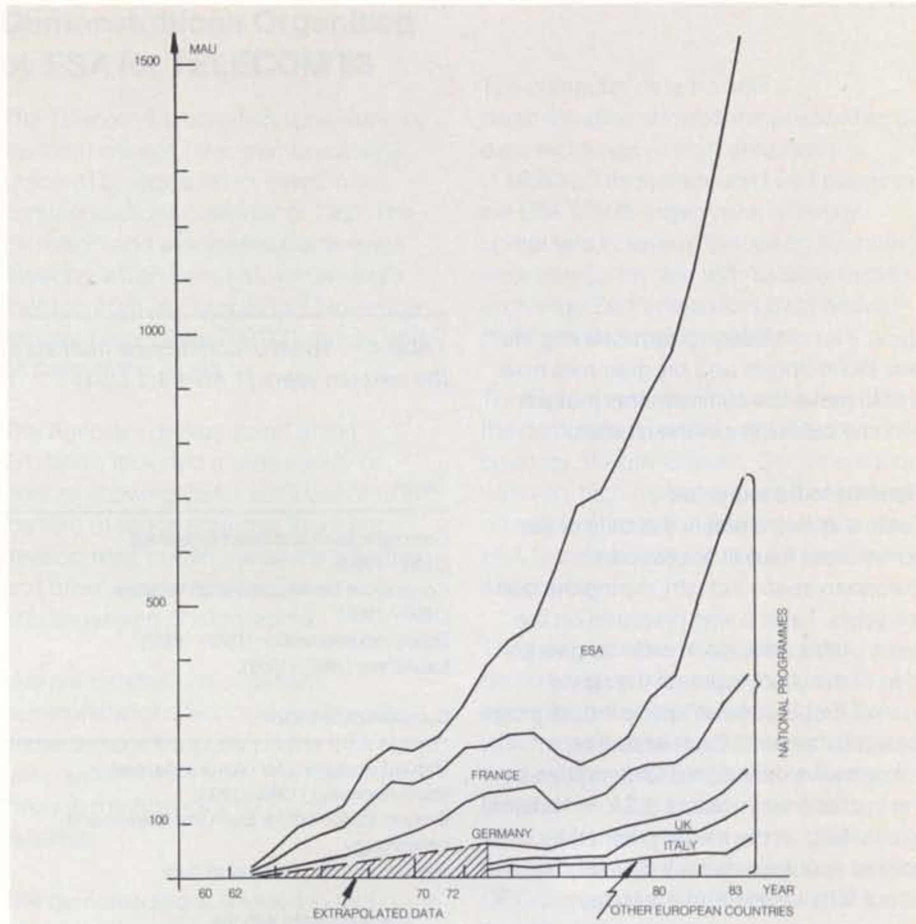
Space expenditures in the Western World (excluding the USA)

Figure 3 gives the trend in institutional space expenditure in the Western World (excluding the USA). As can be seen, the rates of increase in both Japan and India are considerable; the European space effort (ESA plus national expenditures) on the other hand is progressing at a much slower rate in expenditure terms. The space expenditures of the various European countries, with a differentiation between the expenditures made through ESA and those of the national space programmes, are summarised in Figure 4.

The space effort in perspective

Table 3 is an attempt to put the global space effort into perspective. It gives some approximate figures for the effort devoted by the major powers to typical government-sponsored activities, such as defence, research and development, and space activities.

Figure 4 – Space expenditure in Europe (1 AU= ± 1 US$)



The expenditures presented are expressed as percentages of Gross National Product (GNP), i.e. in terms of each country's 'ability to pay'. It is apparent from this overview that the amount of national resources absorbed by space activities is rather modest, not only in absolute terms, but also compared with the much greater percentages devoted to other government activities.

Some extrapolations for the future

Is it possible to forecast the trend for space expenditures in the future? In a recent article in Aeronautics & Astronautics (May 1983), P.W. Keaton presented an approach for determining what the USA could afford to spend in space in the next 22 years. Taking into account past trends and the inertia of the US funding system, his conclusions are that 400 ± 100 B$ could be spent by the USA on space during that period. The uncertainty of 100 B$ is not a statistical factor, but simply an attempt to bracket the range of the most likely occurrences (various extrapolation scenarios were considered in the paper).

Bearing in mind that only one third of this sum may be considered 'discretionary money' for future national commitments, the conclusion is that the US can realistically afford to make a national commitment to a major space programme amounting to 130 ± 30 B$; this would start at about 4 B$/year and grow steadily to 8 B$/year at the end of the period. This kind of money would fund a larger space programme than is publicly suggested today.

P.W. Keaton makes the point that the USA should strive to recognise what can be afforded in space, and to come forward with a long-range perspective 'avoiding the risk of spending the money unwisely by fits and starts'. In other words, after the post-Apollo slump of the 1970s, the USA should try to avoid a post-Shuttle slump by making judicious long-term commitments within the affordable budget boundaries.

Table 3 – Global space expenditures

Country	Expenditures as % of GNP Defence	R & D	Space	Comments
USA	From 10% in 1960s to ~6% in 1990s	2.2%	From 1% in 1966 to 0.34% in 1980	Average space expenditures: 0.51 of GNP between 1960 and 1980 (Source: Astron. & Aeron., May 1983)
USSR	11 ÷ 14%	?	From 2% in 1962 to 1.5% in 1978	On average, 1% of GNP spent on military space activities (Source: Rouppe, 30th IAF Congress, Sept. 1979)
Selected ESA countries				
GB	4.7%	2.0%	Average: ~0.045% between 1966 & 1979	Source: New Scientist, 6 Nov. 1980 and Eurospace
D	3.4%	2.2%		
F	3.3%	1.8%		
I	2.4%	–		
Japan	~0.9%	1.7%	From 0.01% in 1965 to 0.05% in 1980	Source: New Scientist, 6 Nov. 1980, Eurospace

Europe is currently experiencing a boom in space activities, centred mainly on two elements:

- the commercialisation of Ariane
- the proliferation of telecommunications projects.

In several countries, investments are being made to increase industrial capacity, and, in a generally recessionary atmosphere, space industry is actively recruiting. This is the result of the basic investments in technology decided at the beginning of the seventies and implemented over the last decade.

If Europe wishes to continue to support its increasingly important space industry and avoid jeopardising in the medium term the investments that are currently taking place, it is necessary to start defining the new technologies and programmes now and to make the commitments that will become productive in the nineties.

Benefits to be expected

Table 4 shows a recent estimate of the commercial market accessible to European space industry during the next ten years. Table 5 was prepared on the basis of this estimate in order to give an idea of the yearly value of the space market that European space industry can expect to 'absorb'. Even assuming a conservative evolution of expenditure by the Institutional investors (ESA + National Authorities), in the medium term the annual space market will certainly be about 50% larger than it is today.

Conclusions

World space expenditure is dominated by the USSR and the USA, but Europe's share is becoming significant, thanks to the fact that Europe was able to gain access to space technology and develop an original approach to this type of activity.

A first peak in activities, with the Apollo missions, gave way at the end of the 1960s to a slump, which was gradually countered by the Shuttle Programme. Europe has been able to share in the expansive market brought about by this second peak, thanks largely to ESA's Ariane, Spacelab and the telecommunications programmes.

Future space activities in the Western World now await, especially in the USA and in Europe, the new commitments that will permit orderly growth of the space industry in the 1990s.

Such programmes have been shown to be both useful and 'affordable' – concerted political will should hopefully make them possible.

Table 4 – Value of commercial markets accessible to European space industry during the next ten years (1 AU= ± 1 US$)

Sector	Market size, MAU	Annual market (average) during the period of maturity, MAU
Communication and direct broadcast (1984–1993)	2700	270
Commercial Earth-observation satellites (1986–1995)	120	12
Space industrialisation (1982–1992)	–	–
Launchers (1987–1991)	2100	420
Subtotal space sector		702
Ground equipment for communications (earth terminals) (1984–1993)	2000	200
Ground equipment for Earth observation and meteorology	780	80
Services and remote-sensing data	200	20
Subtotal associated with the space sector		300
Total		1002

Table 5 – Average yearly value of space markets accessible to European space industry between 1985 and 1990

Market sector	Value (MAU/year)	Percentage of total market	Note
ESA	720	32.1	85% of a budget of 850 MAU/year
National space agencies	520	23.2	65% of a budget of 800 MAU/year
Subtotal institutional market	1240	55.3	
Communications satellites	270	12.0	
Earth-observation satellites	12	0.5	
Launchers	420	18.7	
Subtotal commercial space sector	702	31.2	
Communications Earth terminals	200	9.0	
Ground equipment for Earth observation	80	3.6	
Services and remote-sensing data	20	0.9	
Subtotal commercial ground sector	300	13.5	
Subtotal commercial	1002	44.7	
Grand total	2242	100	
Total for the space-sector proper, excluding ground equipment and services	1942	86.5	Ground equipment and services excluded

In brief

Demonstrations Organised by ESA for TELECOM 83

The Telecom 83 exhibition sponsored by the International Telecommunications Union (ITU) was a major event in the communications calendar of 1983. The Exhibition and associated Conference sessions, which were held in Geneva's Palexpo from 26 October to 1 November, attracted more than 200 000 visitors from all parts of the World.

The Agency's display stand at the Exhibition included a wide variety of exhibits showing ESA's achievements in the field of space sciences, launcher development, communications satellites and other space missions (see accompanying photographs).

Live demonstrations of satellite communications technology were also presented continuously on the ESA stand, using satellite links from The Netherlands through the Agency's OTS and ECS satellites.

The demonstrations showed in particular the flexibility and versatility of digital data transmission by satellite. The satellite transmission was at a rate of 2 Mbit/s and used only a very small part (less than one-twentieth of the bandwidth and one-tenth of the power) of one transponder of the satellite in use. The receiving earth station at Geneva was a 1.8 m diameter antenna with very simple and inexpensive ancillary equipment. With this transmission system, demonstrations of high-speed facsimile, high-speed computer-to-computer data transfer and video conferencing were shown with excellent results.

The computer data transfer demonstration showed the possibilities of data exchange at high data rates (1 Mbit/s). The system used was based on the ESA SPINE experiment, whereby computers in several European countries were interconnected with satellite links to exchange Earth-resources data derived from remote-sensing satellites.

The high-speed facsimile equipment for the demonstrations was provided courtesy of Agfa-Gevaert. Documentation with very high resolution was transmitted, on request, from The Netherlands to the ESA stand at a rate of one A4 page every 4 seconds.

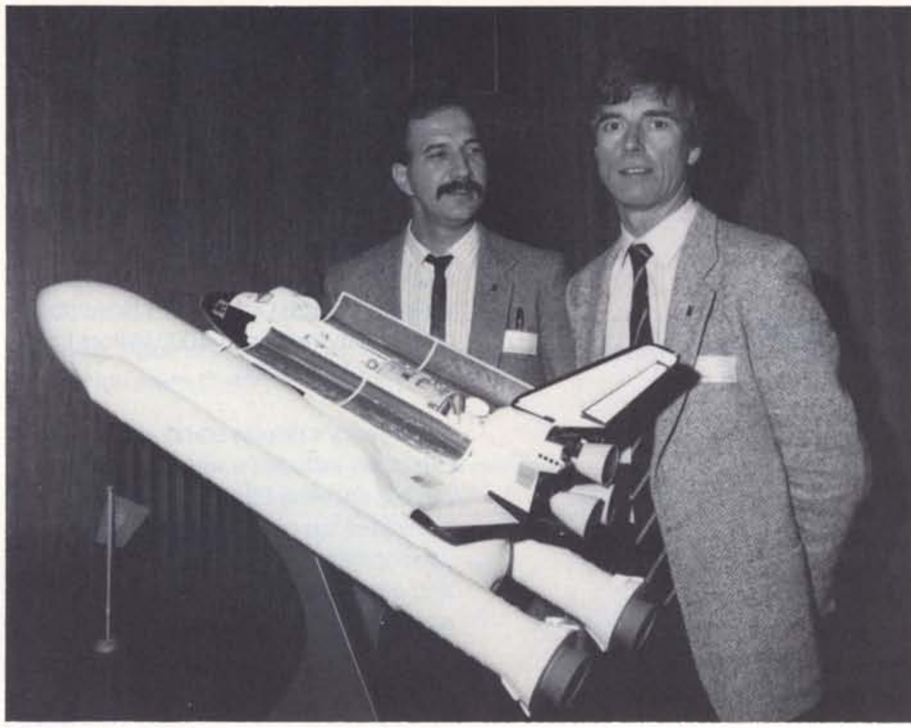
The video-conferencing part of the demonstration was organised in co-operation with The Netherlands PTT, which made its teleconference studio and transmission facilities available for the Dutch end of the satellite link. The teleconferencing equipment for the exhibition stand was provided courtesy of GEC/Jerrold. Many interested visitors participated in the conference demonstrations and all expressed surprise at the high quality of the conferencing facility, especially in view of the low bandwidth (2 Mbit/s) and cost-effective transmission system employed.

The reception was in full 625-line colour and almost unlimited movement of the participants was possible without noticeable picture degradation. One of the accompanying photographs shows a video conference in progress on the ESA stand.

Spacelab-1 Crew Visiting Europe

Following the great success of the first Spacelab mission, the two ESA astronauts Ulf Merbold and Wubbo Ockels, and their American colleagues, have been visiting a number of major European cities between 19 January and 8 February. Planned stops on their tour included Bonn, Stuttgart, Vienna, Bremen, Naples, Rome, Madrid, Lucerne, Paris, Delft and Brussels.

On 11 January Ulf Merbold and Wubbo Ockels were at ESTEC for the General Assembly of the European Low Gravity Association (ELGRA). During their visit they gave a Press Conference for the Dutch media. Also present at this Conference were ESA's Director of Space Transportation Systems, Mr. M. Bignier, and the Spacelab Project Scientist, Karl Knott, of ESA Space Science Department.



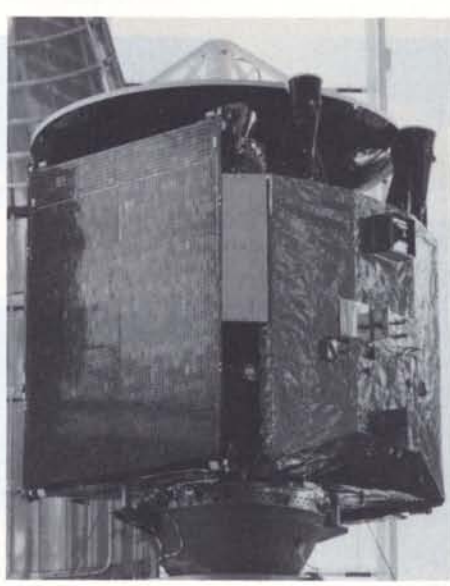
Wubbo Ockels (left) and Ulf Merbold at ESTEC

Prof. M. Trella, ESA's Technical Director and Director of ESTEC, opening the Press Conference. Seated, on his left, is Mr. M. Bignier, ESA's Director of Space Transportation Systems

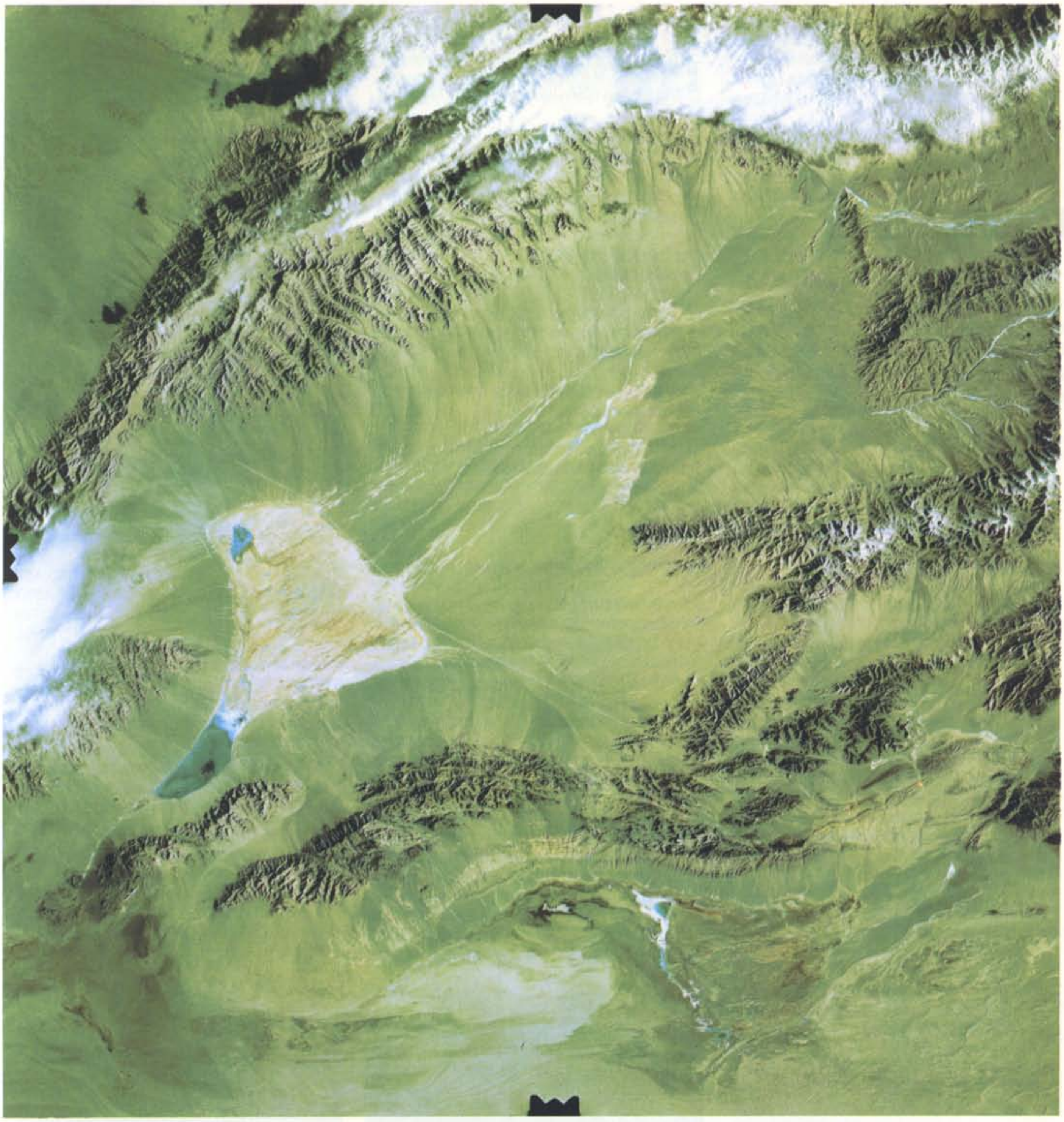
Successful Increase in Marecs-A Communications Capability

At 00.01 GMT on 18 November 1983, at Inmarsat's request, a successful switching operation was performed on board ESA's operational maritime communications satellite Marecs-A, to increase capacity from 30 simultaneous voice telephone channels to 46. The switching was carried out by ESOC, Darmstadt, in less than 10 minutes, thereby avoiding the need to transfer communications to the spare satellite during the switching operation.

Marecs-A, launched on 20 December 1981, has been providing Inmarsat's maritime shore-to-ship and ship-to-shore communications service in the Atlantic Ocean Region since 1 May 1982.



The capacity that Marecs is now providing to the International Maritime Satellite Organisation is in excess of the contractual requirement of 40 voice telephone channels. This additional capacity, together with the success of operations so far, bodes well for the Marecs spacecraft's role in the provision of the rapidly expanding and improving maritime satellite communications services.



Spacelab-1 Metric Camera Delivers Superb Imagery

This sample image from the ESA/DFVLR Earth-Observation Experiment (Metric Camera) on Spacelab-1, is a false-colour infrared image of southwest China (nonenhanced 1:1 contact print).

The particular set of images from which this example is taken was made to assist a joint programme of cooperation between the German Ministry of the Interior and the Ministry of Transport, Housing and Planning of the People's Republic of China. The data analysis will be jointly coordinated by the University of Hannover (Germany) and China's Technical University of Wahan.

The Principal Investigator for the Metric-Camera Experiment was M. Reynolds of ESA's Earth-Observation Programmes Department.

Publications

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

ESA Journal

The following papers have been published in ESA Journal Vol. 7, No. 4:

TEMPORAL SOLAR VARIATIONS
GOUGH D O

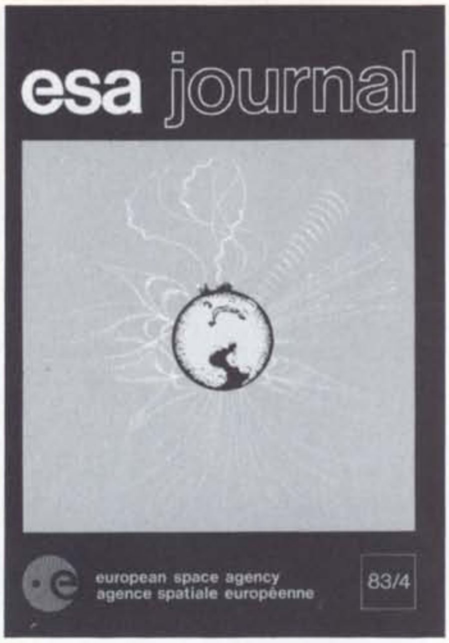
SOLAR WIND AND CORONAL STRUCTURE
WITHBROE G L

COLLISIONLESS SHOCKS
PASCHMANN G

RECENT ADVANCES IN NUMERICAL SIMULATION OF SPACE-PLASMA-PHYSICS PROBLEMS
BIRMINGHAM T J

MAGNETIC-FIELD-ALIGNED ELECTRIC FIELDS
FALTHAMMAR C-G

GLOBAL DYNAMIC MODELS OF THE EARTH'S THERMOSPHERE AND IONOSPHERE
ROBLE R G



Special Publications

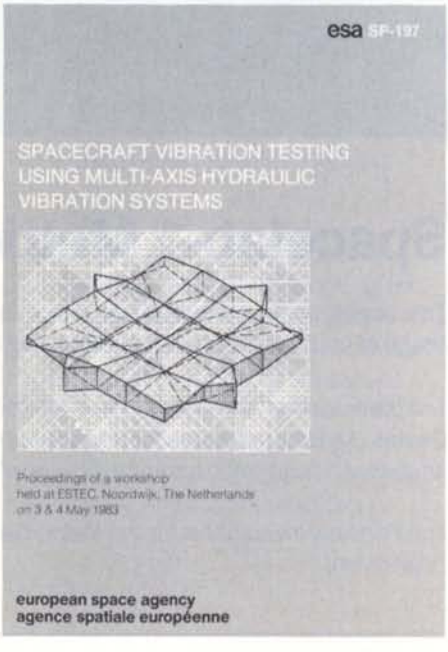
ESA SP-188//291 PAGES
EARSEL/ESA SYMPOSIUM ON REMOTE SENSING APPLICATIONS FOR ENVIRONMENTAL STUDIES, BRUSSELS, BELGIUM, 26-28 APRIL 1983
LONGDON N & MELITA O (EDS)

ESA SP-195//390 PAGES
ACTIVE EXPERIMENTS IN SPACE – PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM HELD AT ALPBACH, AUSTRIA, 24-28 MAY 1983
BURKE W R (ED)

ESA SP-197//179 PAGES
SPACECRAFT VIBRATION TESTING USING MULTI-AXIS HYDRAULIC VIBRATION SYSTEMS, PROCEEDINGS OF A WORKSHOP HELD AT ESTEC, NOORDWIJK, THE NETHERLANDS, ON 3 & 4 MAY 1983
BURKE W R (ED)

ESA SP-201//262 PAGES
STATISTICAL METHODS IN ASTRONOMY PROCEEDINGS OF AN INTERNATIONAL COLLOQUIUM HELD AT STRASBOURG, FRANCE, 12-16 SEPTEMBER 1983
ROLFE E J (ED)

ESA SP-205//188 PAGES
REMOTE SENSING – NEW SATELLITE SYSTEMS AND POTENTIAL APPLICATIONS: PAPERS PRESENTED AT THE SUMMER SCHOOL HELD AT ALPBACH, AUSTRIA, ORGANISED BY ASSA AND SPONSORED BY ESA, CNES, DFVLR & NTNF
BURKE W R (ED)



Contractor Reports

ESA CR(P)-1747//214 PAGES
QPSK SWITCHING MODULATOR – PHASE 2 – FINAL REPORT (MAR 1983)
SPAR, CANADA

ESA CR(X)-1748//85 PAGES
IMPROVEMENTS TO GLOVEBOX FACILITY (MAR 1983)
NORTHWICK PARK HOSPITAL, UK

ESA CR(P)-1749//161 PAGES
DEFINITION OF STANDARD SPACECRAFT POWER INTERFACE CHARACTERISTICS – FINAL REPORT (FEB 1983)
MATRA, FRANCE

ESA CR(P)-1750//50 PAGES/133 PAGES/22 PAGES
LIQUID/VAPOUR PHASE SEPARATOR FOR A CRYOGENIC LIQUID IN A ZERO-G ENVIRONMENT – FINAL REPORT – PART A: EXECUTIVE SUMMARY; PART B: TECHNICAL WORK; PART C: PRELIMINARY PHASE SEPARATOR SYSTEM SPECIFICATION (OCT 1982)
MBB, GERMANY

ESA CR(P)-1751//185 PAGES
RECHERCHE DES CARACTERISTIQUES DE LA POUDRE HAUTE TEMPERATURE TRHA – RAPPORT DE SYNTHESE (OCT 1982)
AVIONS MARCEL DASSAULT, FRANCE

ESA CR(P)-1752//129 PAGES
EVALUATION OF FLECS MODAL DATA (OCT 1982)
AEO, SWITZERLAND

ESA CR(P)-1753//76 PAGES
THEORETICAL AND EXPERIMENTAL INVESTIGATIONS ON HEATING, COOLING AND THERMOMETRY OF MATERIAL SCIENCE SAMPLES IN THE ELLIPSOIDAL MIRROR FURNACE ELLI (JAN 1983)
BATELLE, GERMANY

ESA CR(X)-1754//109 PAGES
TEMPERATURE MEASUREMENT IN ARC MIRROR FURNACES – FEASIBILITY STUDY (DEC 1982)
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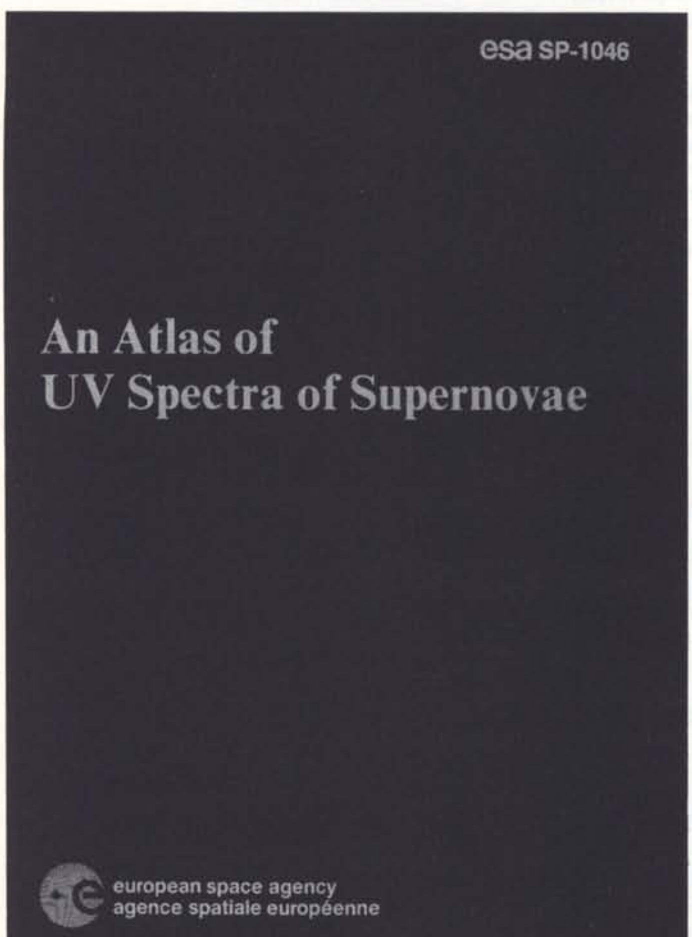

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by P. Benvenuti et al. (Ed. B. Battrick)

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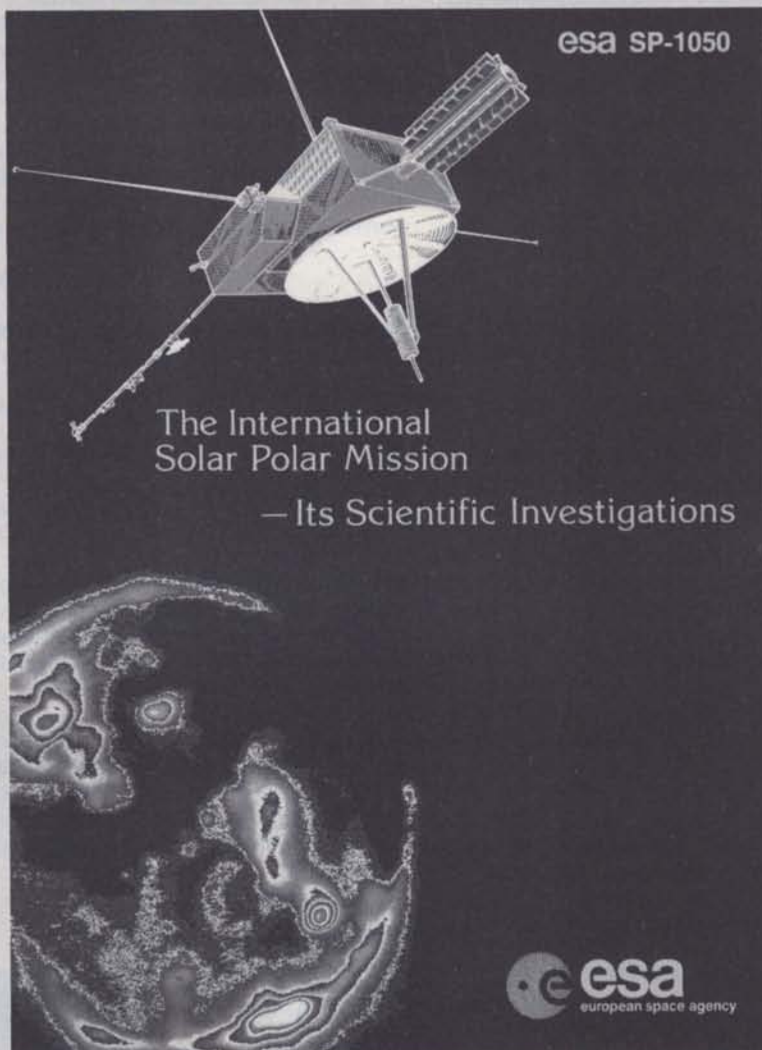

K.-P. Wenzel & R.G. Marsden
Space Science Department of ESA

B. Battrick
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Although the launch of the International Solar Polar Mission will not occur before May 1986, the spacecraft and its scientific payload have already been fully designed, manufactured and integrated. This volume is a comprehensive review of the scientific investigations to be undertaken on this exploratory mission. It addresses the objectives and experimental characteristics of the ISPM investigations and is aimed both at the ISPM investigator seeking a comprehensive understanding of the other instruments on board the spacecraft and at scientists and scientific writers/editors interested in the experimental capabilities of the mission.

After an introductory overview, the nine hardware investigators forming the scientific payload are described. These contributions are followed by descriptions of the radio-science and interdisciplinary investigations. Contributions outlining the spacecraft, the mission operations and the planned Common Data File complete the publication.

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The Fourteenth International Symposium on Space Technology and Science (ISTS) will be held at the Nippon Toshi Center in Tokyo from Monday 28 May to Saturday 2 June 1984. We extend a cordial invitation to attend the Symposium.

The Preliminary Programme is as follows:

Sessions

a. National Space Programme
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c. Materials and Structure
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e. Fluid Dynamics
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n. Applications Satellites
o. Scientific Exploration
p. Space Science and Astronomy
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r. Material Processing
s. Future Utilisation of Space
t. Space Law
u. Student Session (undergraduate students are encouraged to submit papers.)

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May	27 (Sun)	Registration – Sunday to Friday
	28 (Mon)	Opening Session – Plenary Session – Afternoon Session
	29 (Tue)	Morning Session – Afternoon Session – Film Evening
	30 (Wed)	Excursion
May	31 (Thu)	Morning Session – Afternoon Session – Reception
June	1 (Fri)	Morning Session – Afternoon Session
	2 (Sat)	Morning Session

Sightseeing and cultural entertainment for spouses will be organised during the Symposium.

Further information can be obtained from the Programme Committee Chairman:

Dr. Isamu Wada
Director First Aerodynamics Division
National Aerospace Laboratory c/o 14th ISTS Secretariat
Institute of Space and Astronautical Science
6-1, Komaba 4 chome, Meguro-ku, Tokyo 153, Japan.

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We would greatly appreciate receiving films, photographs, models, etc., for exhibition purposes. These will be returned after the Symposium. Such materials would have to be received one week before the Symposium begins.

JSASS/AIAA/DGLR SEVENTEENTH INTERNATIONAL ELECTRIC-PROPULSION CONFERENCE

The Seventeenth International Electric Propulsion Conference, cosponsored by the Japan Society for Aeronautical and Space Sciences (JSASS), the American Institute of Aeronautics and Astronautics (AIAA), and the Deutsche Gesellschaft für Luft- und Raumfahrt, e.V. (DGLR), will also be held in Tokyo from 28 May until 31 May 1984, in parallel with the ISTS.

Topics to be covered include: (1) Performance characteristics of electric-propulsion systems; (2) Power sources and electronics for electric-propulsion systems; (3) Space and ground testing of thruster systems, subsystems and components; (4) Concepts and analyses of missions using electric propulsion; (5) Novel electric or advanced propulsion concepts; (6) Development of thrusters and components for electric-propulsion systems; (7) Interaction of electric-propulsion systems with spacecraft and space plasmas; (8) Nonpropulsive application of electric-propulsion technology.

Potential participants are invited to write for further information to the International Conference Chairman:

Professor Kyoichi Kuriki
Institute of Space and Astronautical Science
Komaba, Meguro-ku
Tokyo 153, Japan

Registrants at the Electric-Propulsion Conference will be entitled to attend the ISTS Symposium and vice versa.

CANADIAN REMOTE SENSING SOCIETY
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CALL FOR PAPERS

The Ninth Canadian Symposium on Remote Sensing will be held in St. John's, Newfoundland, from August 13 to 17, 1984. The theme chosen for the symposium is "Remote Sensing for the Development and Management of Frontier Areas", with emphasis on oceans, the northland and wilderness regions. The conference will consist of plenary, technical and poster sessions.

The Technical Program Committee invites authors to submit a 600-word abstract of papers proposed for presentation at the symposium, no later than February 29, 1984, to the following address:

Dr. Denes Bajzak
Faculty of Engineering and Applied Science
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