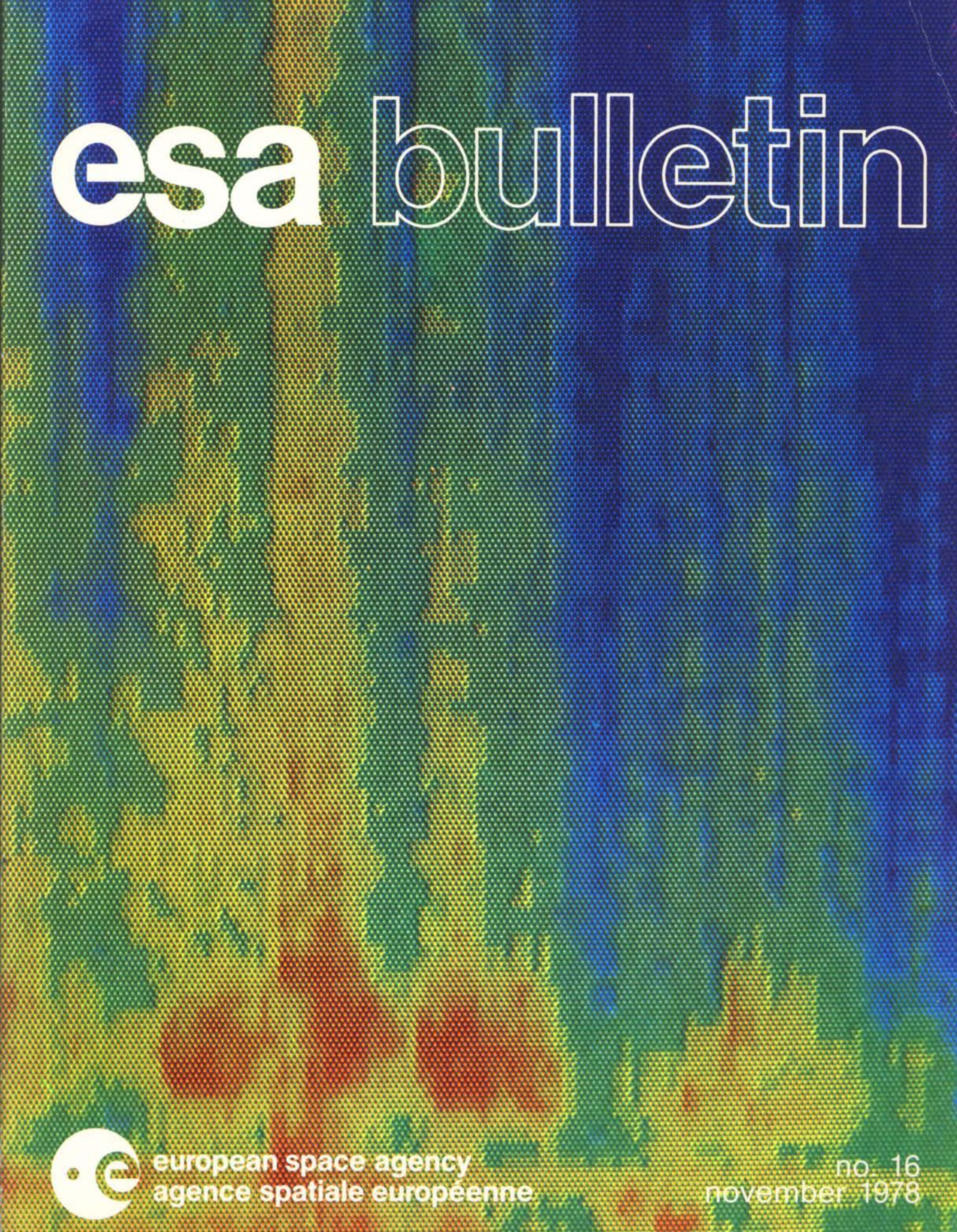

esa bulletin

european space agency
agence spatiale européenne

no. 16
november 1978

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Satellite data display: information on magnetospheric waves observed on Geos-1 displayed on a colour television screen addressed by a computer. The result is a frequency/time plot in which intensity is colour coded: strong signals appear red, weaker signals blue.

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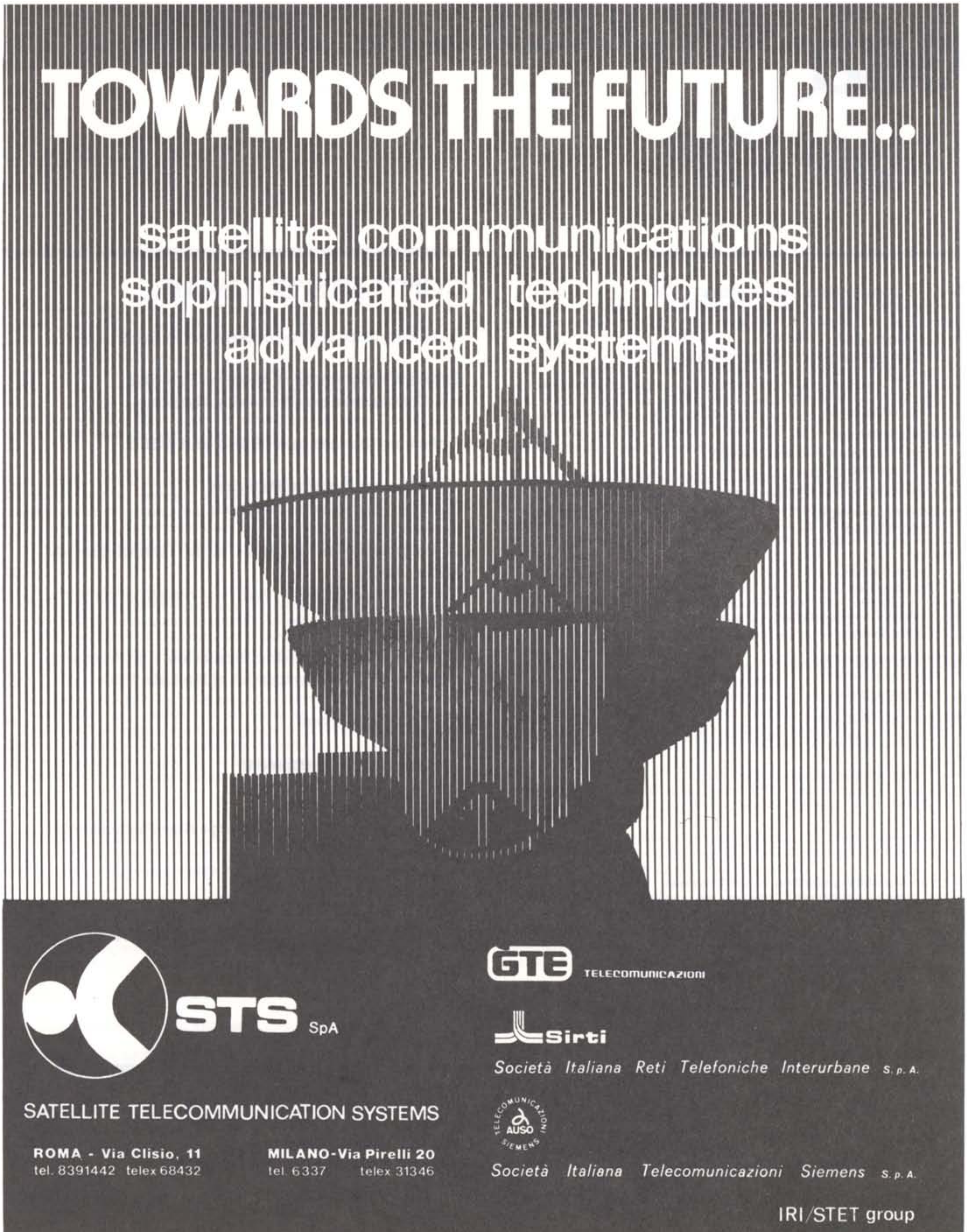
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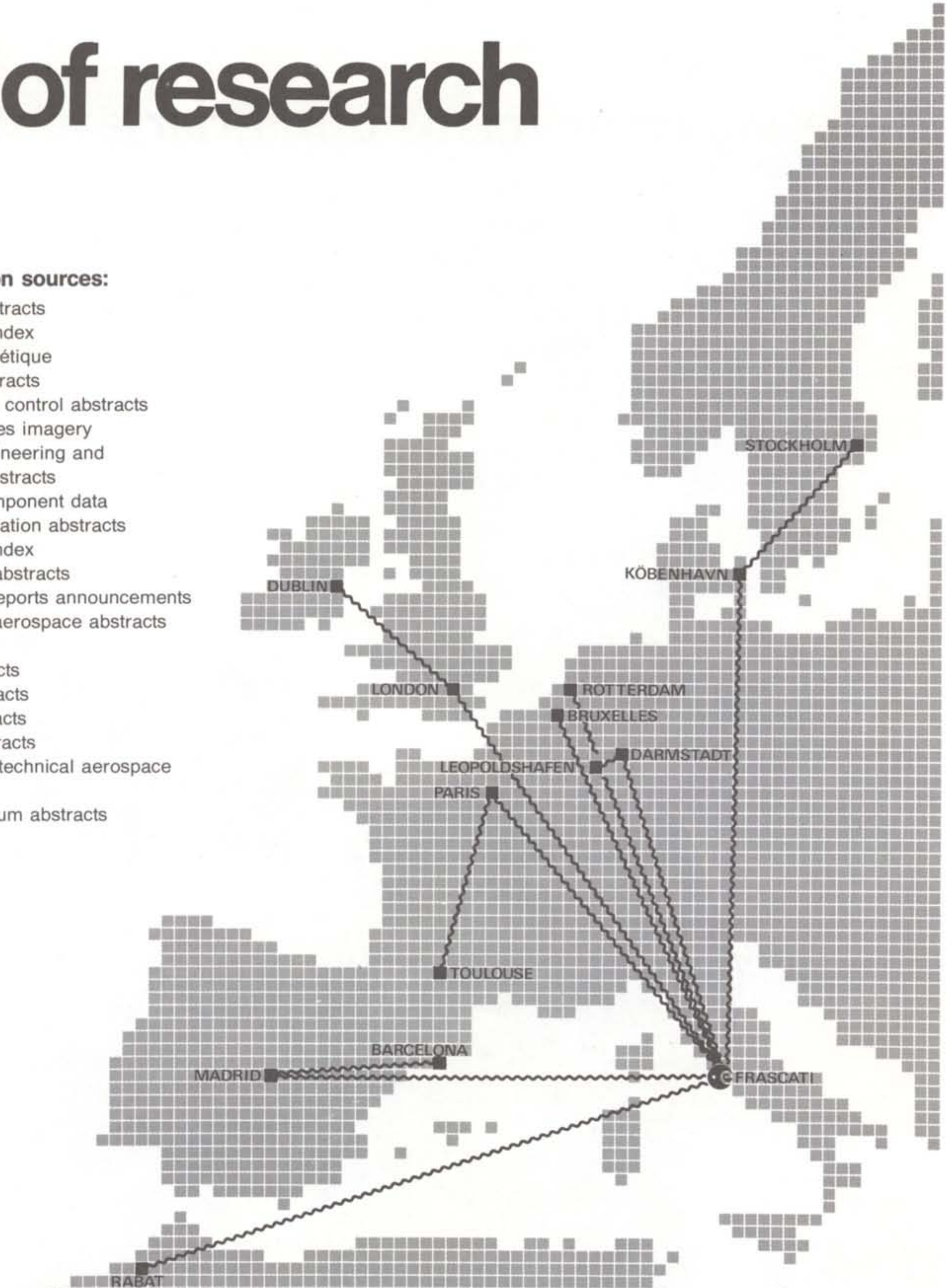

Early Results of OTS's Performance in Orbit

P.J. Bartholomé, E. Ashford & C.D. Hughes, Communications Satellites Department, ESA

The launch of OTS took place on 11 May 1978, one hour before midnight GMT. The launch sequence passed off very smoothly and the satellite separated from the third stage 25 min after lift-off. Two hours later, the parameters of the transfer orbit were known with sufficient accuracy to conclude that they were very close to nominal. The various manoeuvres necessary during the transfer phase were completed without difficulty and OTS was ready for injection into geostationary orbit when it reached the apogee of its fourth transfer orbit on 13 May at approximately 12.00 GMT. The Apogee Boost Motor (ABM) was then fired and OTS went into a quasi-geostationary orbit with the desired drift rate of about 5° per day in an eastward direction.

At that time the longitude of the subsatellite point was 25° W and OTS still had to drift over an arc of 35° to reach its final position at 10° E. In the course of the twenty-four hours following the flawless ABM firing, all necessary attitude manoeuvres were carried out successfully and OTS settled down in its Earth-locked attitude on Sunday 14 May. Two days later, it was in sight of the Satellite Control and Test Station (SCTS) at Fucino, which took over control once the 11 GHz telemetry transmitter had been switched on.*

An initial check on the telemetry, tracking and command functions showed that everything was working normally and on 18 May, when the satellite was 10° away from its final position, the repeater was turned on. All active elements of the six channels, including redundant units, were checked and found to be operating well. This operation, carried out from the SCTS, constituted the first major test sequence of the Orbital Test Programme (OTP).

All had gone extremely well so far and it seemed quite extraordinary that a spacecraft of such complexity could have survived the rough passage from Earth to geostationary orbit without the slightest sign of protest. But life could not go on being so simple and on 19 May, at around midnight, the attitude control system automatically switched to a back-up mode for reasons not immediately identifiable. A few hours later, commands were sent to return the system to its original configuration, but an error in the procedure caused OTS to lose track of the Earth and to go into an emergency Sun-acquisition mode, resulting in loss of SHF contact. Fortunately, a second level of protection had been provided and correct attitude could be re-established by VHF telecommand. The next day, all was back to normal and OTS was quietly looking at the Earth again. This anomaly in the behaviour of the attitude control system has since been investigated thoroughly and measures have been taken to avoid the repetition of such incidents.

During this first period, it was also observed that the temperature in some parts of the satellite was running higher than predicted, and this too gave rise to some anxiety. It took a number of in-depth studies before a clear picture of the situation emerged, but fortunately the problem turned out to be much less serious than initially feared.

By 24 May, OTS had reached its assigned position at 10° E but, because of the loss of attitude that had occurred in the meantime, the final orbit correction manoeuvres could not be completed in time and the satellite drifted slightly too far. A few more days were necessary to bring it back to station, and on 29 May at midday OTS was declared ready for service.

THE PROGRAMME OF TESTS

Despite these minor hitches, the programme of tests could be started somewhat sooner than scheduled, because the injection sequence had been so remarkably close to nominal.

The Orbital Test Programme has been described in detail in Bulletin No. 14; suffice it to recall here that it comprises the following four categories of experiments:

* Further background on OTS and its network of experimental stations can be found in ESA Bulletin No. 14, a special issue devoted to OTS's role in future European communications.

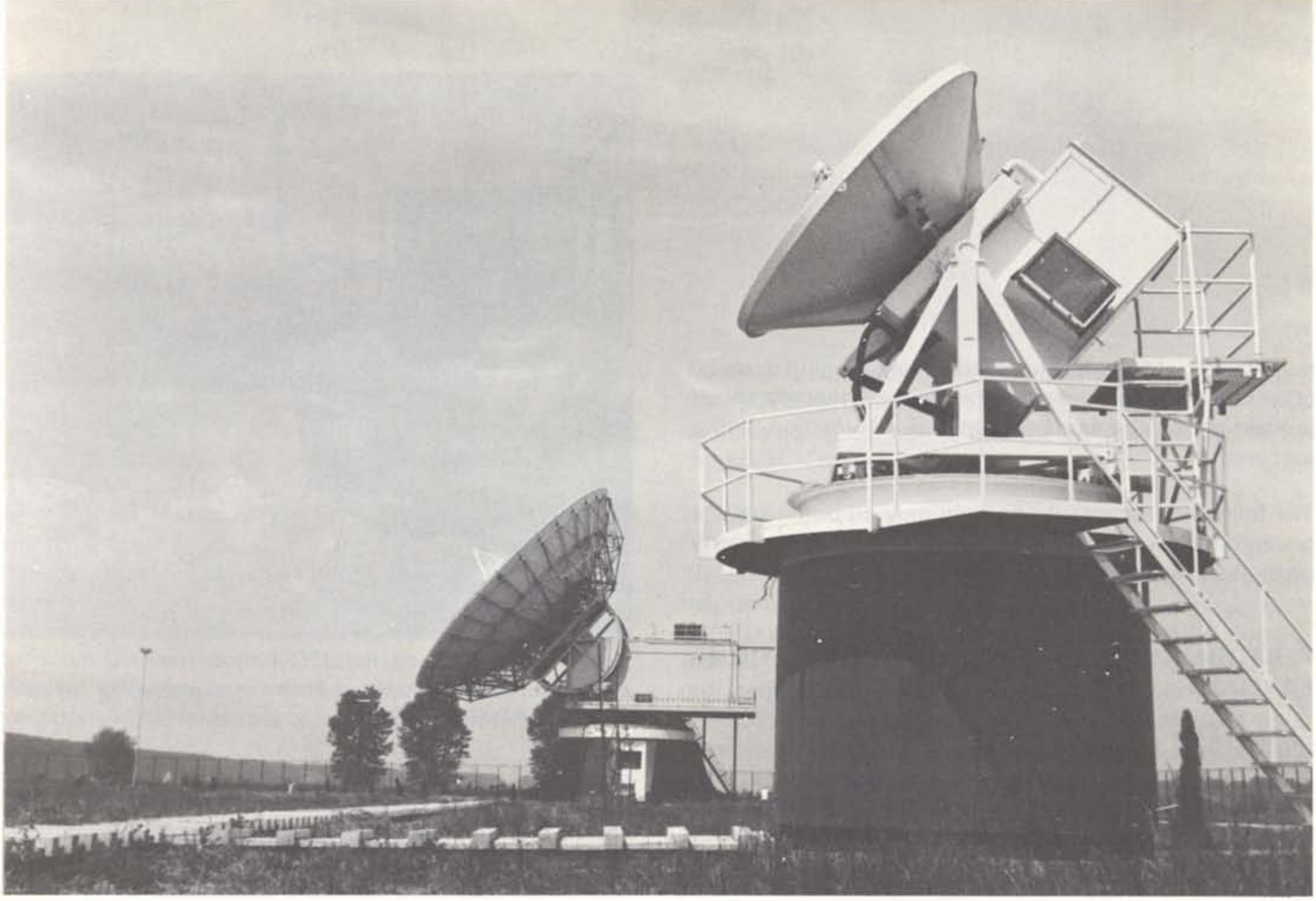

Figure 1 – Two ESA/Telespazio antennas at Fucino, the large one (17 m) being used for accurate measurements on Module-A of the communications payload, the small one (3 m) for measurements with Module-B and for propagation experiments.

(a) verification of satellite performance in orbit
(b) communications tests by the PTT Administrations
(c) propagation measurements at 11/14 GHz
(d) experiments related to new applications.

The plan of utilisation of OTS has been so arranged that all satellite performance tests will be completed by the end of this year, these tests being interleaved with periods during which the satellite is available to the PTT Administrations and propagation experimenters.

The satellite performance tests are of two kinds, namely *passive* tests carried out by simply analysing the data gathered by telemetry, and *active* tests which require changes in the configuration of the satellite and/or transmission of test signals through its communications payload. There are about 20 passive tests, concerned with verification of the performance of the Attitude and Orbit Control System (AOCS), of the power-generation system including its mechanical parts (solar-array mechanism), of the thermal control and of the overall spacecraft system (e.g. propellant consumption). There are approximately 40 active tests, most of which are related to measurements of the RF characteristics of the communications payload, i.e. the two repeater packages (Modules A and B), with their six associated antennas. In addition, the AOCS is the subject of five active tests involving slewing manoeuvres, and there are also two tests concerned with trying out new ranging techniques using the satellite repeaters instead of the more conventional tone ranging system.

At the level of overall system performance, a number of tests are carried out as a matter of routine to monitor the level of RF power radiated by the satellite antennas, the stability of the coverage areas at the Earth's surface, and the quality of the transmission channels.

The propagation experiments have already started, with all RF test signals necessary for the active tests being generated in the SCTS itself and most data being received, logged and preprocessed at the Fucino facilities (Figs. 1 & 2). Additional information is collected by six small measuring stations installed at Villafranca (Spain), Dublin (Ireland), Stockholm (Sweden), Milo (Sicily), Graz (Austria) and ESTEC (The Netherlands).

All test data are being centralised in the Communications Satellites Department at ESTEC for analysis and interpretation, although some of this work is being done by other organisations under contract to the Agency to speed processing of the large volume of information being gathered.

The following paragraphs contain only an outline of the preliminary results to date, but sufficient data has already been analysed to establish a fairly reliable picture.

PERFORMANCE OF THE COMMUNICATIONS PAYLOAD

REPEATERS

The repeater subsystem provides for the reception, amplification, frequency conversion, and re-transmission of SHF signals. It is divided into two independent repeaters:

- Module-A containing two 40 MHz and two 120 MHz channels, receiving and transmitting linear orthogonally polarised signals, used for TDMA telephony and FM television,
- Module-B, consisting of two narrow-band channels, receiving and transmitting circularly polarised signals for propagation measurements using up- and downlink beacon signals, and for transmission of experimental narrow-band signals.

There are also two on-board beacon generators, one in Module-A the other in Module-B, used for the propagation experiments.

All channels of both modules have now been exercised, including all redundancy, and been demonstrated to be capable of passing signals as required. OTS experimentation with the repeater will continue at intervals throughout the expected five-year life of the satellite, to obtain long-term performance and propagation data.

Like previous American and Canadian communication satellites, OTS has experienced a phenomenon whereby a 20 W TWTA in two particular channels switches itself off and transmission via the channel is interrupted until it can be turned on again by telecommand. The TWTAs contain protection circuits designed to switch off the unit when helix currents rise above a certain level, but so far no

Figure 2 – The minicomputer at Fucino used for logging and pre-processing test data.

reasons have been definitely identified to explain why this should have occurred in all cases. Investigation continues into these automatic switch-offs to determine their cause and thence to devise corrective measures.

A number of important repeater measurements have already been made within the OTP using the various earth stations under ESA control. Most of the repeater testing has been carried out from the SCTS and the measurements made so far have included amplitude versus frequency response, group delay versus frequency response, noise figure, gain variation, output power, spurious emissions, and frequency stability. In all cases the results have agreed very closely with the pre-launch measured values. We have also had the opportunity to measure the changes in these parameters with the daily and long-term variation of the satellite's environment in space, such as the changing illumination of the spacecraft body by the Sun and its effect on subsystem temperatures. The results obtained on noise figure, power output and gain stability show satellite performances considerably in excess of original specifications, the repeaters, for example, beaming up to 3 dB more than the specified power towards the Earth's surface.

The European PTT organisations, co-ordinated by the CEPT (Conférence européenne des Administrations des Postes et Télécommunications), have begun using the repeater channels for communications system tests, which will eventually result in the sending of pre-operational telephony traffic via OTS in preparation for the operational ECS satellite to be launched in the 1980s.

ANTENNAS

The antenna subsystem consists of six antennas, providing for the reception and transmission of the 11/14 GHz SHF signals. Detailed pattern measurements, to demonstrate the performance of each antenna, form a significant part of the OTP tests. Preliminary tests have already shown that all antennas survived the launch environment without detectable major misalignment or deformation, and all are operating successfully. Further tests are planned during October and these will yield detailed information on antenna performance and any variations in performance with time and temperature.

PERFORMANCE OF THE SPACECRAFT PLATFORM

For OTS to acquire its planned three-axis-stabilised attitude and begin transmissions at 11/14 GHz, it was necessary for all satellite subsystems to operate satisfactorily, as indeed they did. Within only a few days of launch, it had been determined that all subsystems had survived the launch environment and were generally operational. What was not known at that time was whether all redundant elements within each subsystem were in fact functional, nor how well, in detailed quantitative terms, the various subsystems were performing. Both of these questions are presently in the process of being answered as part of the on-going OTP. Results to date can best be summarised by considering each of OTS's major subsystems in turn.

TELEMETRY, TRACKING AND COMMAND

The TTC subsystem provides the on-board facilities for:

- encoding, modulating, and transmitting telemetry data
- receiving, demodulating, and decoding telecommands sent to the satellite
- transponding tracking signals to allow precise determination of orbital elements.

All of these various combinations of functions have now been exercised, and have been found to operate flawlessly.

As far as telecommand and telemetry data are concerned, the SCTS at Fucino is essentially 'transparent', the satellite being controlled and the telemetry analysed by the ESOC Control Centre.

POWER

The power subsystem consists of two Sun-tracking solar-cell arrays with their attendant bearing and power-transfer assemblies, two series-connected NiCd battery halves, electronics for power regulation and battery monitoring, control and protection, and power-switching circuitry. The power subsystem supplies 50 VDC to a number of satellite subsystems, and various secondary regulated voltages to the TTC and instrumentation subsystems. In addition, during eclipse periods, it provides the same voltages to all essential loads and, at least for short eclipses, to portions of the repeater.

The power subsystem supplied all necessary power during OTS's transfer and drift orbits, and is now providing power to all subsystems well within its specified regulation accuracy, and with more than adequate power margins.

The battery has been used sufficiently to ensure that all cells are functioning and it is now in a standby trickle-charge mode, awaiting the first on-station eclipses.

ELECTRICAL DISTRIBUTION

The electrical-distribution subsystem consists of the power and signal harnesses (excluding RF connections) within the communications and services modules. It is completely passive, so that its performance can only be ascertained in relation to the other satellite subsystems. As these have all been shown to be functioning, it can be concluded that the subsystem survived launch and is operating as intended.

ATTITUDE AND ORBIT CONTROL

The AOCS consists of all sensors, electronics, and active and passive actuators necessary to:
- provide attitude determination, manoeuvering, and control functions required for the spin-stabilised transfer orbit

Figure 3 – The small measuring station at ESTEC, with its 3 m antenna (on right).

- control both the attitude and orbit of the satellite when in its three-axis-stabilised configuration, to maintain antenna boresight pointing accurate to within $\pm 0.2°$
- drive the solar-cell arrays to maintain them Sun-pointing to within $\pm 2°$.

All of these functions have been or are now being performed by the AOCS in an acceptable manner. Some of the OTP tests will determine quantitatively the pointing accuracy being achieved, but the early indications are that this will be found to be within specification.

As mentioned in the introduction, a number of minor AOCS anomalies were encountered during the early days of the mission, following initial acquisition of the three-axis attitude-controlled configuration. These anomalies, which included horizon-sensor and reaction-control thruster discrepancies, have since been corrected and have had the beneficial side-effect of causing all redundant elements within the AOCS to be confirmed to be functional sooner than would otherwise have been the case. Their occurrence has had no impact on the overall OTS mission, however, and has in fact aptly demonstrated the operational flexibility built into the AOCS.

STRUCTURE

The function of the structure subsystem is to provide support for all spacecraft equipment, to maintain relative alignment between certain equipment items (e.g., AOCS sensors and actuators) and to ensure that the natural frequencies of the satellite meet requirements imposed by the launch vehicle authority.

Being a completely passive subsystem, the performance of the structure can only be inferred by noting the performance of other subsystems, notably that of the AOCS and antennas. Quantitative performance figures are not yet available from the OTP tests for these subsystems, but preliminary indications are that all critical alignments have been maintained within acceptable limits. Also, a 'quick look' at launch-vehicle telemetry values immediately following the launch indicated no adverse dynamic interactions between the spacecraft and the launcher, and so it can be concluded that the natural frequency requirements during launch were met.

THERMAL

The thermal subsystem is basically passive in nature, relying upon passive thermal coatings, superinsulation blankets, and special radiating surfaces to control the satellite's overall temperature. Ground-controlled heaters are used to control the temperature of specific equipments, and these systems rely heavily on analysis, substantiated by ground testing, to ensure that all equipment items operate within acceptable temperature limits.

Shortly after launch, telemetry data indicated that some equipment was operating several degrees warmer than expected. Although no units were operating outside acceptable limits, the discrepancies gave rise to some uncertainties in the temperatures predicted for end-of-life operation when, due to expected gradual in-orbit degradation of thermal surfaces, OTS can be expected to operate slightly warmer than it does initially.

Subsequent investigation revealed certain inaccuracies in the thermal computer model used for temperature prediction which were not brought to light by ground testing because they lay in the aft end of the satellite where it interfaced with, and where any inaccuracies would be masked by, the solar-simulation test facility. When the computer model was corrected, close correlation was obtained with the temperatures measured in orbit, restoring confidence in the predicted end-of-life temperatures.

INSTRUMENTATION

Though not an experimental scientific satellite, OTS carries a fairly extensive instrumentation subsystem to measure and condition for subsequent telemetry, parameters required for the OTP beyond those needed for normal 'housekeeping'. This subsystem's temperature sensors, RF detectors, microswitches, and signal-conditioning electronics have so far operated completely as planned.

PYROTECHNICS

This subsystem consists of pyrotechnic squibs, located in the BAPTA (to unlock its bearings following launch), the

ABM (to fire the motor igniter), and on the solar-array release mechanism, a dedicated pyrotechnic electrical harness, and a set of electronics to provide the proper current pulses to fire the pyrotechnic squibs. All functions operated perfectly satisfactorily when needed during the early days after launch, and this subsystem has now completed its role in the OTS mission.

CURRENT STATUS OF EARTH STATIONS

The present network of experimental earth stations working with OTS consists of about 30 terminals equipped with antennas ranging in size from 2 to 19 m. In addition to the SCTS at Fucino, which is used jointly by ESA and Telespazio, there are already two large PTT stations in operation, that of the French Administration at Bercenay-en-Othe (14.5 m dish), and that of the British Post Office at Goonhilly Downs (19 m dish). Like the SCTS, they are equipped for the transmission of digital telephony signals and analogue television programmes on an experimental basis.

Most other stations are smaller and are used only for propagation measurements. Eight are able to transmit a pair of beacon signals which allow attenuation and cross-polarisation to be measured simultaneously on the 14 GHz uplink and 11 GHz downlink; the rest can only receive beacon signals generated or relayed by OTS.

DEMONSTRATIONS

Apart from its role as a forerunner of the future ECS satellites, OTS can also serve for various experiments concerned with other applications of communications satellites. One such application is direct television broadcasting, for which it offers interesting possibilities.

Several demonstrations have already taken place – at ESTEC, at Farnborough and at Wembley (UK) – to show that by relaying a television signal through one of the repeaters associated with OTS's high-gain Spotbeam antenna, it is possible to produce sufficient power flux density to permit reception by relatively small antennas.

The demonstrations made at ESTEC have relied on the 3 m antenna shown in Figure 3, and picture quality has been excellent. The demonstrations at Farnborough and Wembley have also been very successful, with very high quality pictures being received.

PROSPECTS FOR THE FUTURE

The OTP has already achieved many important objectives. The tests carried out so far have shown that, with minor exceptions, OTS is performing to specifications. Indeed in a number of areas these specifications have been substantially exceeded. The satellite has enough fuel on board to sustain full performance for at least five years.

Much of the more detailed test data on the first phase of the OTP has yet to be analysed and this will provide further insight into the satellite's performance and will be of substantial benefit in the design of future satellite systems. Many further experiments, particularly in the field of telecommunications measurements and demonstrations, are planned by ESA, the National PTT Administrations and EUTELSAT, and the passing of live traffic (telephony, television and data) on a pre-operational basis is also an important feature of the future work within the OTP. □

Europe's Programme of Maritime Satellites – A Contribution to a Worldwide System

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The Maritime Satellite Programme currently in progress in Europe under the authority of ESA and the circumstances under which this programme could be used as the basis of a worldwide maritime satellite system can perhaps be discussed most succinctly by first considering the background to the current situation and the international discussions now under way, and then proceeding to a more technical discussion of the spacecraft that would form the basis of the European contribution.

THE BACKGROUND

Soon after the approval of the initial Marots programme in 1973, discussions were commenced with the European User Telecommunications Administrations on the possible operational use of the spacecraft to be developed. In addition to these internal European discussions, the Agency followed closely the meetings of the MARSAT Panel of the Intergovernmental Maritime Consultative Organisation (IMCO), within which maritime administrations were discussing and preparing a new international organisation, INMARSAT, intended to operate a worldwide system of maritime satellites.

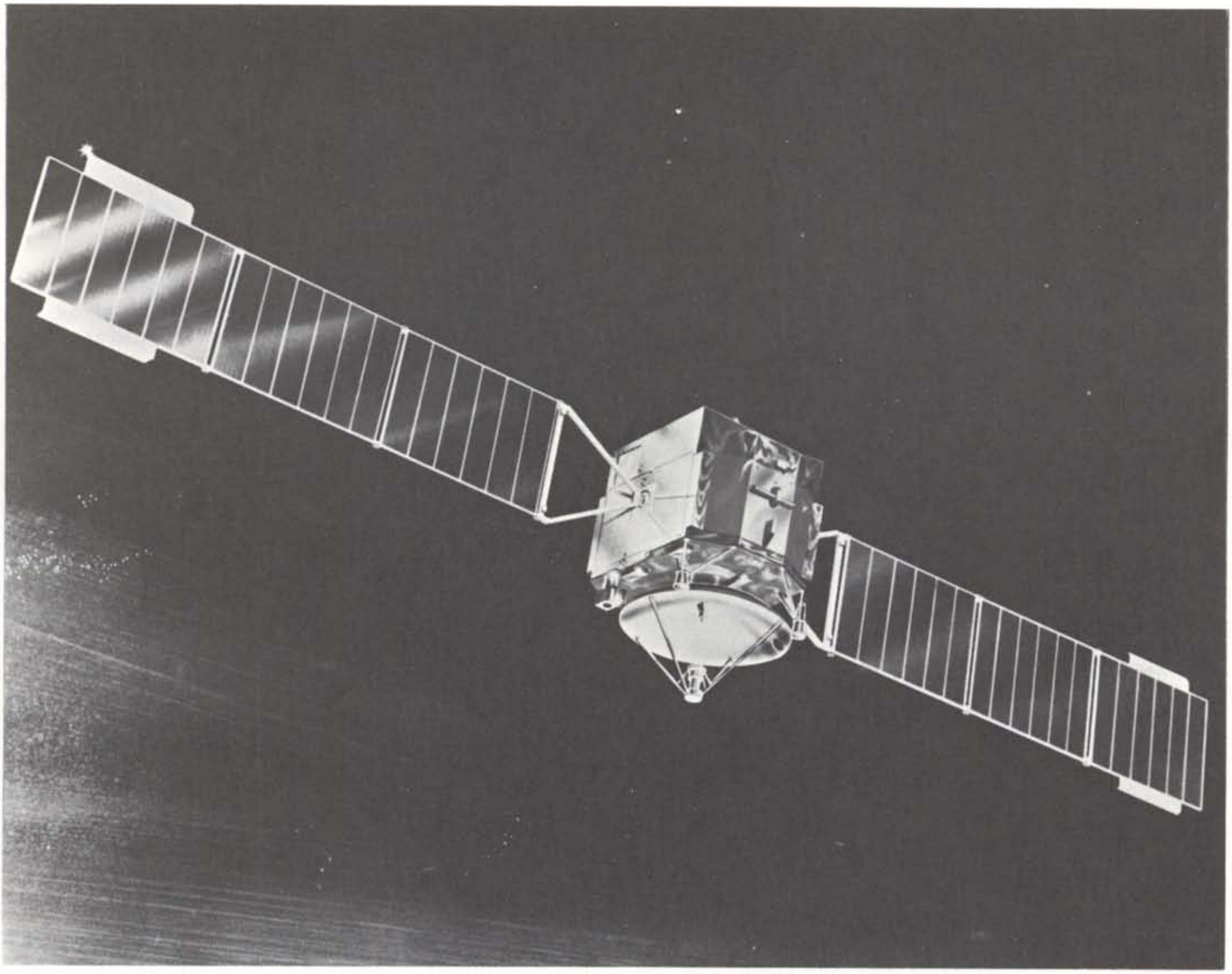
Clarification of the circumstances in which ESA maritime satellites could be used operationally came during the second half of 1976. Firstly, following approval by ESA Delegations, a declaration was made at the second meeting of the INMARSAT Conference panel indicating that the States participating in the Marots programme would be prepared to make available the satellite capacity in orbit, as a European contribution to a worldwide system; secondly, the continuing discussions with European Telecommunications Administrations led to the conclusion that in order to provide an adequate guarantee of the availability of a Marots space segment, it would be necessary for a second spacecraft to be prepared.

This latter conclusion led to the inclusion of a second Marots spacecraft in the overall programme in the field of communications satellites presented to, and approved in principle by, the meeting of the ESA Council at Ministerial level in February 1977. Just prior to this meeting there had been a new development which reinforced the interest of Delegations in the proposed extension of the Marots programme, namely an approach from the MARISAT Consortium, led by COMSAT General, which was beginning to examine the options open to it for a follow-on system to its initial Marisat network (the satellites of which had been orbited in 1976), in order to fulfil the obligation of the Consortium to ensure that a maritime space segment would continue to be available after the end of the nominal lifetime of the original Marisat spacecraft in 1981.

The concept was that, building on the two maritime satellites to be developed by ESA, a consortium of telecommunications administrations, including the MARISAT Consortium on behalf of the United States, would group themselves into a 'Joint Venture' to procure two further spacecraft, so that the four satellites could then be operated as a worldwide system. It is worth stressing that COMSAT General and its partners always made it perfectly clear that the Joint Venture represented only one of the options it was examining, other options being the procurement of wholly American dedicated spacecraft, or of a further generation of hybrid civil/military spacecraft, to be known as Marisat-2.

Essentially, the Joint Venture discussions, as they have developed in the last eighteen months, have been based on the starting position outlined above. Two main lines of progress during 1977 need to be identified, firstly a clarification of the technical content of the programme proposed, and secondly the broadening of the interest in the Joint Venture beyond merely European and American interests (associated with a growing uncertainty as to which entity should represent the USA). During 1978, although the technical content associated with a Joint Venture has become clear, uncertainty as to the American position has continued. A third element has also been introduced: the possibility of INTELSAT as a space-segment option for a worldwide system.

Turning first to the technical development, discussions with COMSAT General in 1977 on the inter-operability of the Marots spacecraft with the existing Marisat system



highlighted various problems; most of these could be overcome, but one outstanding difficulty was that of the frequencies used for the shore-to-satellite links, Marisat using allocations of 4 and 6 GHz whilst Marots had been designed for 11 and 14 GHz. When it became clear in mid-1977 that countries such as Japan and the Soviet Union, which could be expected to play a major role in the exploitation of a worldwide maritime system, would prefer the lower frequencies, and following a recommendation by the European administrations, the Agency's Joint Board on Communication Satellite Programmes (JCB) decided to authorise a change in the Marots shore-to-satellite frequencies to the 4 and 6 GHz bands. Since this change also entailed a delay in the launch of the first spacecraft until 1980, it was further decided to take advantage of the time thus made available to reconfigure the spacecraft to use the upgraded spacecraft platform under development for the ECS programme rather than the OTS platform originally foreseen (which has led to the use of the acronym Marecs to describe these updated spacecraft). This permitted operational improvements in areas such as electrical power and eclipse capability which users had indicated as highly desirable.

On the institutional front, a series of meetings held to discuss the Joint Venture (Paris in November 1977, London in December 1977 and February 1978, Bournemouth in April 1978 and Coventry in July 1978) have been attended by entities representing over 93% of the INMARSAT initial investment shares including, in addition to the Member States and the USA, representatives of such key maritime nations as the Soviet Union, Japan and Greece.

However, the American position has been clouded by internal American affairs linked to the nomination of the US entity authorised to participate in INMARSAT. US representatives attended the London meetings cited above, but not the later meetings (although the Joint Venture participants have repeatedly expressed the hope that US representatives would be able to rejoin the discussion in the near future). The key problem has been that Bills tabled in both the House of Representatives and the Senate have nominated the COMSAT Corporation, rather than the MARISAT Consortium, as the foreseen US signatory of the INMARSAT Convention, and thus virtually as the nominal US participant in a Joint Venture. Whilst some differences (not associated with COMSAT's nomination) persist between the House of Representatives and Senate drafts of the Bills, which will have to be resolved by an inter-House Conference, it is anticipated that the Bills will become law in the near future, and there will then be no formal objection to the participation of COMSAT in the Joint-Venture discussions.

It should be stressed that the Joint-Venture participants have always indicated their wish to encourage the timely and successful commencement of INMARSAT services, it being their intention to offer, as soon as possible after the entry into force of the INMARSAT Convention and Operating Agreement, to sell to INMARSAT on fair and reasonable terms, all property and contractual interests owned by the Joint Venture, with the aim of completing the sale at the earliest possible date.

To underline this intention, it is worth quoting from the Memorandum of the Joint Venture meeting at Coventry to the meeting of the INMARSAT Preparatory Committee which immediately followed it:

> 'The Joint Venture participants are desirous of promoting and endeavouring to ensure the earliest possible entry into force of the INMARSAT Convention and Operating Agreement and the earliest possible practical establishment of the INMARSAT Organisation, but recognise that there is no realistic likelihood of the INMARSAT Convention and Operating Agreement entering into force in time to allow the INMARSAT Organisation to make such decisions and commitments as are required to ensure continuity.'
>
> 'In order to emphasise the relationship between the Joint Venture and INMARSAT and to stress the limited scope and duration of the Joint Venture, the participants have decided to entitle any such organisation which may be created the 'Pre-INMARSAT Joint Venture', and to strictly limit the functions of that organisation to taking such advance procurement decisions as are necessary prior to the establishment of INMARSAT.'

The status of the options has, of course, been progressively refined as the discussions have continued. In order to present the Marecs option on a firm basis, ESA submitted to the Joint Venture participants on 31 March 1978, a documented proposal for the provision of two Marecs spacecraft, together with the costs of running a worldwide three-ocean maritime-satellite system.

This proposal was examined at the Bournemouth meeting of the Joint Venture, which led to a list of questions of clarification being submitted to ESA; replies to these were tabled in an Addendum dated 31 May 1978, which was discussed at a working group meeting in Stavanger in June 1978, as well as at the main Joint Venture meeting at Coventry in July.

At the Bournemouth meeting, the interest of some participants in an option by which a maritime space segment would be provided by INTELSAT, led to the attendance of a member of the INTELSAT Executive, who presented to the participants three suboptions for a seven-year service from 1981 to 1987:

- two-ocean (Atlantic and Indian) coverage based on the incorporation of maritime packages on four Intelsat-V spacecraft
- completion of the above coverage, the Pacific Ocean to be covered by the launch of two dedicated satellites
- three-ocean coverage by the launch of four dedicated satellites.

The Joint Venture consideration of this INTELSAT initiative led to the same series of questions of clarification being addressed to INTELSAT as had been provided to ESA for its proposal. An INTELSAT commentary on the enquiry was provided for, and examined by, the Coventry meeting of the Joint Venture.

With clarification of the INTELSAT suboptions that had

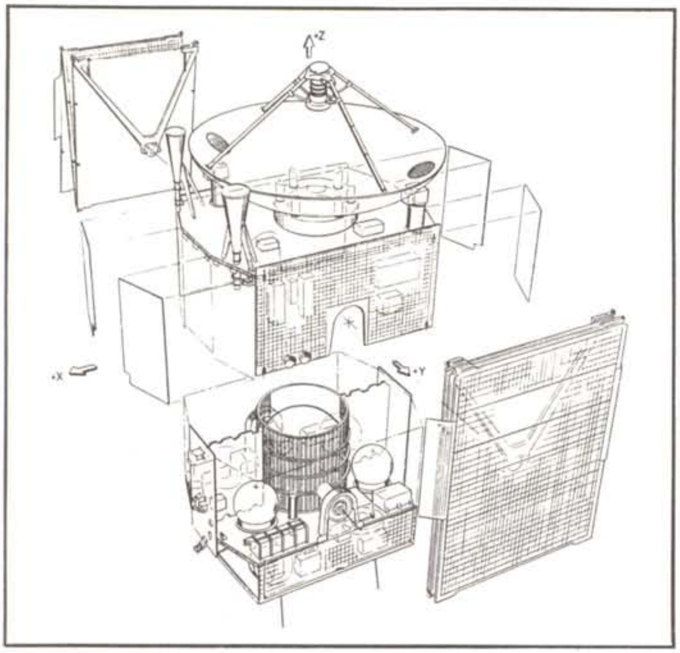


Figure 1 – The Marecs spacecraft.

taken place during April and June, and following analysis of the ESA and INTELSAT proposals, the participants at the Coventry meeting were able to prepare a list of three options for a worldwide space segment for further consideration:

1. Four Marecs dedicated satellites in orbit.
2. Three Intelsat-V satellites equipped with maritime communications systems in orbit, plus two dedicated satellites provided by INTELSAT.
3. Three Intelsat-V satellites with maritime communications systems plus three Marecs satellites in orbit.

Following a detailed study of these options, a preference was expressed for Option 3: three Marecs satellites and three Intelsat-V satellites, with maritime communications subsystem (MCS), in orbit. It was decided to encourage ESA and INTELSAT to develop this option further to effect a substantial reduction in the price and to improve the capacity of the Intelsat MCS. Views were expressed by some participants that final adoption of Option 3 would be conditional on this being achieved and also that, in the meantime, the two other options should be kept open.

As a consequence of this decision, and of the confirmation that the participants plan to hold a Constitutive Conference at Bergen, Norway, in September for the purpose of elaborating and opening for signature the Constitutive Agreement to establish the Pre-INMARSAT Joint Venture, the following actions are now under way within the Executive:

- further refinement of Option 1 (four Marecs satellites in orbit)
- discussions with INTELSAT of the operational and technical problems associated with the implementation of Option 3
- refinement of the cost of the Marecs portion of Option 3; and
- continued discussion with Administrations nominated to represent the Joint-Venture participants on the terms of the necessary contract between the Joint Venture and ESA to govern either the supply of services associated with Option 1 or the Marecs portion of Option 3.

Should the Bergen Conference successfully generate a Constitutive Agreement for the Joint Venture, current planning is that a 90-day period would be allowed for signature. This would imply that a Joint-Venture contract with ESA for the supply of the services associated with the selected option should be signed at the end of 1978/beginning of 1979.

THE TECHNICAL ASPECTS

The second part of this paper describes the mission aspects and the system design of the proposed Marecs space segment which is defined as the Marecs spacecraft (Fig. 1) and associated ground-support facilities required for tracking, monitoring and controlling the spacecraft on-station and during the transfer and drift orbit. It includes:

- the Marecs-A, B, C and D spacecraft, to be procured from a European industrial consortium led by British Aerospace Dynamics Group
- the ground network for transfer and drift orbit telemetry, tracking and command (TTC) operations
- the ground networks for on-station TTC operations
- the Operations Control Centre (OCC)
- any additional ground equipment that may be required for payload monitoring.

Marecs-A, B and C form a worldwide maritime satellite system covering the Atlantic, Indian and Pacific Oceans, respectively. Marecs-D is a completed spare supporting the system against failure.

MISSION OBJECTIVES

The Marecs satellites will be used initially in the frame of a Marisat-type communication system, which has been configured to provide high-quality, full-duplex, reliable, real-time voice, data and teleprinter services between shore stations and ship terminals. In particular, they will be capable of providing the following types of communications channels:

- shore-to-ship and ship-to-shore voice channels for telephone services
- shore-to-ship and ship-to-shore TDMA channels for the telex services
- a random-access channel for ship requests in the ship-to-shore direction.

The Marecs-A and B satellites will in addition be capable of relaying low-bit-rate search-and-rescue messages in the ship-to-shore direction, this capability being offered as an option for Marecs-C and D.

The Marecs spacecraft, the operational design lifetime of which will be seven years, will be capable of being initially positioned anywhere in the geosynchronous near-equatorial orbit and will be able to be relocated to any other position, at a minimum drift rate of 10° per week, at least twice during the design lifetime. They will be designed to allow east-west station-keeping within ±0.5° of the nominal position and orbital inclination will remain less than 3° throughout the design lifetime.

THE SPACE SEGMENT

Marecs will use a payload (Fig. 2) developed under ESA contract by Marconi Space and Defence Systems (MSDS) in the frame of the initial European maritime programme. The C to L-band repeater operates with constant output power. When frequency re-use over the three oceans is a requirement, it is mandatory to keep all carrier levels close to nominal, whatever the traffic load of the repeater. This can be achieved with minimal operational constraints by selecting the number of transistor power amplifier modules, as a function of the traffic requirement, and/or by keeping the load on the repeater artificially constant. The advantage of the automatic level control in the C to L-band repeater is that no absolute power control in the uplink is required. Another important feature of this payload is the quasi-linearity of the L-band amplifier.

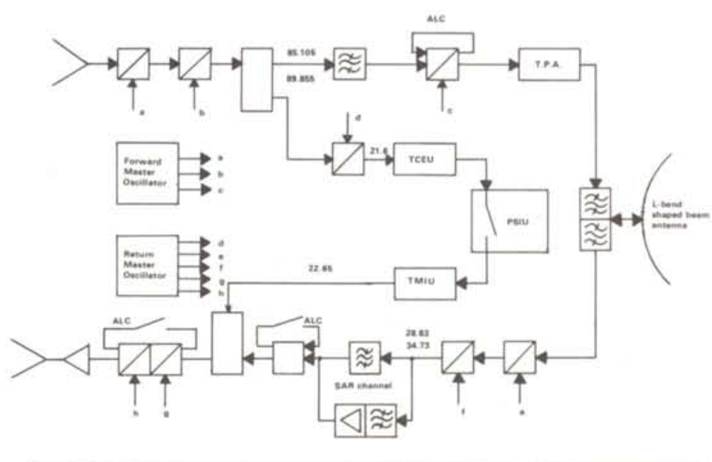


Figure 2 – Marecs-C/D baseline payload configuration.

The frequency plan for communications, together with on-station telemetry (TM) and telecommand (TC), is shown in Figure 3. The VHF frequencies used for the TM/TC function during transfer orbit serve as a backup when operating on-station.

The proposed frequency plans allow the transmission of the essential channels of the Marisat system (forward TDMA and return random-access channels). The frequency translations (4882.5 MHz in the C to L-band repeater and 2556 MHz in the L to C-band repeater) are slightly different, and require a 0.5 MHz frequency shift in the Marisat ground stations.

The Marecs spacecraft bus (Fig. 1) consists of a central body with two solar-array wings, each wing having three panels. Only five of the six panels available will carry live cells for the Marecs mission. The attitude of the spacecraft on-station is three-axis controlled such that the array wings are directed normally to the orbit plane and the antennas, located at one end of the body, are directed to the Earth. Each array wing has an independent revolution/day drive capability to maintain Sun-pointing as the satellite rotates about the Earth. The lower service

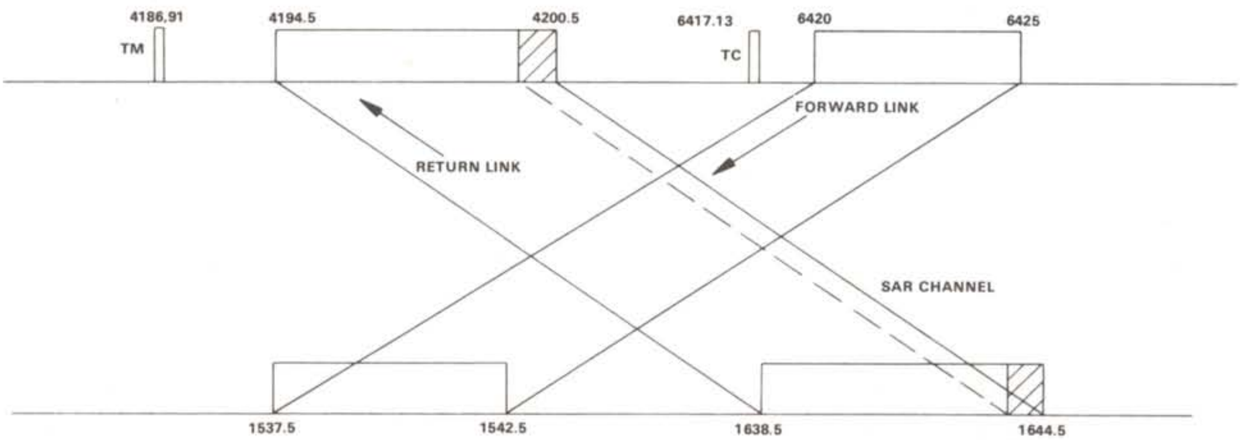


Figure 3 – Frequency plan.

module is almost identical to that of ECS. It comprises a horizontal equipment platform which supports the majority of the service units. The floor is located on a central thrust cone and cylinder inside which is located the Apogee Boost Motor (ABM). The upper communications module comprises a horizontal platform supported by the thrust cylinder, internal vertical walls and edge panels of the service-module platform. These panels support the communications-payload power stages and serve as heat-rejecting radiators. When integrated, the lower edges of these panels are supported via the service-module platform. Cut-outs in the panel allow clearance for the solar-array drive mechanisms, mounted on the service-module platform. Four removable panels close the remaining open external surfaces between the two floors.

Power is distributed to all subsystems from a 50 V regulated main bus derived from the solar array during sunlight and from two batteries during eclipse, providing full capability at all times. In transfer-orbit configuration, the stowed arrays provide sufficient power from the two outer panels to supply all service functions.

Transfer-orbit attitude control is based on conventional measurement and adjustment techniques. On-station attitude is based on an on-board closed-loop system using a two-axis infrared earth sensor and a momentum storage system. All reaction control functions rely on catalytic hydrazine thrusters fed from four storage tanks.

GROUND SUPPORT

The ground-support facilities needed to operate the spacecraft after its separation from the launcher include:
- a VHF TTC network for the transfer- and drift-orbit phase
- on-station TTC terminals
- payload-monitoring facilities
- VHF stations for the back-up mode
- operations control centres.

Redu in Belgium, Kourou in French Guiana, Malindi in Kenya, and Carnarvon in Australia make up the ESA VHF TTC station network and they are connected via data links to the Operations Control Centre at ESOC in Darmstadt.

The proposed TTC network for Marecs, shown in Figure 4, has been selected on the basis of three fundamental criteria:
- *Cost:* Reduction of running costs (manning, maintenance and land-lines) by integration of the facilities on only two sites and maximum re-use of existing ESA facilities.
- *Reliability:* Achievement of good overall reliability

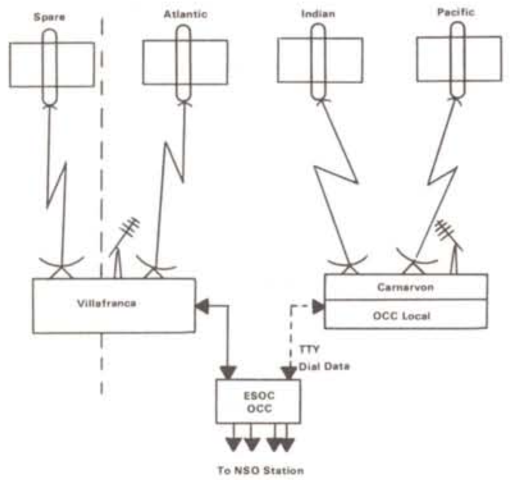


Figure 4a – On-station operating configuration.

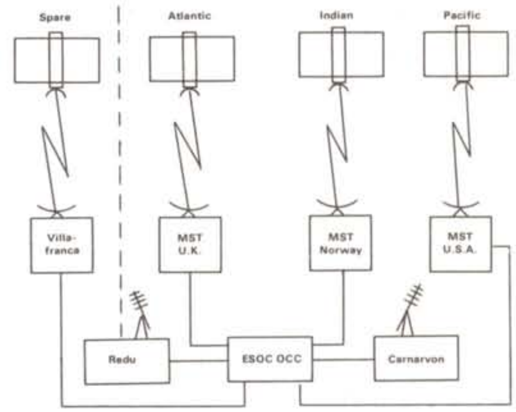


Figure 4b – On-station operating option.

without excessive duplication, ground-support facilities being reorganised to cope with equipment failures, with a minimum back-up operation reaction time.

– *Flexibility:* Possibility to extend the configuration, at minimum cost, if a spare spacecraft is required in orbit, or if improvements are required to achieve more accurate east-west station-keeping.

These considerations lead to concentration of the on-station TTC and payload monitoring facilities at two sites, namely Villafranca in Spain and another site with common visibility of the Indian Ocean and Pacific Ocean areas, such as Carnarvon in Australia (Fig. 4a). In this case, Villafranca would provide data to the OCC at ESOC in Darmstadt, whilst Carnarvon would have a local OCC supported by ESOC. A number of other ground-support-facility options are still under investigation, one example being that in Figure 4b.

CONCLUSION

Marecs-A is scheduled for launch on 30 October 1980 on the fourth Ariane test flight. The second spacecraft, Marecs-B, follows in sequence, with commencement of system tests in November 1980 and an anticipated launch at the end of April 1981, on an operational Ariane flight. The Marecs-C and D programme is a direct follow-on of the Marecs-A and B programme, and Marecs-C would thus be available for launch in December 1981 (should it be decided to use the Space Shuttle rather than Ariane to launch the C and D satellites, the earliest available Shuttle launch for Marecs-C is mid-February 1982). Marecs-D will be ready for storage in June 1982.

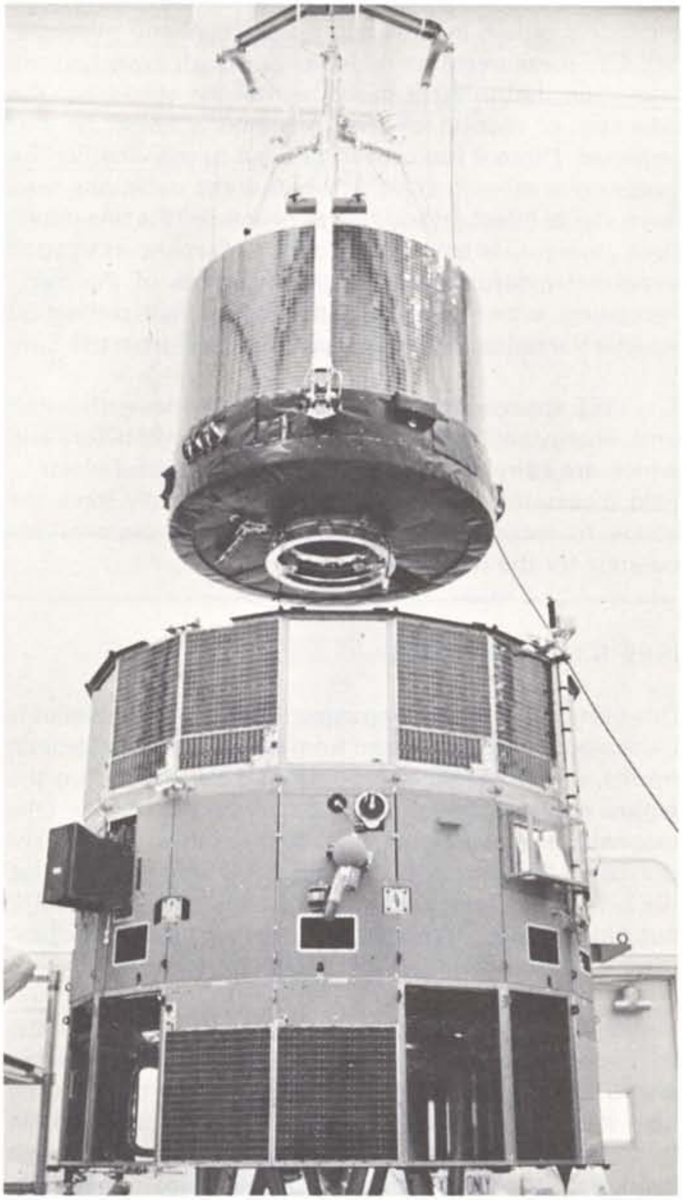
Development work is now proceeding at full pace in European industry on the procurement of Marecs-A and B, and it is the intention that even in the absence of a Joint Venture these spacecraft will be used operationally.

Hopefully, in addition to providing an appreciation of the technical parameters associated with the spacecraft now into procurement, this article has served to illustrate the status of discussions on *one possibility* for the provision of a worldwide maritime satellite service after the current Marisat system. These discussions are still proceeding, as we have said, and it is hoped to report on their progress in a subsequent issue of the Bulletin. □

Preliminary Results from ISEE-1 and ISEE-2

A.C. Durney, Space Science Department of ESA, ESTEC, Noordwijk, The Netherlands

ISEE-1 and 2, launched from Eastern Test Range on a single rocket on 22 October 1977, are travelling in almost identical, highly elliptical orbits which have a maximum height of 137 000 km and a minimum of about 500 km, and whose plane is tilted by about 30° from the ecliptic. This apogee is sufficient to take the spacecraft well outside the magnetosphere, while the 500 km perigee ensures that all interesting features are crossed frequently. The preliminary results of the mission, designed to make a comprehensive assault on some of the most intractable mysteries of our near-earth environment, are already indicative of a richness and detail of measurement that bodes well for the achievement of the breakthroughs in our understanding of magnetospheric physics that are being sought.



As the scientific rationale underlying the three-spacecraft ISEE mission (ISEE-3 was launched separately on 12 August, to be sited 235 earth radii from Earth, on the Earth-Sun line) has been explained in some detail in a previous Bulletin (No. 12, February 1978), it should suffice here, by way of introduction, just to recapitulate the major difficulties inherent in exploring the magnetosphere.

Previous spacecraft exploration has shown that the Earth's magnetic field creates a cavity about 20 Earth radii wide in the solar wind, and that the Earth sits in the centre of this so-called 'magnetosphere' protected from the majority of the solar particles. The boundaries between the various sections of the magnetosphere (magnetopause, bow shock, plasma-pause, etc.) appear quite sharp and are strongly influenced by the shapes of the magnetic fields, and the electric fields present also play a role. The nature of these boundaries needs to be thoroughly understood for a variety of important reasons; for example, they are our chief protection against the harsh environment of interplanetary space (will they disappear one day?), their movements may have a large effect on World weather systems and they involve interesting, basic physical processes which are not understood. All of these boundaries are constantly moving, expanding, contracting and vibrating.

The fact that the various features and phenomena in the Earth's magnetosphere are in motion with speeds of sometimes 100 km per second and more has always been a major problem in previous magnetospheric missions, because measurements by lone spacecraft have had the restriction that in most cases neither the speed nor the direction of motion of the phenomena could be determined. Often it has proved difficult to tell whether the feature was moving at all, or whether the variations seen were a local effect. In addition to obscuring the fine detail, such ambiguities have led to large discrepancies in such important measurements as the thickness of the magnetopause, which constitutes the Earth's main protection against the radioactive particles boiling off from the Sun.

The ISEE spacecraft, which have instruments with better time, energy and direction resolution than ever before and which are carrying some of the first successful electric-field measuring instruments should hopefully have the ability to record the magnetosphere's movements accurately for the first time.

ISEE'S CAPABILITIES

One particularly interesting aspect of ISEE's capabilities is illustrated in Figure 1, taken from the early magnetometer results, where passage through the bow shock into the region between the shock and the magnetopause (the magnetosheath) is clearly marked by a jump in the size of the magnetic field. In this case the bow shock swept past ISEE-1, which was trailing at the time, touched ISEE-2 but did not pass it completely, then retreated back past ISEE-1 once more; the time delays are quite clear.

Figure 2 shows what can be achieved with even the relatively modest time resolution of the solar-wind instrument on ISEE-2. It records a passage through the bow shock and the large increase in flux can be seen followed by a change in energy, after which the plasma becomes isotropic as the spacecraft becomes immersed in the magnetosheath.

THE MAGNETOPAUSE

One of the major problems of the magnetosphere is an understanding of the nature of the magnetopause. Previous measurements have been very patchy and have more often than not added to its mystery. The wide variety

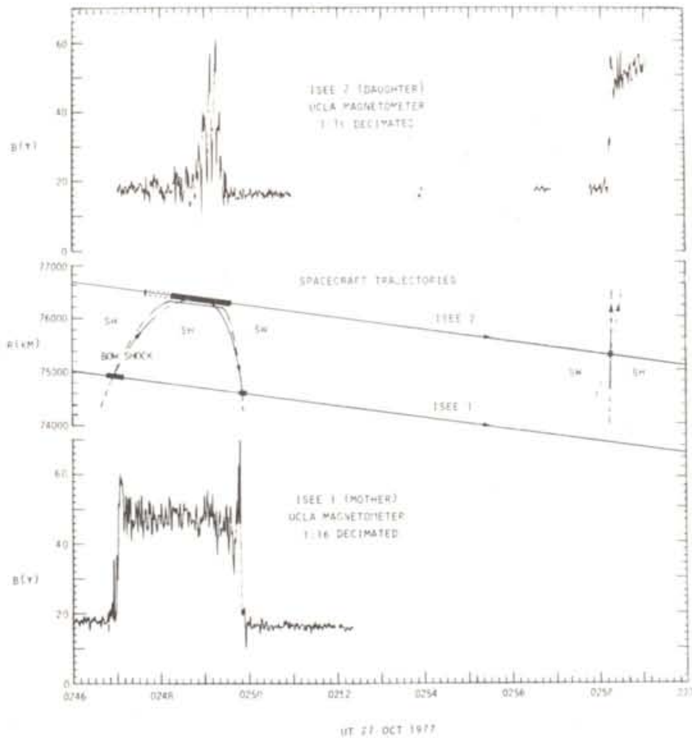


Figure 1 – Magnetometer records from ISEE-1 and ISEE-2 on the second orbit which show how the bow shock swept past ISEE-1, touched ISEE-2, then retreated past ISEE-1 once more. The time delays are quite clear; position co-ordinates on this plot are only approximate.

of theories on the way in which it is formed serve to illustrate how little is known about it.

Many of the ISEE observations have involved multiple crossings, with the magnetopause sweeping backwards and forwards in a random manner, passing and repassing the two spacecraft, which generally move much more slowly than the boundary. Figure 3 shows a set of magnetopause crossings in which the magnetometer identification of the layer is shown by the shaded bands. Sharp changes in the numbers and temperatures of the particles (top two sections) can be noted as the spacecraft passes between two different environments.

The ISEE observations that have been analysed so far have shown the magnetopause to be very erratic. There is evidence that large velocity changes can happen very quickly and there can be rapid structural changes, both of which cause crossings to look very different to the two spacecraft though less than a minute apart. At times, however, the magnetopause can maintain constant

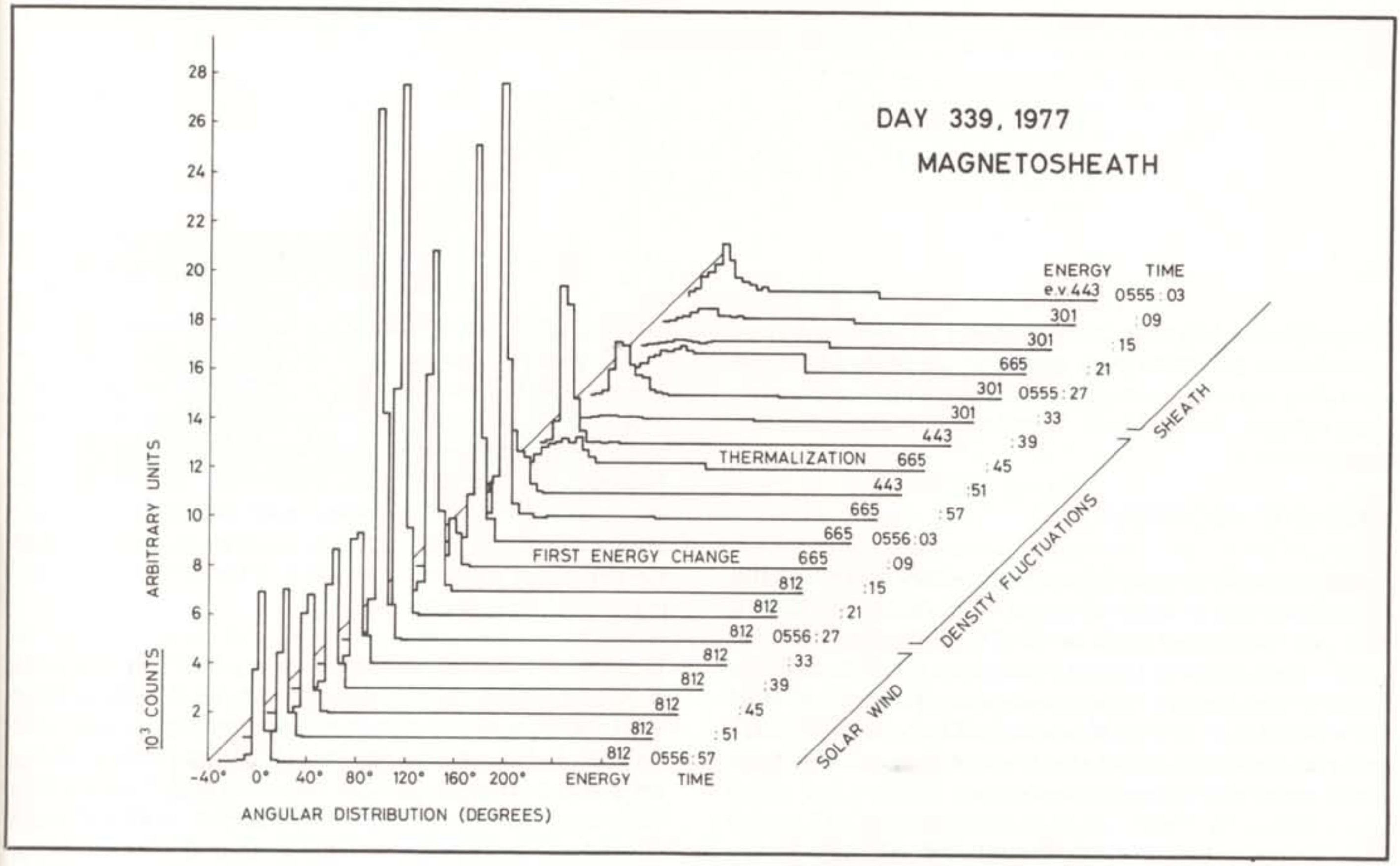


Figure 2 – The passage of the bow shock as seen by the solar-wind instrument on ISEE-2 on orbit 18. The large increase in counting rate was followed by a change in energy of the maximum, after which thermalisation of the plasma took place as the spacecraft became immersed in the magnetosheath.

velocity and structure for a minute or so, and under these conditions its thickness can be measured to be between 200 and 1000 km. The dispersion could be caused by differences in the thicknesses, or could be due to speed changes.

In general, the plasma densities and temperatures recorded within the magnetopause layer agree with those measured in the magnetosheath. For a small number of crossings, two investigators have reported solar-wind ions penetrating deeper into the magnetopause layer than electrons, the penetrations involved corresponding to the turning-circle radii of these particles in the local magnetic field. This is a significant observation because it supports one theory of how the boundary works.

The emerging picture is one of a very lively, sometimes

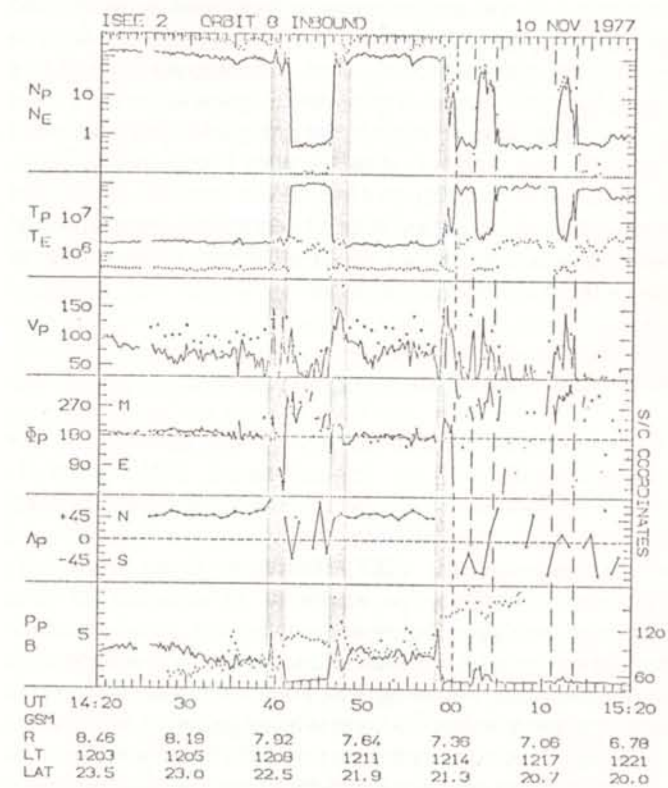


Figure 3 – Plot of quantities from an ISEE plasma detector, with grey bands superimposed to mark the position of the magnetopause recorded by the magnetometer.

transient boundary that at times shows definite structure, and on one occasion even seems to be folded back on itself. It is not surprising, therefore, that single-spacecraft observations have been unable to make effective measurements.

MAGNETIC RECONNECTION

The leakage of particles from interplanetary space into the magnetosphere is another unresolved mystery. A theory was put forward as early as 1961 to the effect that, for certain directions of the interplanetary field (it changes direction frequently), the interplanetary magnetic lines of force could join up with those of the Earth, in which case particles travelling along the lines of force would have direct access to the magnetosphere.

This 'reconnection theory', though thought to be probably correct, had never been directly observed in operation prior to the ISEE mission. The speed of movement of the magnetopause has been seen by one ISEE investigator to approach 90 km/s, which is close to the Alfvén wave velocity, and it is known that if the magnetopause moves at this sort of speed a type of shock can be produced in which the interplanetary magnetic field lines can connect directly with those of the Earth. Subsequent to this hopeful indication that the conditions needed for reconnection might be satisfied, the magnetometer group has in fact reported direct observation of magnetic reconnection in action.

BOUNDARY LAYERS

The streams of plasma following the contour of the magnetopause just on its earthward side, generally known as boundary layers, are well tabulated at high latitudes near the subsolar point. In the low-latitude region observed by ISEE, however, they seem very sporadic in nature. For example, in a series of nine crossings analysed by one investigator, only one substantial boundary layer was encountered. A few brief ones were observed, showing evidence of abrupt and rapid density changes, but no layer was detected at all on three crossings. This contrasts with the IMP-6 measurements at higher latitude where a boundary layer was observed at each crossing.

Interestingly, two of the ISEE crossings that showed no boundary layer were made at low latitude with the interplanetary field directed southward, when a very pronounced boundary layer should theoretically have been seen if magnetic reconnection were taking place. This implies that the basic model for reconnection is incorrect. When the boundary layer was present, it was often found to be moving northward, which was something of a surprise, and the implications of this are presently being considered.

The 'patchy' nature of the boundary-layer observations suggests strong temporal variations, as if plasma entry and/or transport along the boundary were being switched on and off. Flow speed has been found to change rapidly on a short time scale, with 0 to 100 km/s within 10 s commonly being seen. Flow has also been observed in all directions, sometimes reversing during the crossing, which is consistent with eddy convection being the main source of plasma movement in the boundary layer.

The implications of the differences between the boundary-layer observations and those at higher latitudes are not yet understood, but the completeness of the ISEE observations will enable a thorough analysis.

THE MAGNETOSHEATH

The mechanisms of the turbulence between the bow shock and magnetopause have still to be identified. Ignorance of the processes in this region stems partly from the fact that the resolution of the instruments has never been good enough in the past, and partly from the inability to measure the movements.

In the part of the magnetosheath surveyed by ISEE, large fluctuations are observed in both the direction and size of the flow velocity. This is typical of a plasma stagnation region, which is what may be expected at the low-latitude, subsolar point. The flow has been seen to vary between 30 and 200 km/s in less than a minute. The correlation between the variations seen by ISEE-1 and ISEE-2 is generally good, showing that the fluxes are time variations with coherence over distances of several hundred kilometres.

Near the magnetopause a layer has been detected in

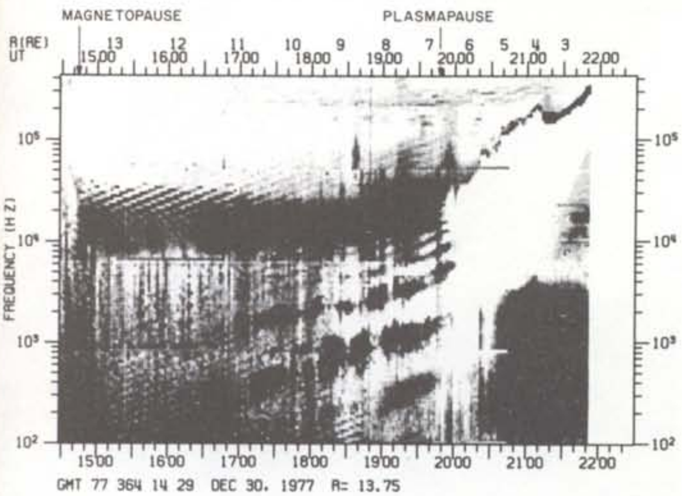


Figure 4 – A low frequency-time spectrogram from the electric-field experiment on ISEE-1, covering a large section of orbit 29. This is a good illustration of the variety of the observations of this experiment. The diagram needs expert analysis, but each part of the structure has a significance.

which the plasma density decreases by about a factor of two, and the field strength increases, the total pressure (plasma plus field) staying approximately constant. This is consistent with a squeezing of the magnetic flux tubes as the interplanetary magnetic field becomes draped around the magnetopause, as has been predicted by several workers in this field.

These first results from the magnetosheath lend promise that ISEE may be able to create some order out of the apparent chaos in this domain also.

BOW SHOCK AND FORESHOCK

Unlike the magnetopause, the formation of the bow shock is relatively well understood, but the extent and speed of its movements have not been checked systematically. ISEE reports show that it moves in a very similar way to the magnetopause, and that the characteristics of each movement are loosely correlated with those of the magnetopause.

Upstream of the bow shock is a confused region of activity called the foreshock, which in the past has produced some baffling observations. The preliminary ISEE observations are that there are occasionally intense medium-energy particle fluxes both ahead of and behind the bow shock. The behaviour of the electrons and the ions in these flows is quite different and is also energy-dependent. The energies of these particles are such that they are probably associated with the random directional changes and decelerations of solar-wind particles that occur in the formation of the bow shock.

The only active experiment in the ISEE payloads is an echo experiment designed to make precise measurements of electron densities. It has already detected echoes in the foreshock, despite predictions that it would never work in this region. These accurate measurements are a very necessary part of the investigation of wave-particle interactions.

ELECTROMAGNETIC WAVES

ISEE's wave-measuring experiments are working spectacularly well and are producing exceptional illustrations of the complexity and variety of wave processes in the magnetosphere (e.g. Fig. 4). These diagrams are very rich in information and need expert analysis. One of the striking features is the extent to which the electron plasma frequency can be identified essentially throughout the orbit. The investigator's pre-launch prediction that this might be possible had been received with some scepticism. The wavelengths of some important features near the bow shock have already been measured.

In the past it has been observed that the Earth is a source of intense radio emission, which appears to come from the auroral regions. The two ISEE spacecraft have detected an astonishing amount of previously unexpected fine structure in this emission and long-baseline interferometry between ISEE-1 and 2 will be used to locate the positions and movements of the sources.

Meanwhile the appearance of bursts with rapidly drifting centre frequencies has been analysed as tentatively implying the source to be some form of disturbance moving down the field lines at a velocity of about 10 km/s. This particular speed raises the interesting possibility that the source is some form of electrostatic shock in transient motion along the auroral field line.

CONCLUSIONS

The above is merely a quick skim through some of the early measurements. Even so, it should be extremely stimulating for the magnetospheric physicist that ISEE appears to be on the edge of breakthroughs in a number of areas. Data on the ultimate unknown of the magnetosphere, the geomagnetic storm, are now in the hands of the investigators and presentation of the preliminary analyses of these at the ISEE Workshop to be held next January is eagerly awaited. □

Promotion du Système Météosat

J. Arets, Service des Affaires Internationales, ESA, Paris
C. Honvault, Division Segment-sol et Coordination des Opérations, ESA, Toulouse

L'Europe a consenti un investissement important pour le développement du Système Météosat: environ 185 MUC. Cet investissement a été réalisé pour mettre à la disposition des services météorologiques européens des moyens nouveaux et pour permettre la première expérience du GARP (Programme de Recherche atmosphérique globale: 1er déc 1978 – 1er déc. 1979).

La satisfaction de ces objectifs ne dispense pas pour autant l'Agence spatiale européenne de chercher à valoriser au mieux l'investissement de ses Etats membres en faisant connaître à des Etats tiers les bénéfices qu'ils peuvent retirer de Météosat.

Figure 1 – Station SDUS installée au Centre Météorologique du Caire.

Parmi les arguments en faveur d'une utilisation maximale de Météosat, on peut en citer plusieurs qui sont de nature très différente:

(a) Le programme Météosat se situe dans le cadre de la Veille Météorologique Mondiale organisée par l'OMM. Les météorologues ne sont pas intéressés par les données relatives à leur seul pays. Par exemple, l'installation de plates-formes de collecte de données en Afrique présente à la fois un intérêt particulier pour les pays africains et un intérêt général pour le développement de la météorologie sur le plan mondial.

(b) La plupart des services météorologiques africains disposent d'équipements rudimentaires et l'acquisition de données Météosat, à peu de frais, pourrait constituer une amélioration sensible de la quantité et de la qualité de données dont ils disposent.

(c) Météosat déborde le cadre strictement météorologique et intéresse également les milieux qui s'occupent de télédétection. A cet égard, on peut mentionner l'intérêt déjà manifesté, entre autres, par la FAO et par le Conseil Régional Africain pour la Télédétection.

(d) Les contacts que l'Agence établit avec des pays africains à l'occasion de la promotion Météosat devraient l'aider à définir et à assurer le meilleur usage de son programme futur de satellites de télédétection dont une des missions essentielles sera orientée vers les pays en voie de développement.

(e) L'Europe, en assurant une bonne utilisation de Météosat, apportera aux pays d'Afrique une aide dont le coût sera largement inférieur à la valeur des services rendus, en raison de la disponibilité du ou des satellites. L'action dans ce domaine sera coordonnée avec les organisations d'aide au développement et en particulier avec la Commission des Communautés Européennes (Fonds Européen de Développement).

(f) Enfin l'intérêt pour l'industrie européenne de fournir des équipements de réception mérite d'être mentionné. Il faut noter, toutefois, que ce marché ne représente pas un chiffre d'affaires considérable pour l'industrie et que les firmes européennes ne sont pas assurées d'en avoir le monopole.

HISTORIQUE

Les premières idées de promotion ont germé en 1975. En dehors des Etats membres participant au programme et de

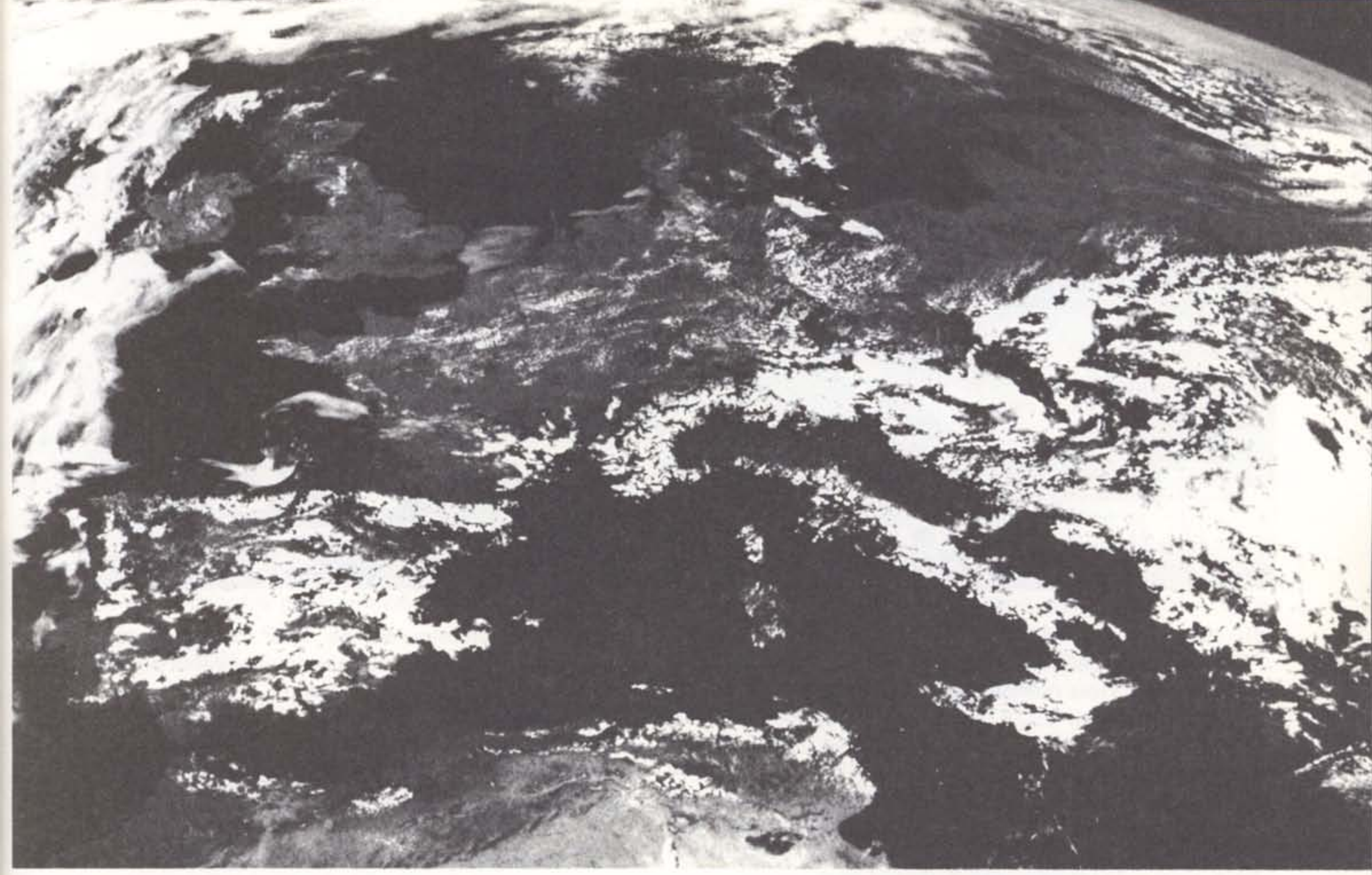


Figure 2 – Image de Météosat reçues par la station PDUS de Telespazio.

leurs services météorologiques, le Système Météosat était pratiquement inconnu, alors que des missions telles que la dissémination – en particulier des images sous forme analogique (WEFAX) – et la collecte de données apparaissent comme utiles et intéressantes en dehors de l'Europe. La convention établie au début de 1976 entre l'ESA et EUROSAT 'pour confier à cette Société un rôle de promotion des systèmes en cours de développement au sein de l'Agence' a permis de matérialiser les premières idées sous forme de deux contrats confiés à EUROSAT, visant à établir le 'marché potentiel' des deux missions mentionnées ci-dessus. De façon à formuler un plan d'action global couvrant tous les aspects possibles de la promotion, un groupe de travail inter-Directions a été créé début 1977 et a remis ses conclusions au Directeur général en juin 1977. C'est ainsi qu'un 'Groupe de Promotion Météosat' a vu le jour et dont les travaux sont brièvement présentés ci-dessous.

ACTIVITES DE PROMOTION

Trois domaines ont été identifiés: l'information, la démonstration et l'expérimentation.

INFORMATION

Dès 1975, un document de présentation générale du Système Météosat a été envoyé à la plupart des pays de la zone de couverture du satellite, leur suggérant de prendre contact avec l'Agence pour plus amples renseignements. Comme suite aux réponses obtenues, des missions de contact ont eu lieu, fin 1976, pour d'une part fournir des informations complémentaires, et d'autre part évaluer le marché potentiel. Les intentions des Etats de la zone de couverture en matière d'équipement de réception de Météosat se sont manifestés comme suit:

- pour les stations secondaires d'utilisation de données (SDUS): environ 20 stations nouvelles et 10 adaptations à des stations APT existantes;
- pour les stations primaires d'utilisation de données (PDUS): deux stations;
- pour les plates-formes de collecte de données (DCP): environ 130 plates-formes.

Il est apparu nécessaire de renforcer l'action d'information vis-à-vis des pays de la zone de couverture et à cette fin il a été décidé:

(a) de publier un 'Journal Météosat' qui informe des progrès dans le développement et l'utilisation du système. Trois numéros ont déjà paru en mai 1977, janvier et mai 1978. En phase de routine, il sera publié au rythme de 3 ou 4 numéros par an et envoyé à environ 2000 destinataires.

(b) de constituer un ensemble de documents descriptifs des différents moyens. Cette documentation est diffusée en anglais et en français:
- description sommaire du Système Météosat
- guide des utilisateurs du Système Météosat
- brochure descriptive de la Mission dissémination à haute résolution, incluant les spécifications de la PDUS
- brochure descriptive de la Mission dissémination WEFAX, incluant les spécifications de la SDUS
- guide d'utilisation des DCP incluant les spécifications des DCP
- brochure 'Stations et Equipements pour l'utilisation de Météosat – Coûts indicatifs et Fabricants' (en Europe).

DEMONSTRATION

L'information, telle qu'elle est réalisée, est une démarche essentielle mais qui n'est suffisante en général que pour les pays familiers avec les activités de météorologie spatiale. Dans la majorité des cas, il y a lieu de la prolonger par une action en profondeur, à savoir la conduite de démonstrations en vraie grandeur, avec les prototypes de stations (primaires et secondaires) et de plates-formes de collecte de données. En effet, ces moyens ont été conçus de façon à être transportables à des degrés divers. Il est bien évident qu'une démonstration de stations primaires est beaucoup plus lourde sur le plan logistique, donc financièrement plus coûteuse, qu'une démonstration de station secondaire ou de DCP. Dans la mesure du possible, comme il n'est pas envisageable de visiter tous les pays de la zone de couverture, on recherche en liaison avec l'OMM, l'ONU et d'autres instances internationales la possibilité de toucher le maximum d'organismes intéressés, à l'occasion de conférences, colloques, réunions d'associations régionales de l'OMM, etc.

A Nairobi (Kenya) en février 1978 où se tenait la réunion de l'Association Régionale I de l'OMM, regroupant tous les pays africains membres de l'OMM, c'était l'occasion de démontrer les possibilités du Système Météosat auprès de délégations de météorologues d'une quarantaine de pays africains. En plus d'une présentation orale, les équipements de la SDUS prototype, transportés par avion, ont été installés au Kenyatta Center, lieu de la conférence, et ont fonctionné pendant quatre jours de façon satisfaisante.

En mai-juin 1978, la station intégrée dans son conteneur a effectué une tournée en Egypte (Le Caire), en Grèce (Athènes) et en Tunisie (Tunis). Dans chaque pays, une présentation générale des activités de l'Agence et du Système Météosat est organisée devant un auditoire composé non seulement de météorologues, mais aussi d'autres utilisateurs potentiels du Système et de représentants d'organismes gouvernementaux. Sur chaque site la station est installée pendant quelques jours et reçoit les données qui sont remises aux bureaux météorologiques locaux et commentés par un spécialiste européen participant à la présentation.

Il est envisagé d'effectuer une seconde tournée en septembre-octobre 1978 pour prendre avantage de la première réunion du Conseil Régional Africain de Télédétection à Ouagadougou (Haute Volta) du 25 au 29 septembre. Cette tournée engloberait la Côte d'Ivoire, la

Figure 3 – Station SDUS installée au Centre Météorologique d'Athènes.

Haute Volta, le Ghana, le Maroc et l'Espagne (qui ne participe pas au programme Météosat).

Quant à la PDUS, il est prévu de l'installer à Rome début octobre (à l'occasion des cours sur les 'Applications des satellites météorologiques et de télédétection à l'agro-météorologie' organisés conjointement par la FAO, l'OMM et l'Agence) et à Prague du 17 au 25 octobre pour la réunion de l'Association Régionale VI de l'OMM qui regroupe l'ensemble des pays européens.

EXPERIMENTATION

A un stade plus avancé, l'expérimentation laisse du matériel à la disposition du client intéressé pour qu'il en use à sa guise. Dans le cas des DCP où le marché potentiel est important, et où la conviction s'acquiert principalement par la constatation des avantages opérationnels, une procédure d'expérimentation est d'un très grand intérêt. Deux campagnes de ce type ont eu lieu:

La première, d'avril à juin 1978, a consisté à installer une DCP de série, construite par Dornier, associée à un dispositif de stabilisation d'antenne, sur un navire français. L'expérience a été conduite par la Direction de la Météorologie Nationale française avec les objectifs suivants:
- adéquation de la DCP aux besoins
- utilité du dispositif de stabilisation.

Les résultats de cette campagne sont en cours d'analyse.

Une seconde campagne expérimentale est prévue d'octobre 1978 à mai 1979 sur le navire RSS Bransfield du British Antarctic Survey. Cette campagne permettra de tester les limites géographiques de la couverture de la Mission de collecte des données.

D'autre part, une DCP a été prêtée à l'ORSTOM (Office de la Recherche Scientifique et Technique d'Outre-Mer) en France, pour une expérience de collecte de données à partir du Sénégal.

Des expérimentations utilisant les prototypes PDUS et SDUS, de durée variable (entre un et trois mois), sont prévues en 1979 en France et en Allemagne. Indépendamment de ces expérimentations relatives aux Missions 2 et 3 de Météosat, l'Exécutif de l'Agence a confié des études de promotion à EUROSAT pour étudier l'utilisation des images Météosat dans les bulletins télévisés. Le problème fondamental est la réception en temps quasi réel des images Météosat au centre de diffusion TV, donc la transmission entre l'ESOC (Darmstadt) ou tout autre centre national suffisamment équipé, et ce centre de diffusion. Pour l'instant la seule expérimentation réalisée a consisté à fournir au réseau Eurovision, par l'intermédiaire d'une chaîne de télévision allemande, des films d'animation réalisés à partir d'images Météosat sur une période d'une journée et remis soit sous forme de films, soit sous forme de cassettes video.

Une étude similaire sur l'utilisation des images Météosat par la presse européenne est en cours et l'Agence a déjà servi de catalyseur entre le Centre de Météorologie Spatiale de Lannion (France) et le journal 'Le Matin', qui a diffusé quotidiennement une image de la couverture nuageuse au-dessus de la France pendant les mois d'été.

Enfin des études sont en cours avec l'OMM, la Commission des Communautés Européennes, sur la possibilité d'accroître les moyens de lutte contre la sécheresse au Sahel grâce à l'implantation de plates-formes de collecte de données dans cette région particulièrement éprouvée par les conditions climatiques. Une connaissance plus détaillée des différents éléments qui conditionnent le temps dans cette région permettrait de lutter plus efficacement contre le fléau de la sécheresse.

CONCLUSION

L'Agence, en entreprenant cette action de promotion, a conscience de dépasser quelque peu les limites d'une activité strictement technique. Elle y est encouragée par ses Etats membres qui lui ont reconnu un rôle à jouer dans la promotion de l'activité spatiale européenne. Elle est aussi consciente de l'impact limité mais réel que ses activités et ses moyens peuvent avoir sur le développement de la coopération internationale et sur la construction de l'Europe. Elle s'efforcera, avec des moyens modestes, de poursuivre cette activité dans l'intérêt de tous et espère développer celle-ci en étroite collaboration avec ses Etats membres et les autres organisations européennes. □

Le Programme de Systèmes et de Technologies de Pointe (ASTP)

P. Imbert, Département Technologie, Industrie & Infrastructure, ESA, Paris

Vers la fin des années 60, lorsqu'il fut proposé d'étendre les activités du CERS/ESRO – jusqu'alors plutôt orientées vers la recherche scientifique au moyen de satellites et de fusées-sondes – au domaine des programmes spatiaux d'application, le secteur des télécommunications vint au premier plan. C'est ainsi qu'il fut décidé d'entreprendre un programme de satellites de télécommunications européens qui, dans une première étape, devait comporter le développement d'un satellite à caractère essentiellement expérimental avant d'aborder la réalisation de satellites à caractère plus opérationnel. Tenant compte des travaux en cours conduits en Europe dans ce même domaine, au plan national ou plurinational, avec les projets Sirio et Symphonie, il apparut qu'il était à la fois possible et souhaitable de donner à ce projet de satellite expérimental des objectifs techniques de niveau très élevé; ceci devait permettre à l'Europe de démontrer ainsi sa capacité dans ce domaine et de rattraper le retard technique éventuel qui pouvait exister vis-à-vis des Etats-Unis. C'est ainsi que l'on décida notamment que ce satellite travaillerait dans la bande des fréquences GHz inutilisée jusqu'alors pour les télécommunications spatiales, qu'il serait stabilisé suivant les trois axes et comporterait des réseaux solaires orientables. Toutefois pour être en mesure de réaliser dans des temps raisonnables et avec des risques techniques acceptables ce satellite expérimental (désigné sous le nom d'OTS), on estima qu'il était nécessaire d'entreprendre rapidement un *programme de technologie de soutien*. Ce programme, connu sous le nom de STP (Supporting Technology Programme), fut défini en tenant compte bien sûr des développements technologiques déjà effectués en Europe, notamment dans le cadre des projets nationaux précités, et planifié pour répondre non seulement aux exigences technologiques du projet OTS mais aussi à celles estimées des satellites opérationnels qui devaient suivre (première génération des satellites ECS).

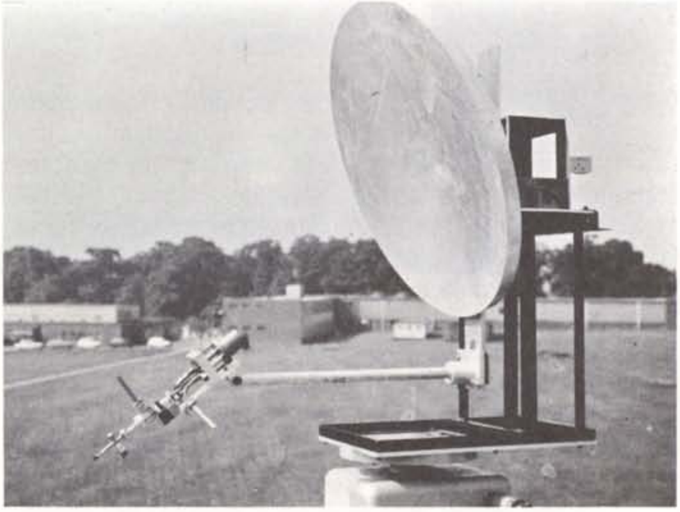


Figure 1 – Antenne multifaisceau à grand gain en ondes millimétriques (30 GHz).

Le programme de technologie de soutien (STP), conduit dans le cadre des phases 1 et 2 du programme d'ensemble de satellites de télécommunications de l'Agence, est maintenant achevé et peut être considéré comme une réussite technique (Voir Bulletin ESA no. 14, en particulier pp. 33-39). En effet de nombreuses technologies, qui ont été mises au point et qualifiées dans le cadre de ce programme, ont non seulement permis de réaliser le satellite OTS dont on connaît le succès en vol, mais seront également reprises dans les différents projets de satellites qui constituent le programme actuel de télécommunications de l'Agence, à savoir les satellites ECS-1 et 2, les satellites Marots-A et B et le projet H-Sat. On doit également signaler, fait assez rare pour la technologie spatiale européenne, l'exportation d'équipements et composants développés dans le cadre STP (TOP pour Anik, SBS et Intelsat-V, antennes pour Intelsat-V). Sur la base de cette réussite, il est apparu hautement souhaitable dans le cadre de la phase 3 du programme de télécommunications de l'Agence de poursuivre l'effort entrepris avec ce premier STP. C'est ainsi qu'a été introduit dans ce programme d'ensemble, conjointement avec les trois projets de satellites précités, un nouveau *programme de systèmes et de technologies de pointe*, intitulé couramment ASTP (Advanced Systems and Technology Programme). Toutefois, par comparaison avec la période de

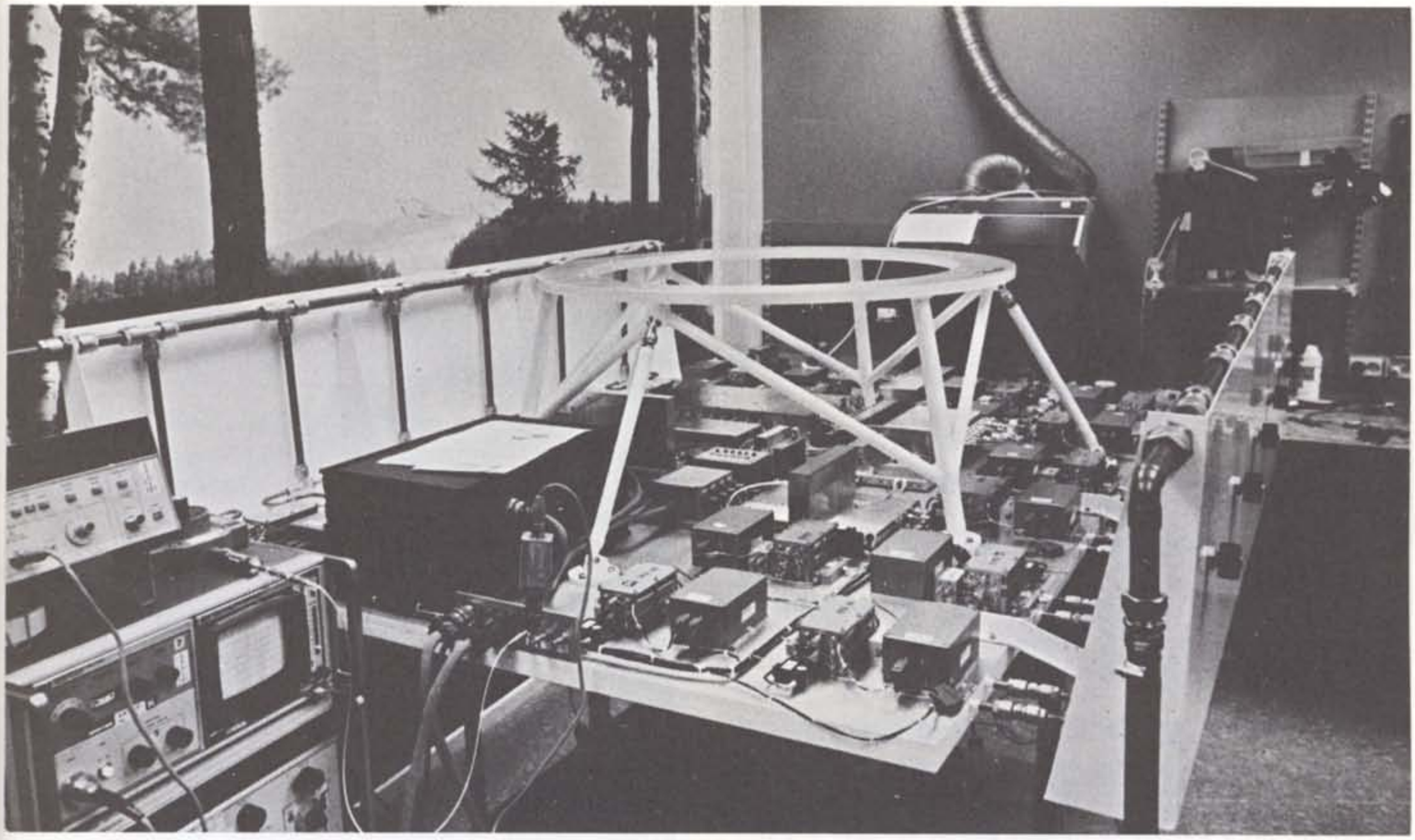


Figure 2 – Maquette électrique d'un répéteur pour antenne à balayage électronique destiné aux satellites de télécommunications de service mobile (maritime, aéronautique, terrestre).

démarrage du premier STP, la situation a sensiblement évolué tant sur le plan de la politique spatiale que sur celui des exigences techniques. C'est pourquoi ce nouveau programme ASTP présente des caractéristiques notablement différentes de celles du premier STP, caractéristiques qui sont décrites succinctement dans ce qui suit.

OBJECTIFS DU PROGRAMME ASTP

Par comparaison avec le premier STP qui visait essentiellement à soutenir sur le plan technique et technologique la réalisation de projets bien définis (OTS, puis ECS), on peut noter que les objectifs recherchés avec l'ASTP recouvrent un domaine plus vaste puisqu'ils portent à la fois sur le court et le moyen terme avec une prépondérance accordée à ce dernier aspect. En effet les objectifs généraux du programme ASTP peuvent être résumés de la façon suivante:

- *Préparer la modernisation ultérieure des systèmes à satellites* en cours de développement (système de télécommunications point à point, système pour le service maritime, système de diffusion de télévision) en maintenant l'état des connaissances européennes au niveau des progrès généraux accomplis tant en matière de configuration des systèmes qu'en matière de technologies proprement dites.

- *Préparer la réalisation de nouvelles missions* dans des domaines tels que la transmission de données entre des terminaux sol de taille moyenne, les communications avec d'autres mobiles que les bateaux, les transmissions directes de satellite à satellite, de nouveaux services publics de type courrier ou documentation électronique, etc., ainsi que l'évolution des télécommunications spatiales vers des fréquences plus élevés (notamment 20/30 GHz). Pour cela il sera nécessaire d'entreprendre des études de configuration approfondies et dans de nombreux cas la réalisation d'équipements nouveaux.

- *Etablir les conditions qui permettront à l'industrie européenne* d'aborder avec une certaine chance de succès le marché des télécommunications spatiales en dehors de l'Europe (marché à l'exportation). Pour ce faire il faudra étudier, préparer et financer un certain nombre d'activités techniques qui seront sélectionnées pour répondre aux besoins les plus probables en termes de marché dans le domaine des satellites de télécommunications sur le plan mondial.

- *Permettre l'introduction progressive de certaines* *améliorations technologiques* dans les modèles de vol ultérieurs de satellites qui seront réalisés dans le cadre des projets ECS, Marots et H-Sat.

ASPECTS PARTICULIERS DE L'ASTP

Pour répondre aux objectifs et orientations présentés ci-dessus, des activités de natures différentes doivent être entreprises dans le cadre de l'ASTP. Si l'on tient compte de leur nature, ces activités peuvent être réparties en trois grandes catégories définies comme suit:

(i) analyse et conception de *systèmes* de télécommunications et des configurations correspondantes de véhicules spatiaux, une partie appréciable des activités de cette catégorie devant porter sur des expérimentations relatives aux télécommunications par satellites (essais de propagation et de transmission);

(ii) développement de la technologie et des équipements de télécommunications destinés aux *charges utiles* des satellites et aux stations terriennes;

(iii) développement de la technologie et des équipements pour les *sous-systèmes de véhicules spatiaux*.

ETUDES DE SYSTEMES ET R&D

On peut ainsi constater que le programme ASTP couvre à la fois les aspects systèmes, charges utiles et véhicules spatiaux. Ces trois aspects ne sont évidemment pas indépendants les uns des autres, et le fait de les traiter au sein d'un même programme devrait permettre d'assurer une très bonne corrélation entre les travaux menés dans les différents secteurs et même de réorienter certaines activités d'un secteur en fonction des résultats acquis dans d'autres secteurs. Cette relation étroite qui existera entre les études de systèmes et les recherches et développements technologiques est certainement une caractéristique importante de l'ASTP qu'il convient de souligner ici; mais on doit aussi noter que cette dépendance entre les différentes activités impliquera une certaine évolution du contenu du programme, contenu qui ne doit donc pas être considéré comme figé dans sa définition actuelle.

ASTP ET RT DE BASE

Un autre aspect intéressant de l'ASTP mérite d'être abordé brièvement ici; c'est la relation qui peut exister entre ce programme et le programme de recherche technologique (RT) de base de l'Agence. Ce dernier a déjà fait l'objet de présentations dans d'autres numéros de ce Bulletin (notamment dans les numéros 10 d'août 1977 et 12 de février 1978) et nous ne rappelerons ici que les principaux points qui permettent de faire une distinction entre la RT de base et l'ASTP. Il convient de remarquer d'abord une certaine différence entre les domaines généraux couverts par ces deux programmes. Alors que l'ASTP est centré sur le domaine des télécommunications, la RT de base couvre l'ensemble des technologies nécessaires aux différentes catégories de projets (Science, Observation de la Terre et également Télécommunications), mais en mettant surtout l'accent sur les technologies communes. Par ailleurs, comme cela a déjà été souligné précédemment, une partie de l'ASTP porte sur des études de systèmes et de configurations, alors que ce type d'activité n'est pas inclus dans la RT de base, beaucoup plus orientée sur les aspects technologiques. On notera également que la RT de base, tout en cherchant à satisfaire les besoins en matière de recherche technologique des projets à moyen terme, prend aussi en compte le futur plus lointain sous la forme de recherches exploratoires et d'études prospectives sur les applications de techniques très avancées. Les objectifs de l'ASTP sont eux limités au court et au moyen terme (modernisation des systèmes actuels et préparation de nouvelles missions) et ne se recoupent que très partiellement avec ceux de la RT dans un domaine limité aux applications des télécommunications. Rappelons enfin un objectif particulier de l'ASTP qui n'est pas pris en compte dans l'orientation actuelle de la RT de base, à savoir la promotion du marché à l'exportation dans le domaine des télécommunications spatiales. Il ressort de cette analyse succincte que les domaines de la technologie qui relèvent à la fois de l'ASTP et de la RT sont en nombre limité. Dans ces domaines conjoints, les deux programmes jouent un rôle différent: alors que les études de faisabilité et les premiers développements sont conduits dans le cadre de la RT de base, l'ASTP doit assurer le relais des travaux en orientant les développements et en assurant leur qualification en vue d'applications spécifiques aux satellites de télécommunications.

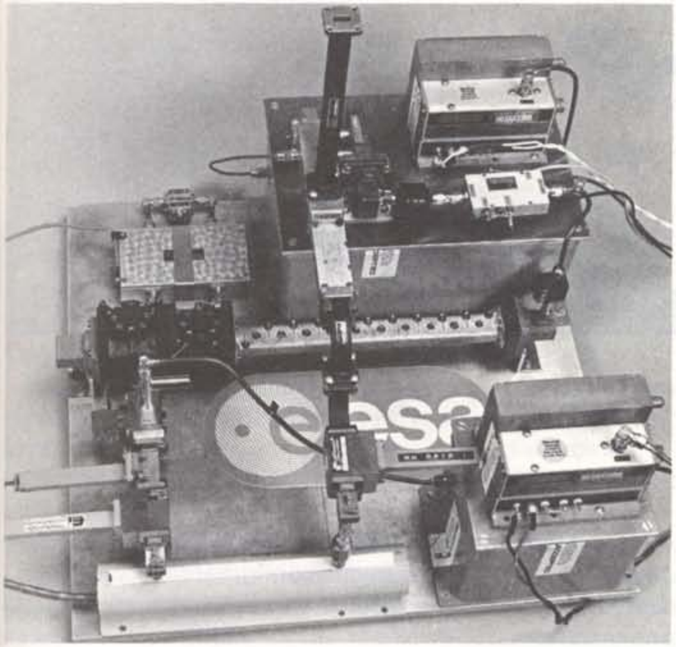


Figure 3 – Modèle de laboratoire d'un répéteur de 30/20 GHz pour satellites de télécommunications.

ASTP: PROGRAMME OPTIONNEL

Un troisième aspect particulier de l'ASTP réside dans le fait qu'il s'agit d'un programme optionnel d'un type nouveau conduit dans le cadre des activités de l'Agence. En effet, pour tenir compte des positions variées des différents Etats membres, qui participent déjà partiellement ou totalement à l'ensemble du programme de télécommunications, vis-à-vis de l'opportunité d'un programme ASTP et de l'ampleur qu'il convient de lui donner, l'Exécutif a été conduit à proposer une formule optionnelle permettant à chaque Etat membre d'adhérer à ce programme en définissant son niveau de participation. La formule qui a ainsi été adoptée est basée sur le fait que les contributions d'un Etat membre doivent servir à financer les travaux qui seront exécutés sur son territoire, les orientations techniques de ces travaux devant être établies en accord avec l'Etat membre considéré. C'est une formule souple qui a l'avantage de laisser une assez grande liberté de choix aux Etats membres, compte tenu de leurs disponibilités financières et de leur potentiel industriel, mais qui doit aussi être appliquée en tenant compte d'autres contraintes exposées plus loin.

MISE EN OEUVRE DE L'ASTP

Vu les caractéristiques particulières de l'ASTP, l'Exécutif a été conduit à proposer aux Etats participant au programme d'adopter un règlement d'exécution spécifique. Ce règlement définit les rôles et obligations respectifs des Etats participants et de l'Agence en ce qui concerne la définition, l'exécution et l'exploitation des résultats de l'ASTP. Sans entrer dans les détails, nous pouvons indiquer ici quelques points qui nous semblent essentiels:

- l'ASTP est un programme de l'Agence et à ce titre il doit être exécuté conformément aux règles en vigueur dans la mesure où des dérogations n'ont pas été prévues dans son règlement d'exécution;

- c'est un programme entrepris pour une période initiale de quatre ans, mais cette période pourra être prolongée si les participants en décident ainsi;

- les Etats qui adhèrent à ce programme (les 'participants') en assurent le financement intégral. Pour ce faire ils s'engagent sur un niveau de contribution globale pour la période de quatre ans, et le programme est exécuté sur la base de budgets annuels;

- la contribution de chaque participant sert à financer les travaux exécutés sur son territoire (ce qui correspond à un coefficient de retour géographique de un) mais couvre également une part des frais internes de l'Agence relatifs à la définition et à la gestion de ces travaux;

- les participants approuvent le plan d'ensemble et le plan annuel des travaux et suivent l'exécution du programme. Ils sont seuls habilités à voter dans le cadre des organes délibérants de l'Agence sur les questions concernant ce programme;

- l'Agence est chargée, en liaison avec les Etats participants, d'orienter les objectifs du programme pour prendre en compte les points de vue des utilisateurs potentiels des futurs systèmes, de définir

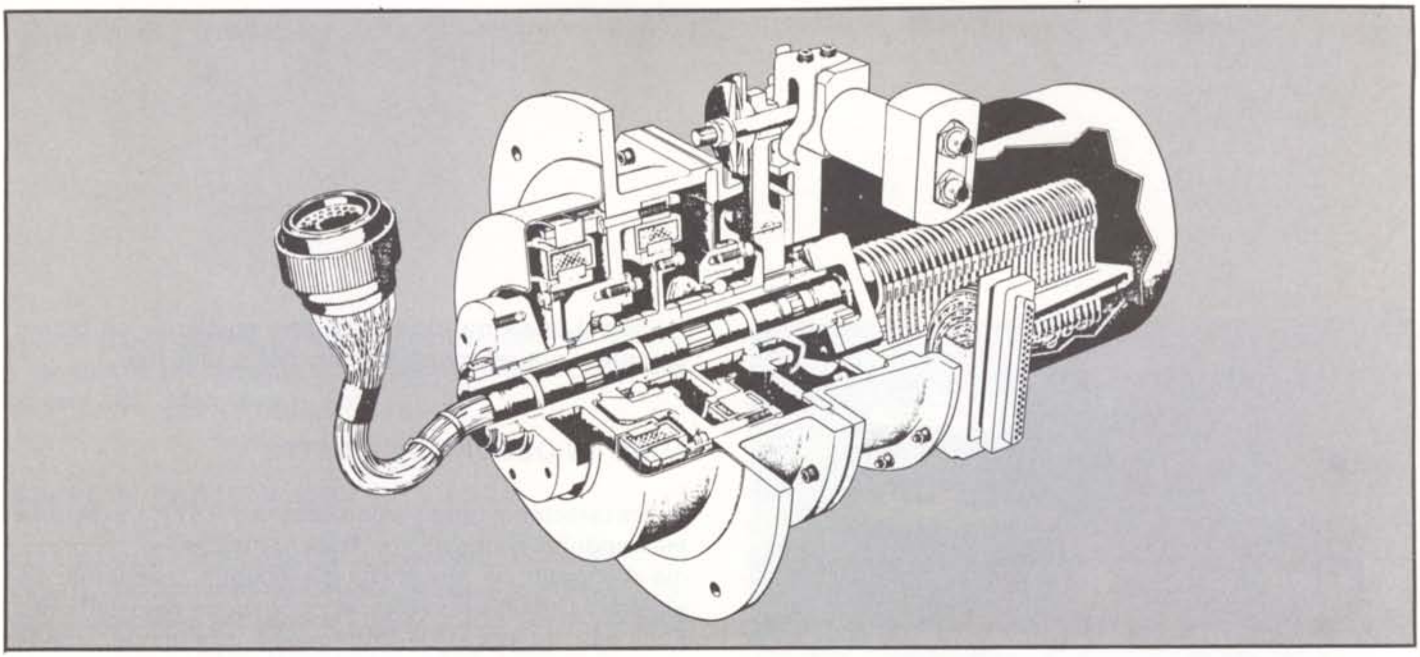


Figure 4 – Mécanisme d'orientation de réseau solaire et de transfert de puissance.

le contenu et de procéder à l'exécution de l'ASTP;

- pour ces deux derniers aspects: définition des activités à entreprendre et exécution de celles-ci, l'Agence veille à harmoniser et à coordonner les travaux de l'ASTP avec ses activités de recherche technologique de base ainsi qu'avec les activités pertinentes conduites au plan national. Elle suit une politique industrielle cohérente eu égard aux diverses spécialisations industrielles acquises au cours du développement de l'actuelle génération de plates-formes et de charges utiles de télécommunications;

- les droits de propriété intellectuelle et l'accès aux informations découlant de l'exécution du programme sont réservés aux participants mais l'Agence a le droit de les utiliser gratuitement pour l'ensemble de ses activités;

- l'Agence devra s'efforcer, au mieux de ses possibilités, d'utiliser la technologie acquise dans le cadre de l'ASTP pour ses programmes futurs.

CONTENU TECHNIQUE DE L'ASTP

Une description détaillée du contenu du programme qui a été ainsi établi déborderait du cadre de cet article. Nous limiterons donc cette présentation en indiquant seulement quels ont été les grands axes techniques qui ont été suivis pour sélectionner les activités à inscrire dans l'ASTP.

SYSTEMES ET CONFIGURATIONS

Au niveau de l'analyse et de la conception des systèmes de télécommunications et des configurations correspondantes de véhicules spatiaux, l'accent a été mis sur les points suivants:

- l'utilisation future de fréquences plus élevées pour les transmissions (bande des 20/30 GHz) et son impact sur les possibilités des systèmes de télécommunications par satellites;

- l'amélioration des transmissions par l'utilisation de nouvelles techniques (par exemple la propagation en diversité);

- la recherche d'une simplification des systèmes de télécommunications par satellites tant au niveau du segment spatial que du segment sol pour en faciliter la vente à l'exportation (réduction des coûts de production et d'opérations, amélioration de la fiabilité);

- la définition des systèmes opérationnels de satellites de radiodiffusion de télévision en tenant compte notamment des plans d'allocation de fréquences et de positions orbitales de la Conférence administrative mondiale des Radiocommunications (WARC);

- la définition de la deuxième génération de systèmes de télécommunications par satellites pour le service mobile, qui pourraient prendre le relais du système Marisat actuel;

– la recherche de nouveaux champs d'application des télécommunications spatiales (par exemple la transmission de données à large bande).

CHARGES UTILES

Dans le domaine de la technologie et des équipements de télécommunications destinés aux charges utiles des satellites, les activités prévues dans le cadre de l'ASTP porteront principalement sur les points suivants:

La préparation des *nouveaux systèmes de télécommunications* par satellites sera centrée sur le développement de répéteurs à hautes performances fonctionnant dans la bande GHz et sur le développement d'antennes à réflecteur de haute précision et de grandes dimensions en utilisant de nouvelles technologies pour les structures. La disponibilité de larges bandes de fréquences allouées et l'emploi de faisceaux étroits multiples permettront de développer des systèmes à très grande capacité qui devraient être intéressants même pour des réseaux domestiques. L'utilisation de répéteurs à régénération de signal et la technique de la commutation interurbaine effectuée à bord des satellites augmenteront notablement les bilans de liaison et les possibilités d'interconnexion entre faisceaux et répéteurs en grand nombre. On envisage de développer à cet effet des circuits digitaux à grande vitesse et des processeurs.

Pour les missions de *télécommunications du service mobile*, suite aux études de système et de marché qui seront effectuées pour définir la deuxième génération mentionnée plus haut, on entreprendra la réalisation d'équipements pour des charges utiles de type avancé en faisant appel à la technique des réseaux à éléments en phase.

Pour les *antennes à moyen gain* (Eurobeam) et à *grand gain* destinées aux missions de type ECS et à la diffusion de programmes de télévision par satellite, on cherchera à améliorer les performances en gain et en pureté de polarisation en s'orientant vers des solutions nouvelles telles que la configuration à source excentrée, et en utilisant des moyens d'analyse plus élaborés.

On entreprendra également, sur la base de technologies d'avant-garde, des travaux de développement dans le domaine des filtres et autres circuits de sortie, ainsi que dans le secteur des équipements qui assurent les *interfaces électrique et thermique* entre la charge utile et le véhicule spatial (par exemple les alimentations à très haute tension, l'utilisation de caloducs dans les amplificateurs de puissance à tubes et à semiconducteurs).

En vue du marché à l'exportation, des travaux préparatoires seront effectués sur les *sous-systèmes de télémesure et de télécommande* fonctionnant en bande C et dans des normes différentes de celles de l'ESA.

En matière de technologie d'avant-garde, l'effort sera poursuivi pour qualifier et introduire dans les équipements de charge utile de *nouveaux composants* tels que les circuits hybrides en couche épaisse ou en couche mince, les microprocesseurs, ce qui devrait contribuer à l'amélioration de la compétitivité de l'industrie européenne sur les plans technique et commercial;

On notera que dans les activités décrites ci-dessus deux secteurs importants qui représentent une partie essentielle des charges utiles de télécommunications à hautes performances ne sont pas couverts: il s'agit des antennes à très grand réflecteur de type déployable et des amplificateurs haute puissance en hyperfréquences (tubes à onde progressive). En fait, dans ces deux secteurs, des travaux de développement importants ont déjà été entrepris en Allemagne et en France, et l'on a bon espoir que ces activités pourront être harmonisées pour répondre aux exigences établies par l'Agence.

SOUS-SYSTEMES DE VEHICULES SPATIAUX

En ce qui concerne la technologie et les équipements pour les sous-systèmes de véhicules spatiaux, compte tenu des travaux importants qui ont déjà été entrepris dans le cadre des programmes de recherche technologique de base, l'ASTP a été orienté vers deux objectifs principaux, à savoir la réalisation d'équipements qui répondent à des besoins spécifiques des satellites de télécommunications et, pour les équipements plus classiques, la recherche d'une réduction des coûts. Sur ce dernier point, il convient de noter qu'il s'agit de réduire le coût au niveau du système global et que l'une des méthodes suivies consiste à améliorer les performances des équipements et sous-systèmes afin d'augmenter les marges disponibles lors de la conception des satellites et de rendre ainsi cette dernière plus sûre et plus économique. Les travaux prévus dans le cadre de l'ASTP porteront notamment sur les sous-systèmes suivants:

Alimentation en énergie électrique: développement des techniques existantes de réseaux solaires en vue d'augmenter la puissance disponible sur les plates-formes ECS et H-Sat, réalisation de convertisseurs et unités auxiliaires compatibles avec une gamme plus étendue d'applications, adaptation d'alimentations pour TOP à de nouvelles applications et aux marchés d'exportation, définition d'une instrumentation destinée à observer les décharges électrostatiques survenant en orbite.

Régulation thermique: mise au point de techniques et de technologies qui augmenteront les marges disponibles lors de la conception des satellites, application de technologies d'avant-garde aux charges utiles de télécommunications.

Commande d'orientation et stabilisation: analyse de méthodes nouvelles pour préparer une recherche de solutions optimales au niveau de l'ensemble du système à satellites, simplification des équipements et réduction de leurs coûts par l'utilisation de technologies d'avant-garde.

Structures et mécanismes: mise au point d'équipements requis par les besoins spécifiques des missions futures (structure de grandes antennes de forme spéciale, mécanismes de déploiement, d'orientation d'antennes, et mécanismes de réseaux solaires etc.).

Traitement de l'information: analyse des tâches à effectuer à bord du satellite et au sol en recherchant une répartition optimale de celles-ci sur le plan économique, application des technologies d'avant-garde au sous-système de traitement des données à bord.

Il convient de noter ici que les tendances techniques présentées ci-dessus sont celles qui ont été retenues pour permettre un démarrage rapide de l'ASTP. Un effort de réflexion est en cours pour élaborer de façon plus approfondie le programme d'ensemble, ce qui pourrait conduire à un élargissement des orientations techniques déjà retenues.

Figure 5 – Senseur infrarouge de précision à deux axes destiné aux satellites géostationnaires stabilisés trois axes.

SITUATION ACTUELLE DU PROGRAMME

L'ASTP est devenu un programme effectif de l'Agence le 7 avril 1978 lorsque les représentants d'un certain nombre d'Etats ont souscrit à une déclaration par laquelle ils décidaient d'entreprendre le programme, en chargeant l'Agence de son exécution. A ce jour, huit Etats ont souscrit à cette déclaration, à savoir l'Autriche, le Danemark, l'Espagne, l'Italie, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse, et un Etat, la Belgique, a manifesté son intention de participer à ce programme. On doit noter ici d'une part que les deux Etats membres qui apportent les plus grosses contributions au budget global de l'Agence, à savoir l'Allemagne et la France, ont décliné l'offre qui leur était faite de participer à ce programme, et d'autre part que l'Autriche qui n'a pour l'instant qu'un statut d'observateur au sein de l'ESA, participe à l'ASTP. Cette situation particulière a posé quelques problèmes à l'Exécutif lors de l'élaboration du contenu du programme, notamment dans la mesure où les industries des deux Etats non participants jouent un rôle essentiel dans les projets de télécommunications en cours de réalisation. C'est ainsi que certains secteurs de la technologie où une compétence quasi exclusive n'existe que dans l'un ou l'autre des deux pays non participants n'ont pu être pris en compte dans l'ASTP; mais il faut souligner que ces cas sont assez rares (par exemple tubes hyperfréquences pour applications spatiales, batteries, grandes structures d'antennes déployables, etc.). Une autre difficulté soulevée par cette situation particulière a porté sur la nécessité de coordonner et d'harmoniser les activités entreprises dans le cadre de l'ASTP avec les travaux pertinents exécutés au plan national, sachant que l'Allemagne et la France conduisent des travaux importants dans les secteurs technologiques intéressants pour les télécommunications spatiales. Sur ce point un compromis a dû être trouvé entre le respect des intérêts des Etats participants qui souhaitent soutenir leur industrie dans les secteurs clés des télécommunications spatiales et la nécessité d'éviter au maximum une duplication des efforts entrepris en Europe.

Lorsque l'Exécutif a connu les intentions des Etats de participer à ce programme et les montants envisagés de leurs contributions, un premier projet de programme, portant essentiellement sur les activités qu'il convenait d'entreprendre rapidement, a été préparé et des discussions ont été menées avec chaque Etat participant pour définir plus précisément les activités à exécuter sur le territoire concerné et se mettre d'accord sur le choix des firmes à qui seraient confiés ces travaux. Dans la conduite de ces discussions, un certain nombre de considérations ont dû être prises en compte; elles portaient principalement sur les points suivants:

- disponibilités financières de l'Etat participant,
- capacité de l'industrie et des organismes de recherche du pays concerné,
- coordination des activités ASTP avec les travaux technologiques entrepris dans le cadre de l'Agence ou sur le plan national,
- nécessité d'éviter dans toute la mesure du possible les duplications au sein de l'ASTP,
- cohérence avec la politique de spécialisation industrielle qui commence à se dégager dans l'exécution des programmes de l'Agence (recherche technologique et projets),
- nécessité d'orienter la constitution de l'ASTP vers un nombre limité d'activités de dimensions suffisamment importantes pour en faciliter la gestion.

Compte tenu de ces contraintes, on peut dire que les discussions avec les différents participants se sont déroulées dans d'excellentes conditions puisque le contenu détaillé du programme ASTP à entreprendre en 1978 a pu être présenté aux participants à la fin de mai 1978 et a alors reçu leur approbation. Si l'on prend en compte les activités qu'il est proposé d'entreprendre en Belgique et en Suède (mais qui n'ont pas encore été approuvées officiellement), le programme ASTP pour 1978 correspond à un niveau de crédits d'engagement pour les contrats à placer dans l'industrie d'environ 4 millions d'unités de compte, chiffre que l'on peut rapprocher du niveau global des contributions qui sont actuellement envisagées pour l'ensemble de l'ASTP et qui s'élève à 13,3 millions d'unités de compte.

REMARQUE FINALE

Dans les lignes précédentes, nous avons essayé de situer l'ASTP dans le cadre des activités de l'Agence, et d'en décrire sommairement les objectifs, le contenu et les modalités d'exécution. Nous aimerions, en terminant cette présentation, souligner un aspect nouveau que ce programme apporte à la politique générale suivie par l'Agence. L'ASTP en effet peut être considéré comme un programme 'à la carte' de recherche technologique dans un domaine particulier. Il permet à chaque Etat qui souhaite y participer de définir non seulement son niveau de contribution mais aussi, en accord avec l'Agence, les objectifs techniques et industriels à satisfaire sur son territoire. Pour la plupart des pays participants, il constitue un substitut à des activités qui auraient pu être conduites au plan national et la tendance serait dans le cas de l'ASTP de ne considérer l'Agence que comme le gérant de programmes nationaux. C'est néanmoins un véritable programme de l'Agence qui doit être conçu et géré comme tel tout en respectant les objectifs visés par chacun des participants.

Cette orientation générale a nécessité l'établissement de modalités nouvelles de gestion d'un programme. Elles ont commencé à être mises en application mais ceci constitue une première expérience pour l'Agence et ce n'est probablement que vers la fin de l'année prochaine que l'on pourra tirer les enseignements de celle-ci et se prononcer sur la validité de la formule. Il reste donc à vérifier que cette innovation sur le plan des procédures est un succès mais l'on peut dès à présent examiner son application éventuelle à d'autres programmes de soutien en matière de recherche et développement technologique. □

Ion Field-Emission Electric Propulsion:
– A Promising Technology for the Spacecraft of the Late 1980s

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ESA began its research programme on Field-Emission Electric-Propulsion (FEEP) in 1972 with a first feasibility study conducted by the Culham Laboratory (UK). Since then, the work sponsored by the Agency has involved several European contractors in addition to the tests carried out at ESTEC. Today, the feasibility of FEEP has been firmly established, the performance parameters are already acceptable, and the original goals of simplicity, flexibility and low cost compared with classical electrical propulsion are still very realistic. The proposal is therefore to pursue development of ion FEEP, with the aim of providing Europe with an advanced space propulsion capability at affordable cost.

In an earlier Bulletin*, we discussed the use of ion electric propulsion (EP) specifically for North-South Station-Keeping (NSSK) for long-life geostationary applications satellites, and we concluded that the mass savings and lifetime increases that it would bring had economic benefits well beyond the costs associated with the development and use of this complex technology. At that time, the so-called 'first-generation' EP technologies being developed in the United Kingdom and in Germany were closest to final development and subsequent qualification for space flight. Since then, the United Kingdom has terminated its EP programme and only the final development and qualification of the radio-frequency ionisation system (RIT 10) pioneered in Germany is still being actively pursued. The Agency is closely associated with this activity through its industrial harmonisation programme. RIT 10 will be given its first test flight on ESA's Heavy Satellite (H-Sat), which thereby becomes the first European spacecraft to carry an ion EP system.

But in addition, the Agency has, since 1972, been exploring a 'second-generation' EP system based on the principle of ion generation by electric fields, or as it is more commonly known, 'FEEP' (Field-Emission Electric Propulsion). The Agency is presently about to request approval from its Industrial Policy Committee (IPC) to pursue a further programme of technological research, the contents of which have already been endorsed by a round-table of experts nominated by the Agency's Delegations.

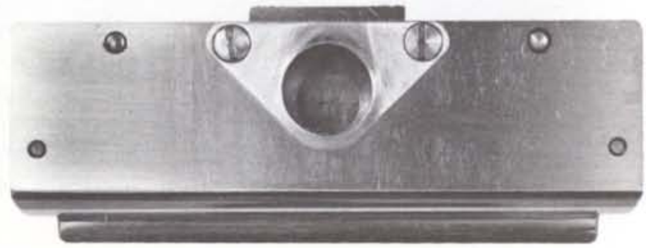


Figure 1 – Elementary FEEP module relying on a linear emitter slit (cf. Fig. 3).

The case for this second-generation EP system is presented here.

TYPES OF PROPULSION

Any space mission depends on propulsion in at least one of its following aspects:
- *launch propulsion*, to place payloads into Earth orbit,
- *space propulsion*, which can be subdivided into three impulse classes:
  - small impulses (such as attitude control)
  - medium impulses (such as station-keeping and modest orbit manoeuvring)
  - large impulses (primary space propulsion).

* ESA Bulletin No. 10, August 1977: 'Electric Propulsion – A Controversial Must for Long-Lived Applications Satellites'.

FUNDAMENTALS OF PROPULSION

THRUST, EXHAUST VELOCITY AND SPECIFIC IMPULSE

The thrust force F (Newtons) produced by a rocket motor is proportional to the mass it ejects per second (propellant flow rate $\mathring{m}$, kg/s) and to the velocity with which this propellant leaves the rocket motor (exhaust velocity v_e, m/s):

$$F = \mathring{m} \cdot v_e$$

The specific impulse I_{sp} (sec) is defined by v_e/g, where g is the gravitational acceleration (9.81 m/s^2). Its advantage is that it is expressed in seconds.

IMPULSE AND VELOCITY INCREMENT

After thrusting for a time T (sec) the amount of propellant ejected is $M_p = \mathring{m} \cdot T$ and the rocket motor has delivered an impulse $I = F \cdot T = M_p \cdot v_e$ (Ns). When M_p is only a small fraction of the total mass M_o of the spacecraft, the spacecraft has undergone a velocity change ΔV (m/s) defined by

$$M_o \cdot \Delta V = M_p \, v_e \text{ or } \Delta V = v_e \frac{M_p}{M_o} = \frac{I}{M_o}$$

When M_p/M_o becomes significant (say above 0.1), the reduction in spacecraft mass during thrusting must be taken into account, and

$$\Delta V = v_e \ln \frac{1}{1 - M_p/M_o}$$

When ΔV or I is large, and if M_p/M_o *is* to remain small, v_e must be correspondingly high. Table 1 shows v_e's required for given ΔV and M_p/M_o pairs.

JET POWER

The kinetic power P (Watts) of the jet is given by

$$P = \frac{1}{2} \mathring{m} v_e^2 = \frac{1}{2} F \cdot v_e$$

Therefore at constant thrust F, more power is required to achieve higher exhaust velocities, but as a result the mass flow needed is reduced.

Of these, only launch propulsion calls for very powerful chemical rockets, to deliver the large thrust needed to lift off from the Earth's surface. Once in Earth orbit, high thrust levels are no longer essential, and many other propulsion concepts are available to meet the various requirements.

When the total impulse required is small, as is the case for the attitude control of satellites and probes, propellant mass is not a constraint, and emphasis can be placed on the use of simple and reliable systems of only modest specific impulse ($I_{sp} = 40 - 100$ s). The European ISEE-B, Cos-B, HEOS, TD-1, UK 4 and 5, D2B and Helios spacecraft could be cited as typical in this context.

For medium-impulse requirements, such as orbit acquisition and control for geostationary satellites, low-thrust monopropellant and bipropellant chemical propulsion systems are used, the propulsive performance of which ($I_{sp} = 220 - 280$ s) is adequate to contain propellant mass within an acceptable 5 – 15% of the satellite's total mass. Typical European examples are Geos, OTS, ECS, H-Sat, Symphonie, Aeros, Sirio, Meteosat and Exosat.

An interesting situation arises when a propulsive requirement is proportional to satellite lifetime, as in the case of NSSK: increases in satellite lifetime then require corresponding increases in the chemical propellant carried, up to very significant fractions of the satellite's total mass

(20 – 25% for a 10-year lifetime). It is here that one of the justifications lies for the search for better performing propulsion systems, to improve the economics of the overall space segment (station-keeping by electric propulsion).

Large-impulse requirements embrace a wide spectrum of applications and needs, including:
- the Apogee Boost Motor (orbit-injection propulsion), which must deliver 1500 – 1800 m/s and represents 50% of the total vehicle mass in transfer orbit when using today's solid- or liquid-propellant motors (OTS, Meteosat, ECS, Symphonie).
- Interplanetary trajectory injection motors, which are called upon to deliver velocity increments from 2 km/s to 20 – 30 km/s (and sometimes even more) for the most demanding missions. Such missions require the most efficient propulsion systems available (high-energy chemical, or electric propulsion).
- Space Tug missions, in which a re-usable propulsion module carries payloads from low to high orbit and back (several km/s). The highest propulsive performance is required to make a Space Tug even worthwhile.

THE HIGH-PERFORMANCE PROPULSION OPTIONS IN THE CONTEXT OF EUROPE'S NEEDS

The greater the impulse required on any given space mission, the greater will be the propellant mass required, and the greater the attention that has to be paid to restricting it by using propulsion concepts of higher performance, since the total mass that can be placed in orbit still remains a severely limiting factor.

Long-term plans for European programmes requiring high-impulse primary space propulsion are not yet well defined, but such missions are bound to materialise sooner or later, with the orbital transfer of large payloads, drag compensation for space stations, interplanetary probes, etc. It is quite certain also that it will be necessary to be able to provide this propulsion at high specific impulses, for reasons of both mission feasibility and overall cost minimisation (increased payloads, reduced launch costs).

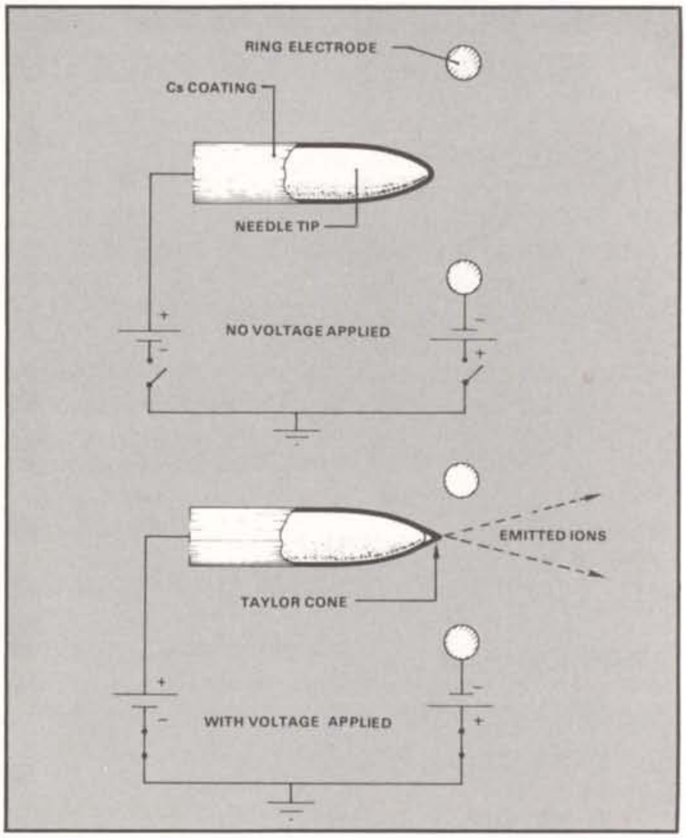


Figure 2 – Basic ion field emitter.

For Europe to have a capability in this area implies finding a technology that:
- is significantly simpler, and thereby cheaper to develop and produce than the present classical technologies, in order to remain commensurate with European financing capabilities
- offers high propulsion performance with high efficiency, and
- is versatile enough to be readily adapted to a wide range of applications/impulse ranges.

If we now review the possible technologies with which large impulses could be delivered at high specific impulse, the various limitations and problems encountered with most concepts will serve to highlight the choice of FEEP as a very promising propulsion option.

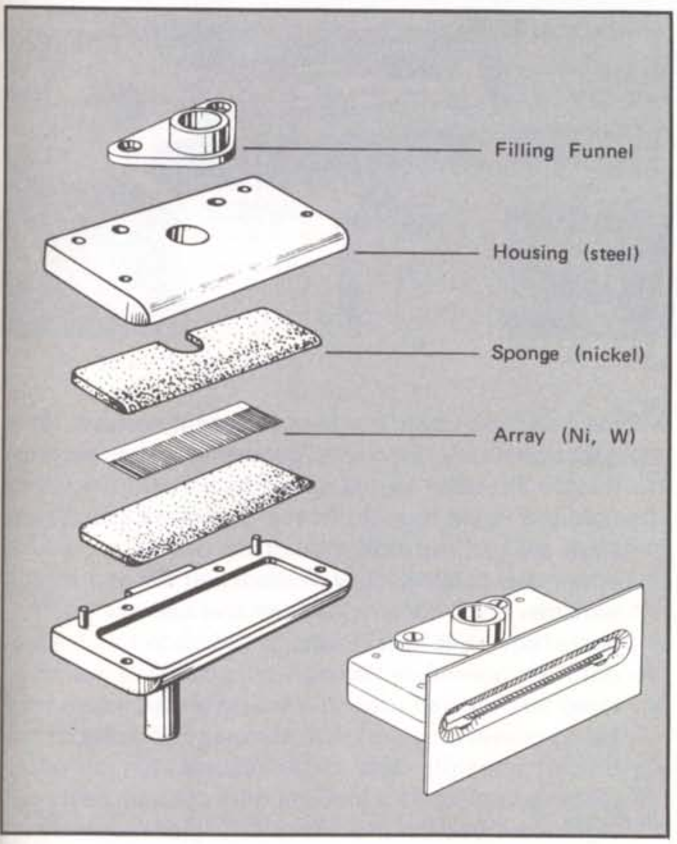


Figure 3 – Exploded view of an elementary FEEP module.

In classical chemical propulsion, the jet power is supplied by the exothermal reaction between the propellants when brought together in a reaction chamber. The reaction generates gases at high pressure and temperature, which are then accelerated by expansion through a nozzle. Their exhaust velocity is limited by the energy released per unit mass of propellants, and the most energetic chemical reactions release energies in the range of $8-25 \times 10^6$ J/kg. A practical high-energy reaction such as $O_2 + H_2$ releases 13.4×10^6 J/kg, which corresponds to a theoretical exhaust velocity of 5200 m/s, the highest practical values being about 4500 m/s. It can be seen from Table 1 that this is not sufficient to execute velocity changes above say 3 km/s with reasonably small propellant mass fractions (say below 0.5).

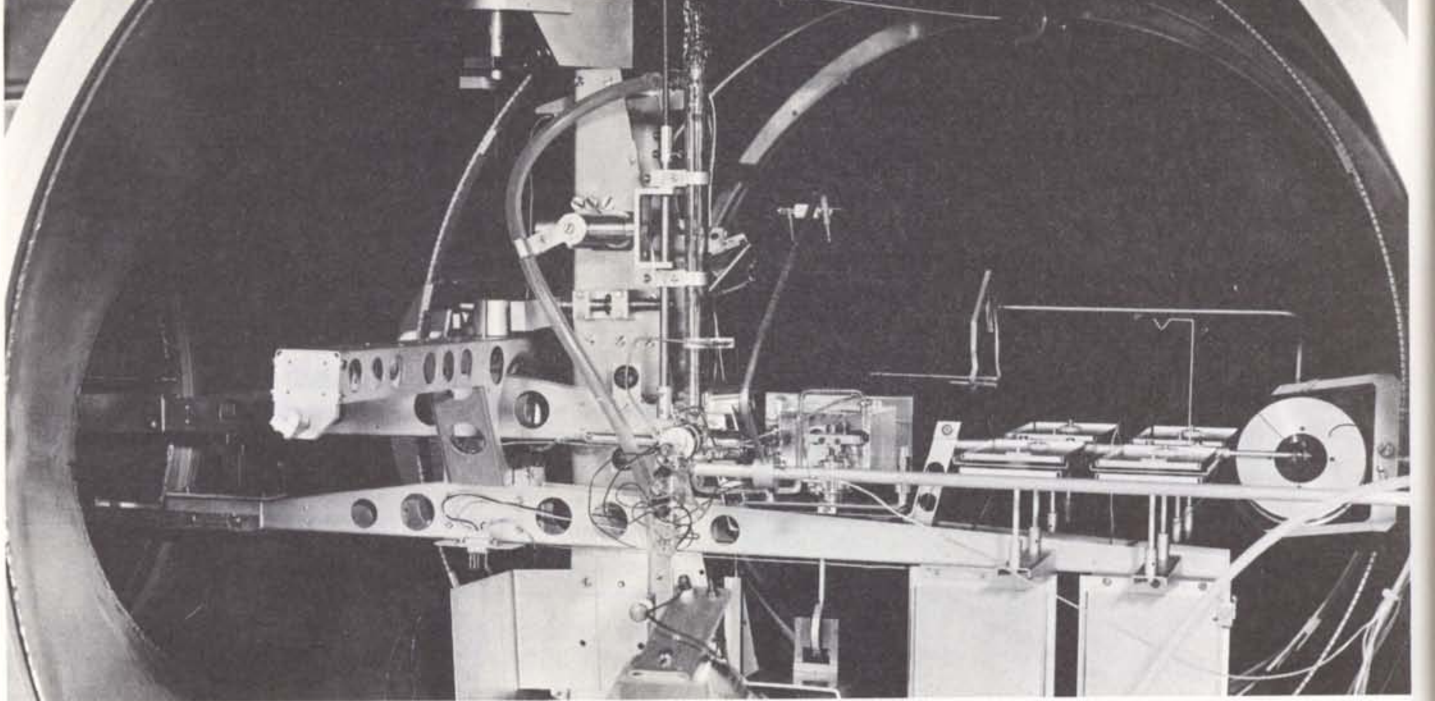
TABLE 1.
Requisite Rocket-Jet Exhaust Velocities v_e for Given Velocity Increments ΔV and Propellant-Mass Fractions

ΔV, km/s	Required v_e, m/s			
	M_p/M_o			
	0.1	0.2	0.5	0.9
1	9 500	4 500	1 450	440
2	19 000	9 000	2 900	880
3	28 500	13 500	4 350	1 320
4	38 000	18 000	5 800	1 760
5	47 500	22 500	7 250	2 200
10	95 000	45 000	14 500	4 400
20	190 000	90 000	29 000	8 800

To reach higher exhaust velocities therefore implies injecting more power into the propellant flow than is possible by the strongest chemical reactions. An external source of power is required, and means must be found to effectively transform this power into kinetic jet power with the greatest conversion efficiency possible.

Power can be thermal (nuclear reactor, or solar concentrators, or from electricity generated by solar cells) or electrical (derived from thermal sources, or produced directly by solar cells). The former can be used to heat a working fluid such as hydrogen, but the temperatures possible are limited by the resistance of the manufacturing materials to values comparable to those for high-energy chemical reactions ($\sim$3000 K). The gain in exhaust velocity is mainly due to the low molecular mass of hydrogen. Realistic exhaust velocities are then in the order of 8000 m/s.

Electrical power can be used to heat a working fluid by ohmic heating, in which case the same limitations apply as above, or by striking an electric arc through which gas is flowing. The temperatures in the arc can be much higher than the tolerable wall temperatures, and the exhaust velocity is correspondingly higher. At these high temperatures, the propellant becomes partly ionised (a plasma) and electromagnetic forces can be applied to accelerate it still further. Exhaust velocities in the region of 10 000 – 40 000 m/s can be achieved with this approach, but the efficiency in converting electric power into kinetic jet power is rather low ($\sim$30%).



For electrical power to be used directly, the propellant to be ejected must be electrically conducting (e.g. plasma engines, but the creation of a plasma is difficult) or in the form of electrically charged particles (such as small droplets or ions). With the latter, one can apply electrostatic forces and the main characteristic of these electrostatic engines is that their exhaust velocity is determined only by the electrical forces applied and high temperatures are no longer needed, in contrast to the cases of thermodynamic or plasma propulsion. It is this decoupling of exhaust velocity from the temperature of the working medium that makes the electrostatic engine the most attractive concept for high-performance propulsion.

Most electrostatic engines eject positively charged ions (i.e. atoms stripped of one electron) of various elements and electrical power is required to convert the propellant into ions (ion-generation power). High ion-beam exhaust velocities are possible (20 000 – 100 000 m/s), but the beam power levels can become high (0.2 – 10 kW) even for seemingly low thrust levels (0.005 – 2 N). This leads to very long operating times to deliver the total impulse needed.

The various types of engine are best distinguished on the basis of their method of ion production and three methods have been realised in practice:

- Ionisation by contact, a method applied only to caesium ionised on a hot (1250°C) tungsten surface. The large heat losses make this principle of ion generation very power consuming.
- Ionisation by electron bombardment (or collision), a method applicable to almost any propellant in a gaseous phase. Electrons generated either by thermionic emission or energised by a radio-frequency field are made to swirl in the propellant gas. When such an electron collides with a neutral propellant atom, the outer electron is knocked off and an ion remains. Many ions recombine and become neutrals again, but some ions reach a set of electrified grids at different potentials through which they are accelerated and ejected into space. The technologies now being pursued in the USA, Germany and Japan rely on this principle. The power required for ion generation is less than for ionisation by contact, but is still significant, and the process calls for close control over operating conditions.
- Ionisation by electric fields, a method in which the ions are drawn directly from the liquid-metal propellant. A judicious choice of propellant (such as caesium) allows operation at very modest temperatures throughout (with the exception of the neutralisation requirement). Power consumption for ionisation is almost negligible and only simple electrical control is required.

It is the last of these three methods that forms the basis for the Agency's current programme on FEEP. This technology's ability to meet the simplicity, cost, and adaptability constraints that we have postulated has already been demonstrated. As the selection of the correct propulsion technology will play a major role in the economics of future space projects, the economies that FEEP could eventually bring when reaching operational use justify its receiving careful and early attention.

Figure 4 – A FEEP emitter under test, on a specially developed wire-probe arrangement, in one of ESTEC's vacuum chambers.

CONCEPT OF THE FIELD-EMISSION ELECTROSTATIC ION ENGINE

By subjecting a liquid metal to a sufficiently strong electric field at the *atomic* level (of the order of 0.5 V per Ångström), electrons can be repelled into the bulk of the liquid and ions left at its surface. These ions are then accelerated by the same electric field that created them, and this constitutes the basic process of ion field emission.

To create such high electric fields without excessively high voltages (0.5 V/Å is equivalent to 5×10^6 V/mm!) requires electrodes with very small radii of curvature. One possible approach is to use a thin metallic needle (Fig. 2), terminating in a cone with a tip radius of say 10 μm, placed inside a ring electrode. Liquid metal is then made to flow to coat the needle's tip with a metal film. Applying a potential difference of a few kV between the needle and the ring electrode creates an electric field which at the needle's tip is already of the order of 10^5 V/mm, because of the small radius of curvature involved. While this field level is not yet sufficient to induce field ionisation of the liquid metal, it is strong enough to pull the liquid surface at the tip of the needle into so-called 'Taylor cones'. Their apex is extremely sharp and it is here that the electric field is strong enough to generate ions, which are then accelerated by the potential difference between the needle (emitter) and the ring electrode.

A practical realisation of this principle then involves placing many needles side by side in an 'array' and converting the ring electrode into a slit. The array can be clamped between two metallic sponges and the whole encased in a housing filled with liquid metal (usually caesium) to form an 'emitter module' (Fig. 3).

It is the mechanical and electrical simplicity of such an emitter, thanks largely to the very straightforward method of ion generation, that constitutes the primary advantage and attraction of the FEEP principle. This simplicity should make for very low system fabrication costs, which should favour field-emission's application not only for primary propulsion, for which the manufacturing cost of the FE modules should be much lower than that of the alternative electron-bombardment engines, but also for spacecraft attitude control, for which the final FE hardware should not differ significantly in cost from that of today's chemical thrusters, whilst delivering superior performance*.

THE AGENCY'S FEEP PROGRAMME

It is now necessary to consolidate the FEEP technology by demonstrating the claimed advantages, and this is the object of the medium-term (until 1983) programme about to be proposed by the Agency to the IPC, representing about 1 MAU. This does not yet aim at a specific mission application of FEEP, but is to prepare for the subsequent phase of the development of a fully integrated, flightworthy system.

At present an FE 'engine' is seen as an assembly or cluster of individual emitter modules, each consisting of a solid-edge slit or a set of arrays fed from a central tank, with the associated extraction optics, and producing a thrust of about 2 – 4 mN. In the programme until 1983, therefore, emphasis is being placed on the development, optimisation and long-life testing of an emitter module, and the verification that clustering is indeed feasible and that auxiliary systems (power conditioner, neutraliser, tankage, etc.) already partially available from work on classical ion systems can be easily adapted to FEEP. Once caesium-fed emitter modules with predictable characteristics are established, the emission of other selected metal or alloy propellants will also be studied.

This proposed approach should prove very cost effective, as the work on emitter modules requires only modest test facilities, and design iterations aimed at lower manufacturing costs can easily be introduced as and when they manifest themselves (Fig. 4).

If the FEEP principle becomes an engineering reality, it will represent an important milestone in high-performance space propulsion, comparable in terms of its significance to the vacuum tube's replacement by the transistor in electronic engineering. Such prospects must more than justify the modest investments now being planned. □

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* Those readers interested in the detailed principles of FEEP are referred to the technical synthesis published in ESA Journal 78/2.

The EURAB Terminal

N.E.C. Isotta, Head of ESRIN, Frascati, Italy

A major linguistic breakthrough in the Arab language was probably assured on 30 June this year, when ESA signed a licensing agreement giving SELI, an Italian electronics company, the industrial production rights for a completely new kind of computer terminal. Patented by ESA, this terminal is capable of displaying side by side, on the same screen, two texts in different alphabets. The particular version of the system that will make the breakthrough possible – the EURAB terminal – is designed to display both Arabic and Latin characters simultaneously.

Some two years ago, during a meeting with Moroccan authorities, which had been catalysed by the installation of an SDS terminal system in the Centre National de Documentation, Rabat, the ESA delegation, which included the Director General, was fortunate enough to meet Professor Lakhdar, Director of the Institut d'Etudes et de Recherches pour l'Arabisation (IERA) in Rabat. In a fascinating verbal essay, Prof. Lakhdar expounded on a new alphabet, the Arabe Standard Voyellé (ASV), that he has developed during twenty years of work, the characters of which are 'standardised' to make reading easier and unambiguous. There are two unique features to this patent alphabet, the incorporation of the vowels, and a reduction in the number of character forms to a standardised set.

In its first conception, ASV was intended to make it possible to print Arabic as cheaply as Latin characters, and in this respect it has already done for the Arabs what Gutenberg did for the Europeans. ASV has since received the official approval of twenty-one countries in which Arabic is used (at a UNESCO Conference in Nairobi). Recent research on the system has been financed by UNESCO and the UN Development Programme, and as a result, Arabic printing machines, etc. now cost about half what they used to. The reduction in the number of characters to only 107 has also reduced the cost of fonts for handsetting by about 80%, since the traditional versions used well over 300 characters, and still had no vowels. This in turn meant that only the erudite could read newspapers.

Listening to Prof. Lakhdar, it was easy to believe that a completely new era was opening up for Arabic education and development. It also seemed fairly certain that the system would be universally adopted throughout the Arabic-speaking world, and the UNESCO Conference subsequently confirmed this view. The next important step was initiated by the UNESCO expert assigned to work with Prof. Lakhdar, Dr. G.F. Romerio, who foresaw the possibilities of using ASV for computer applications. Prof. Lakhdar consequently asked ESA's Director General whether ESRIN might consider the development of a suitable computer terminal, and a preliminary evaluation of the possibilities, in consultation with the UNESCO expert, was subsequently agreed upon. The final result was the development by Mr. Hans Orrhammar (an ESRIN staff member) of what is now known as the EURAB terminal (Fig. 1).

TERMINAL DEVELOPMENT

For the EURAB version of the terminal, parallel development of a coding system was necessary. The result was ASV-Codar. The principle behind the development of Codar was that it had to use, or be totally compatible with, an existing international standard, in this case ASCII, so that the terminal would be completely 'transparent' to the computer system to which it was to be attached. In other words, no special conversion or translational black-box would need to be inserted between the terminal and the computer before 'dialogue' could take place.

Other basic questions had also to be resolved, such as how material would be presented on the screen, and it was agreed that it was essential to provide side-by-side presentation of the two alphabets. Furthermore, only one keyboard was to be used, and a dual-alphabet printer for local attachment had also to be available. Finally, the best representation of the character forms within a 5×9 dot matrix had to be agreed, compatible with the forms used in ASV. Altogether, a fairly formidable list of requirements.

The basic character forms developed by Prof. Lakhdar are illustrated in Figure 2.

Figure 1 – The EURAB terminal.

In displaying characters on the screen, a problem emerged almost immediately in that the basic ASV system is intended to employ separated characters in words, whereas normal Arabic joins letters together so that they flow as word units. To eliminate the initial shock experienced by persons used to classical Arabic, Mr. Orrhammar has since developed a method of connecting characters that ought to be joined together, according to the context, thus approximating the normal flowing style. This facility is offered as an option for the EURAB terminal. It was also apparent at about the same time that another operator-selectable option was required, namely the ability to present only one page on the screen at a time, in enlarged form.

The resulting system can show, for example, page 1 or page 2, or pages 1 and 2 together, side by side. In fact, the second prototype of the terminal now has the ability to display up to 8 individual pages (although only two at any one time). This means that several alphabets may exist in one terminal, although by this time a single keyboard might become rather crowded (this could be overcome by

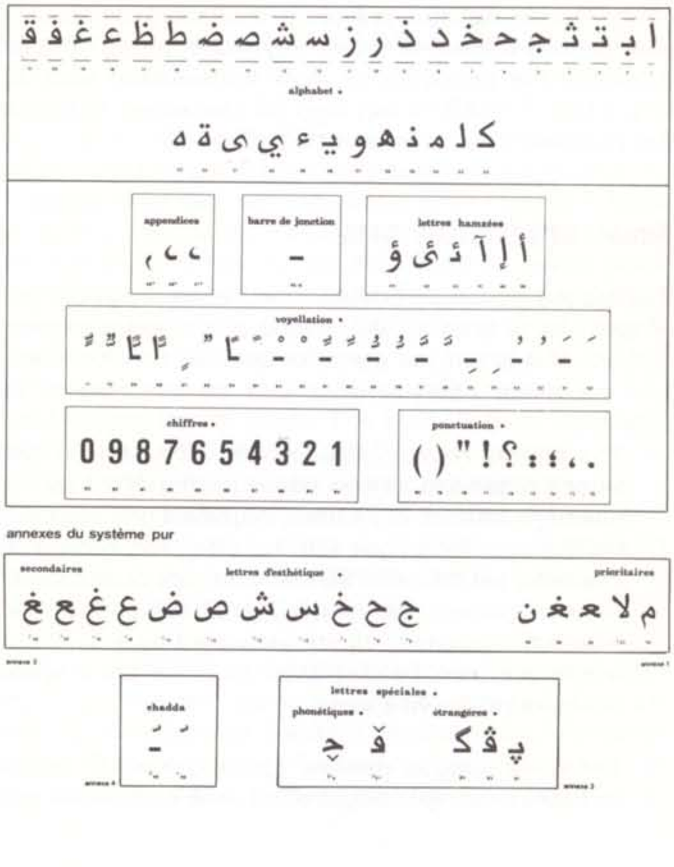


Figure 2 – Basic character forms developed by Prof. Lakhdar, Director of IERA, Rabat.

Figure 3 – The ASV-Codar system character set as used in EURAB.

the use of a multisymbol liquid-crystal key). A further advantage is that an operator can be working on page 1, whilst printing out locally from page 2 which is still stored in the terminal.

The next requirement was to produce a bilingual local printer able to operate at up to at least 120 characters/second. In fact, 240 characters have been achieved using a modified FACIT printer, which can produce characters in either direction (left-to-right and right-to-left) and, by using two character generators, is able to print very clearly in either Latin or Arabic characters. The development of this printer and its attachment to the EURAB terminal has greatly enhanced the possible applications of the system.

It is perhaps worthwhile emphasising also the considerable versatility of the ASV-Codar system as used in EURAB. This Codar contains a number of 'concision levels', which means that there is a range of character sets compatible with, for example, 5, 6, 7 or 8-bit codes. For Codar, there are basically 6 groups, extending from 32 characters to 88 and providing increasing degrees of comprehensiveness. A most important group is that providing the possibility of telex transmission with 35 characters. EURAB in fact uses 64 characters, although the complete character set is 128 (Fig. 3).

FINAL SPECIFICATIONS

The second prototype EURAB which emerged at the end of last year is both a very flexible and a very complete system. This is not the place for detailed specifications, but the major characteristics can be summarised as follows:

– The *display format* includes 960 × 2 character positions organised as two pages having 40 character positions on each of 24 lines, displayed one page at a time, or as two pages side by side. The basic 128 character set contains 96 standard, upper and lower case characters; the remaining 32 are control and function characters; all are generated by a 5 × 7 dot matrix and can be displayed in black on a white background, or vice versa.

  There are various options up to Option E, which includes selectable pages of an Arabic character set, using 64 symbols generated by a 5 × 9 dot matrix. Writing movement is reversed on the even-numbered pages. Russian or Greek characters are also possible.

– The *keyboard* can generate all 128 ASCII code signs, compatibly with the ASV-Codar. Keys are of the solid-state, Hall-effect generator type. For ease and speed of operation, vital function and control keys are duplicated and arranged side-by-side above the normal typewriter-organised key set. Page selection is possible from the keyboard or from the CPU.

  In the multialphabet version, keys show the two character sets. In switching from one alphabet to the other, the keyboard layout automatically follows established standards for the symbol distribution of the keys.

– The *communications interface* uses either
  (a) asynchronous 10 bit start-stop, even parity V24 (RS232C) standard signals, at speeds from 30 – 120, 180, 240, 480, 720, 960 characters per second, with synchronous or asynchronous modems; or
  (b) the same arrangement as (a), but pollable (meaning that the CPU has to authorise it to 'speak'), with extensions related to page selects.

– The *local output* matches the communications interface. Depending upon output device, printer or recorder, Arabic pages will be transmitted either 'reversed' (for printers typing from left to right) or in chronological order (first-in, first-out) for tape recorders. Output from a page can go on while the operator is working online on another page. A special command allows the local output to continue to print the next higher order page number automatically, after the previous page has been completed. The printer will automatically select the alphabet related to the page being printed.

MANUFACTURE

The second EURAB prototype described has already been installed in Rabat. Under the terms of the licensing agreement already mentioned, SELI has acquired the

				a8	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
				a7	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
				a6	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
				a5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
a4	a3	a2	a1		00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
0	0	0	0	00	NUL	TC_7 DLE	SP	0	@ç	P	` ç	p				0	@	ـْ	بـ	ظ
0	0	0	1	01	TC_1 (SOH)	DC_1	!	1	A	Q	a	q			!	1	ـَّ	ْ	تـ	عـ
0	0	1	0	02	TC_2 (STX)	DC_2	"	2	B	R	b	r			"	2	ّ	ـّ	ة	غـ
0	0	1	1	03	TC_3 (STX)	DC_3	#é	3	C	S	c	s			#	3	ـُّ	ّ	ثـ	فـ
0	1	0	0	04	TC_4 (EOT)	DC_4	¤è	4	D	T	d	t			¤	4	ُّ	أ	جـ	قـ
0	1	0	1	05	TC_5 (ENQ)	TC_8 (NAK)	%ê	5	E	U	e	u			%	5	ـِّ	آ	حـ	كـ
0	1	1	0	06	TC_6 (ACK)	TC_9 (SYN)	&	6	F	V	f	v			&	6	ِّ	ؤ	خـ	لـ
0	1	1	1	07	BEL	TC_{10} (ETB)	'	7	G	W	g	w			'	7	ـَ	ئ	د	مـ
1	0	0	0	08	FE_0 (BS)	CAN	(	8	H	X	h	x			(	8	َ	ـأ	ذ	نـ
1	0	0	1	09	FE_1 (HT)	EM	)	9	I	Y	i	y			)	9	ً	إ	ر	هـ
1	0	1	0	10	FE_2 (LF)	SUB	★ô	:	J	Z	j	z			★	:	ـُ	ي	ز	و
1	0	1	1	11	FE_3 (VT)	ESC	+à	;	K	[	k	{			+	;	ُ	[	سـ	يـ
1	1	0	0	12	FE_4 (FF)	IS_4 (FS)	,	<	L	\	l	¦			,	<	ٌ	\	شـ	¦
1	1	0	1	13	FE_5 (CR)	IS_3 (GS)	—	=â	M	]	m	}			—	=	ـِ	]	صـ	ى
1	1	1	0	14	SO	IS_2 (RS)	.	>	N	^	n	¬			.	>	ِ	ـء	ضـ	¬
1	1	1	1	15	SI	IS_1 (US)	/û	?	O	→	o	DEL			/	?	ٍ	ا	ط	DEL

production rights for these terminals and exclusivity for a period of two years. A pre-production series of 10 terminals will be manufactured by the company and sold to IERA at a discount. These will be used, among other things, for general demonstration and promotion of the EURAB system. Full-scale industrial production will begin in January 1979, and the terminals will then be sold in Morocco and other Arab countries.

In view of the already considerable success of ASV in terms of printing, typewriters, telex, etc., it is anticipated that a fairly strong demand will build up as the system becomes better and better known. Bearing in mind the adoption of the UNESCO Nairobi resolutions by ALESCO (Arab League Educational, Scientific and Cultural Organisation), these expectations would appear to be not unrealistic.

APPLICATIONS – LEXAR

Prof. Lakhdar, in a fairly casual remark, has expressed the importance of the ASV system very simply: 'Children no longer have to learn to read, spending perhaps 10 years at it, before they can learn anything else. They can learn while they are reading'. In other words, the importance of the system in terms of the education of future Arab generations is almost inestimable. This applies basically to written texts, but of course the availability of present generation computers will also be exploitable by the Arabs now that a totally transparent standard code input/output device exists. The EURAB terminal would appear to be the first, and one of its initial applications could clearly be in education, for example using computer-controlled educational dialogues. A great deal of research is currently going on in western countries on this particular subject, and it is clear that such methods of education are extremely powerful.

Looking at more commercial day-to-day use, management systems will obviously be an area where such terminals may be used. Banks in particular have a need for bilingual representation of names and account details. In this area in fact, pure transliteration by the terminal of an

Figure 4 – Screen display of airport flight information in both Latin and Arabic characters.

Arab name into, say, French or vice versa, can ensure a completely standardised version of names in all banks. This, of course, is not to be confused with an automatic translation system.

Another important application could be for airport displays of flight information, as illustrated by Figure 4. Obviously generalised linguistic analysis and translation will also benefit from such devices. Translation in particular could be simplified by this method, since the text to be translated could be displayed on the left-hand side of the screen in French for example, whilst the translator compiles the Arabic text on the right. A portion of the screen (e.g. lower third or quarter) could be used for a separate dialogue with the dictionary capability stored in the associated computer. The completed translation could eventually be transmitted to the computer for storage and further treatment for output.

One of the more fascinating projects, however, is that planned by Prof. Lakhdar and his collaborators at IERA. The idea is to produce the first complete Arabic lexicon (hence LEXAR), which will contain both English and French equivalents together with notations concerning the texts and sources. LEXAR will be available to all those interested in the modernisation and standardisation of Arabic, in order to enable it to keep up with normal scientific and technical progress. As Prof. Lakhdar himself points out, about 7000 new words a year are coined by scientists and technicians, and it is quite difficult to standardise Arabic equivalents.

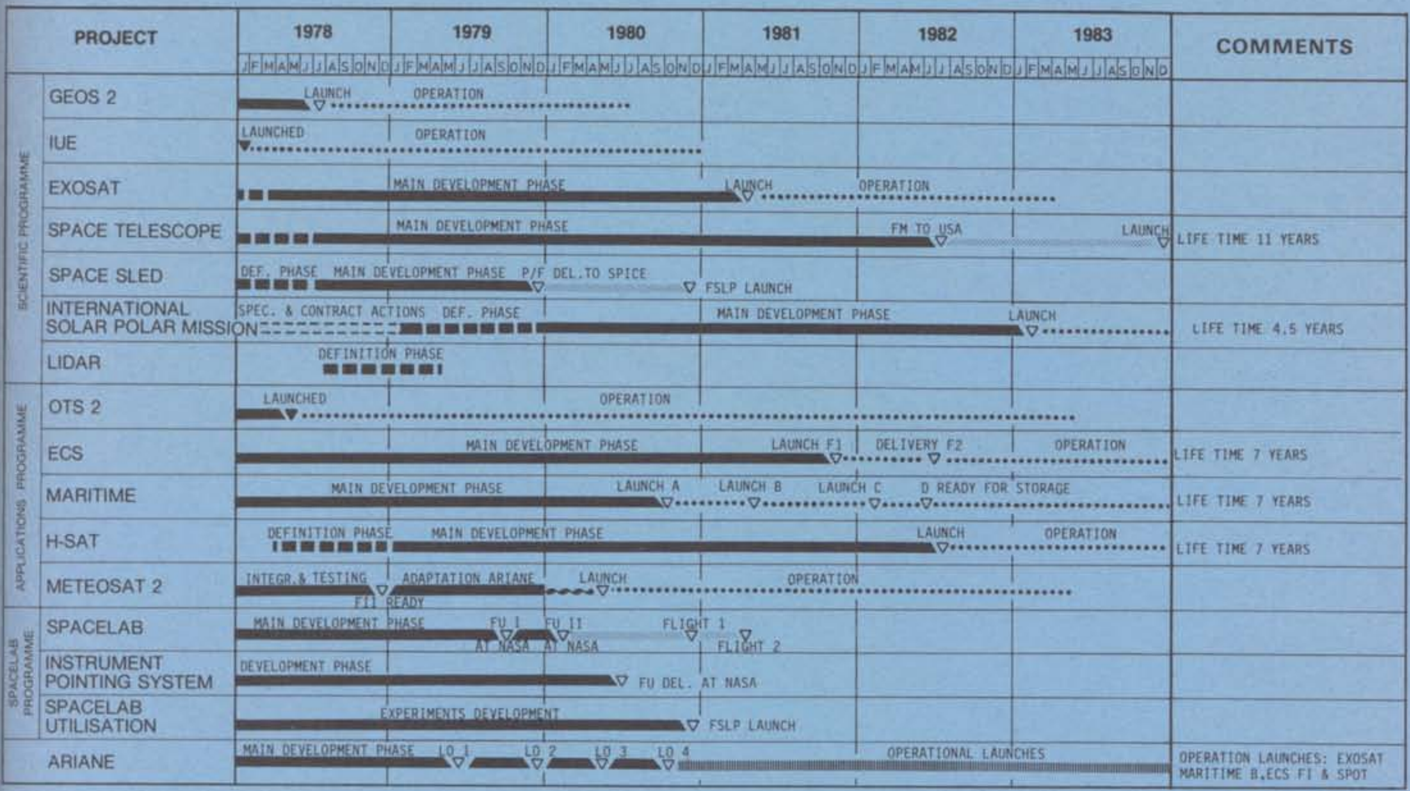
Although until now there has been almost total anarchy in devising such equivalents, for example even by using anglicised Arabic terms, it is clear that classical Arabic itself has sufficient word and root forms to avoid the need for new ones.

In the first stages of the LEXAR project, it is intended to use four or five terminals installed at the Institute in Rabat to input online to the computer in Frascati the first elements of the word bank containing 600 000 definitions currently stored in the catalogues of IERA. The task will take some five years, and will cost between 1$\frac{1}{2}$ and 2 million dollars.

It is gratifying to feel that this technological spin-off from space activities may lead to such fundamental development in such an important field. This is a considerable encouragement to the Agency in its intention to promote the exploitation of its patents on a systematic basis. □

Projects under Development
Projets en cours de réalisation

THE ESA DEVELOPMENT AND OPERATION PROGRAMME (END AUGUST 1978)



EXOSAT

Satellite

The project passed an important milestone at the end of June when the contract for development, integration and testing of the Exosat observatory satellite was awarded, on completion of the project definition phase, to the COSMOS industrial consortium, led by MBB.

In view of the delays announced for deliveries of various subsystems to MBB, the start of the integration and testing of the engineering model in December already appears questionable. In an attempt to propose the most realistic plan for the engineering-model programme by the end of September at the latest, MBB is presently reviewing the status of work at the premises of its co- and subcontractors.

From a technical point of view, two issues related to the extension of the coast phase for the satellite/Ariane fourth stage composite from about 90 min to 180 min are causing concern, namely battery capacity and solar-array structural/thermal performance. Detailed studies are being carried out by industry to identify the need for design adaptation, if any.

A further technical element to receive more than the normal attention is the question of endurance of the star-tracker's image dissector tube (IDT) in Exosat's dynamic environment. Prequalification tests performed at the supplier's site at reduced test levels showed no apparent degradation in tube electrical characteristics. It also appears from recently completed preliminary investigations that optical performance may not be influenced by the presence of loose particles inside the tube under zero-g conditions. Confidence is further enhanced by the fact that the same tube has been flown on American satellites without degradation of optical performance due to blemishing of sensor areas being noted. Final conclusions, however,

EXOSAT

Satellite

Une étape importante a été franchie par le projet à la fin du mois de juin, le contrat pour la réalisation, l'intégration et l'essai du satellite Exosat ayant été été attribué au consortium industriel COSMOS – dont le chef de file est MBB, Allemagne – après l'achèvement de la Phase de définition du projet.

En raison des retards annoncés pour la fourniture des différents sous-systèmes au contractant MBB, le démarrage de l'intégration et de l'essai du modèle d'identification en décembre apparaît douteux. Afin de proposer le plan le plus réaliste possible pour le programme du modèle d'identification vers la fin de septembre au plus tard, le contractant étudie actuellement les travaux en cours chez les co-contractants et les sous-traitants.

Du point de vue technique, deux questions liées à la prolongation de la phase de vol balistique du composite satellite plus quatrième étage d'Ariane, passée de 90 mn à 180 mn, soulèvent des inquiétudes: la capacité des batteries d'accumulateurs les performances en matière de structure et de thermique du réseau solaire. Des études détaillées sont effectuées dans l'industrie afin de déterminer la nécessité éventuelle d'adapter la conception.

Une autre question technique qui est l'objet d'une attention plus que normale est la question de l'endurance du tube dissecteur d'image (IDT) du suiveur d'étoiles dans l'ambiance dynamique d'Exosat. Des essais de préqualification effectués chez le fournisseur à des niveaux réduits ont montré qu'il n'y avait pas de dégradation apparente des caractéristiques électriques des tubes. Il semble également, à la suite de recherches préliminaires récemment achevées, que les performances optiques pourraient ne pas être influencées par la présence de particules libres à l'intérieur du tube dans les conditions d'impesanteur. La confiance à cet égard est renforcée par le fait que le même tube a été utilisé à bord de satellites américains sans que l'on ait noté une dégradation des performances optiques consécutive au blêmissement de la surface du détecteur. Des conclusions définitives ne pourront cependant être tirées que lorsque les tubes dissecteurs d'image, auront été soumis à des essais de qualification au niveau normal et l'on attend avec impatience les résultats définitifs de l'analyse des essais.

Charge utile

Un certain nombre de problèmes techniques se sont posés dans le domaine de l'interface fonctionnelle entre les détecteurs au plan focal et l'électronique des étages d'entrée (des fuites aux bornes du détecteur moyenne énergie et des défaillances de composants dans deux circuits à couche épaisse); des mesures correctrices ont été appliquées. Le travail technique d'ensemble, dans les domaines de la fabrication, de l'assemblage, de l'intégration et des essais au niveau équipement d'expérience progresse de façon satisfaisante.

On étudie actuellement le blindage des détecteurs moyenne énergie à bord du satellite contre les rayons X parasites. Il est nécessaire d'avoir une conception compatible avec les caractéristiques dynamiques de la plate-forme principale du satellite.

Le comité d'adjudication a approuvé la passation avec AEG d'un contrat pour la fourniture des cellules à gaz du compteur proportionnel à scintillation.

Lanceur

Selon le concept envisagé qui a été soumis par le CNES pour l'étude et la réalisation d'un système au quatrième étage pour freiner la rotation du composite, la faisabilité et la compatibilité de ce système seront étudiées dans le détail jusqu'à la fin de septembre et la solution retenue sera réalisée jusqu'en avril de l'année prochaine.

ESOC

L'examen de la conception du système au sol, qui a eu lieu à l'ESOC au mois de juin, a permis de dégager plusieurs recommandations et de nombreuses mesures ont été prises. Par ailleurs, la situation a été en général jugée satisfaisante.

Les impératifs du logiciel de la dynamique de vol, du planning de mission, et du traitement des données, ont été le sujet d'un certain nombre de réunions avec des représentants qui sont membres du groupe 'Exploitation et traitement des données'. Le but est d'achever les spécifications de conception du logiciel vers la fin de l'année.

TELESCOPE SPATIAL

Réseau solaire

Les travaux supplémentaires, nécessités par la correction des divergences révélées par l'examen de la configuration de référence et par la mise au point finale de la phase de définition, ont eu pour résultat une mise à jour de l'adaptation de la conception et du programme qui a été présentée dans le rapport de la Phase de définition. Ce rapport de Phase-B a été soumis par BAe en août; on procède actuellement à son évaluation. Entre-temps, les discussions entre BAe/LMSC/ESA et la NASA sur les conceptions détaillées des interfaces entre le réseau solaire et le Télescope spatial se poursuivent. Des progrès considérables ont été enregistrés au cours d'une réunion du groupe de travail sur les interfaces qui a eu lieu chez LMSC. Les préparatifs pour le démarrage de la Phase de réalisation (C/D) sont en cours.

Chambre

Les études de définition détaillée ont fait apparaître la nécessité d'apporter plusieurs modifications au système. Il a été démontré que l'introduction du relai optique et d'une focale de f/48 avec fente et réseau pour la spectroscopie est réalisable; cette amélioration sera donc apportée. Les discussions détaillées sur les conceptions des interfaces entre la chambre pour objets à faible luminosité et le télescope ont fait apparaître plusieurs domaines de difficultés qui devront être résolues au cours des réunions du groupe de can only be drawn once the ID tubes have been subjected to full unit qualification levels, and analysis of the final test results is anxiously awaited.

Payload
A number of technical problems have come to light in the functional interface between focal-plane detectors and front-end electronics (leaky terminals in the medium-energy detector and component failures in two thick-film circuits) and remedial action has been initiated. The overall technical work, in terms of manufacturing, assembly, integration and test at experiment unit level, is proceeding satisfactorily.

Shielding of the satellite's medium-energy detectors against stray x-rays is currently being investigated. A design compatible with satellite main platform dynamic characteristics is required.

The placing of a contract with AEG to supply gas cells for the gas-scintillator experiment has been approved by the Adjudication Committee.

Launcher
On the basis of the planning concept submitted by CNES for the study and implementation of a fourth-stage system for despinning the composite, detailed feasibility and compatibility will be examined until the end of September and the design of the solution selected will be developed until April next year at the latest.

ESOC
A review at ESOC in June of the status of the overall ground-system design resulted in several recommendations and numerous actions being taken, but the design was nevertheless in general considered satisfactory.

Detailed requirements for flight dynamics software, mission planning and data processing have been the topic of a number of interface meetings with representatives drawn from members of the Operations and Data Handling Panel. The aim is to complete the software design specifications by the end of the year.

SPACE TELESCOPE

Solar array
The additional effort needed to correct the deficiencies identified during the Baseline Configuration Review and to finalise the definition phase has resulted in an updated design and programmatic adaptation, presented in the definition-phase report. This Phase-B report was provided by BAe in August and is presently being evaluated. In the meantime, discussions between BAe/LMSC/ESA and NASA on the detailed design of the interfaces between the solar array and the Space Telescope (ST) are continuing; considerable progress was made during an Interface Working Group Meeting at LMSC, and preparations for the start of the main development phase (Phase C/D) are under way.

Camera module
The detailed definition studies highlighted the need for several system modifications, which have now been incorporated. It has been shown that the inclusion of the f/48 optical relay with slit and grating for spectroscopy is feasible, and this improvement will be implemented. The detailed discussions on the Faint Object Camera (FOC) to ST interface designs have revealed several problem areas to be resolved at Interface Working Group Meetings between LMSC, Perkin-Elmer, Dornier, NASA and ESA. The detailed designs for the interfaces between Photon-Detector Assembly (PDA) and Camera Module (CM) are being developed by a Dornier/BAe/ESA Interface Working Group. To align the schedules of the FOC, ST and other scientific instruments and to achieve economies in the programme, it has been decided to introduce a protoflight model programme, the details of which are still being worked out. The optical-bench technological programme has led to demonstration of the feasibility of one of the alternative designs investigated, which has subsequently been selected for implementation.

To allow a complete definition of the CM using the baseline that has emerged during the early months of the programme, it has been decided to extend Phase B until the end of October. The Project Requirements Review is scheduled to start with data-package delivery to the Agency on 21 September.

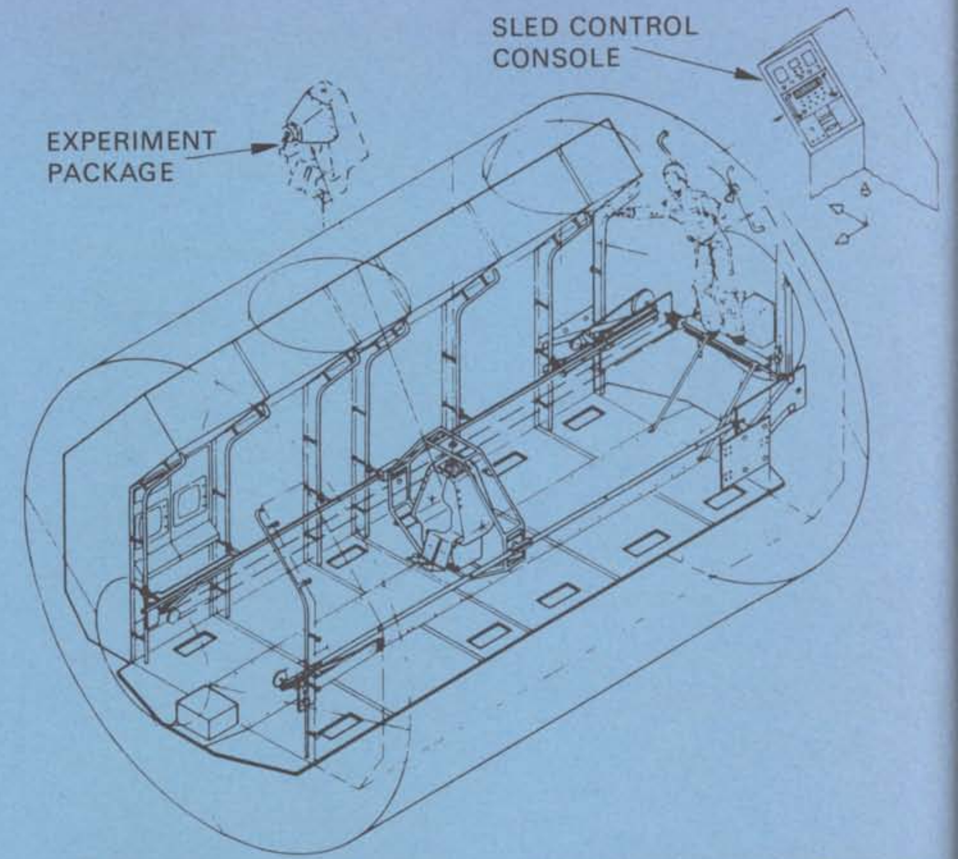
Photon-detector assembly
The Preliminary Design Review held in the period 7-30 June, at which the Instrument Science Team, NASA and Dornier were represented, showed progress to be generally satisfactory. The most significant problem encountered was the fact that the signal-to-noise margin for the I^2-EBS (two-stage intensifier and EBS camera tube) system was shown to be insufficient (by detailed development and analysis measurements). A modification introducing a three-stage intensifier has therefore to be made. Other deficiencies relating to the detailed design of some units can be overcome with considerably less impact. Authorisation has been given to BAe to initiate Development Phase II.

NASA interface
Progress of the ST was as planned. The last months have been characterised by a substantial increase in activities on interface designs through Interface Working Groups, set up by NASA and involving the various contractors. A refinement of requirements is also taking place and this led to NASA-requested modifications in several areas, some of which have a considerable impact on the ESA programme (e.g. reduction in power available for the FOC from 150 W to 140 W). Meetings to discuss these modification requests in depth have taken place at GSFC and MSFC, and most problems have been resolved. One exception is the FOC power allocation, where detailed designs will have to be finalised before possible remedial actions can be identified.

SPACE SLED

The Sled Facility System Design Review took place on 27 and 28 July. It was concluded that although

Le traineau spatial à l'interieur du Spacelab.
The Space Sled mounted inside Spacelab.



travail sur les interfaces entre LMSC, Perkin-Elmer, Dornier, la NASA et l'ESA. Les conceptions détaillées des interfaces entre le détecteur de photons et la chambre sont mises au point au sein d'un groupe de travail Dornier/BAe/ESA sur les interfaces. Afin d'accorder les calendriers de la chambre, du télescope et des autres instruments scientifiques, et de réaliser des économies sur le programme, il a été décidé d'introduire un programme pour un modèle de prototype de vol, dont les détails sont en cours d'élaboration. Le programme technologique relatif au banc optique a démontré la faisabilité de l'une des conceptions possibles étudiées et celle-ci a été retenue.

Afin d'avoir une définition complète de la chambre reposant sur la configuration de référence telle qu'elle est apparue au cours des premiers mois du programme, il a été décidé de prolonger la Phase B jusqu'à la fin d'octobre. L'examen des impératifs du projet commencera par la fourniture à l'Agence, le 21 septembre 1978, des liasses de données.

Détecteur de photons (PDA)
L'examen préliminaire de conception qui s'est tenu du 7 au 30 juin, auquel participaient des représentants de l'équipe 'Science des instruments', de la NASA et de Dornier, a fait apparaître des progrès généralement satisfaisants. Le problème le plus important que l'on ait rencontré a été la preuve (fournie par une analyse détaillée et des mesures) que la marge du rapport signal/bruit du système I^2 – EBS (intensificateur à deux étages et tube analyseur EBS) est insuffisante. On envisage donc une modification consistant à introduire un intensificateur à trois étages. Les autres insuffisances concernaient la conception détaillée de certaines unités, défaillances qui pourront être réglées avec beaucoup moins de répercussions. BAe a été autorisé à mettre en route la Phase de développement II.

Rapports avec la NASA
L'avancement des travaux sur le Télescope spatial est conforme aux plans. Ces derniers mois ont été caractérisés par une augmentation substantielle des activités de conception des interfaces au sein des groupes de travail sur les interfaces qui ont été mis sur pied par la NASA et qui groupent les différents contractants. En outre, l'affinement de certains impératifs a conduit la NASA à demander dans plusieurs domaines des modifications dont certaines ont des incidences considérables sur le programme de l'Agence (par ex. : réduction de 150 W à 140 W de la puissance disponible pour la chambre pour objets de faible luminosité). Des réunions en vue d'étudier de façon approfondie ces demandes de modifications ont eu lieu au GSFC et au MSFC; la plupart des problèmes ont été résolus. L'une des exceptions à noter est l'attribution de puissance à la FOC, pour laquelle des conceptions détaillées devront être mises au point avant que l'on puisse entrevoir la possibilité de résoudre cette question.

TRAINEAU SPATIAL

L'examen de la conception du système s'est déroulé les 27 et 28 juillet. Il a amené à conclure qu'en dépit d'améliorations considérables enregistrées dans plusieurs domaines depuis le précédent examen qui a eu lieu plus tôt dans l'année, des travaux poussés s'imposent avant que la fabrication puisse commencer. Les problèmes les plus importants à régler sont les suivants: analyse de la charge en vol, compatibilité EMC du système, possibilités de commande de l'accélération, essais, définition des interfaces et chiffrage détaillé du coût du programme. Les expérimentateurs américains du Traîneau ont maintenant commencé à travailler avec deux contractants pour leurs deux blocs expérimentaux. Les expérimentateurs européens ont eux aussi entamé des activités de conception et d'interface les plus critiques.

D'autres réunions ont eu lieu pour mieux définir les interactions avec les opérations de la charge utile du Spacelab avant le vol et en vol.

there has been considerable improvement in various areas compared to the previous Review earlier this year, further work is necessary before the start of manufacture. The most important items to be finalised are flight-load analysis, testing, interface definition and detailed programme costing. The US Sled experimenters have now started work with two contractors for their two experiment packages; the European experimenters have also started detailed design activities, initially concentrating on the most critical design and interface matters.

Further meetings have been held to improve definition of the inter-relationship with Spacelab-payload flight and pre-flight operations.

INTERNATIONAL SOLAR POLAR

Change of project title
It has been decided by the ESA Directorate that the project known as the Out of Ecliptic (OOE) mission shall henceforth be known as the International Solar Polar Mission (ISPM), bringing it into line with NASA terminology.

Overall status
The overall status remains good. Since the last Bulletin the US Senate Appropriations Committee has restored the 1979 Fiscal Year funding cuts imposed by the House of Representatives Appropriations Committee. Discussions are taking place to eliminate the discrepancy and a definitive decision is expected in the immediate future.

Scientific payload
Discussions are continuing with each experimenter to elucidate grey areas. The major hardware problem that has arisen to date is an apparent incompatibility between the Stone (GSFC) experiment and the vector helium magnetometer incorporated as part of the Hedgecock (London) experiment. This problem has already been discussed at a Science Working Team meeting early in September.

A further problem concerns the radio-science investigators who are requesting more capability from the spacecraft than is planned. Again, a dialogue is taking place in the hope of finding an acceptable solution.

Phase B1 tender
The Invitation to Tender for Phase B1 of the ESA spacecraft was issued, as planned, on 24 July. An industrial briefing took place on 4 August at which a number of questions from potential tenderers were answered. The closing date for submission of tenders is 27 October.

Future activities
Until the tenders are received in late October it is not possible to have any contacts with industry. The major activity in the intervening period is therefore the continuing clarification of experimenter requirements and the resolution of anomalies. A certain amount of configuration design is continuing in house in an attempt to arrive at a better understanding of experimenter needs.

LIDAR

The Lidar (Light Detection and Ranging) is intended as a Spacelab-borne, pallet-mounted, re-usable facility which will allow experiments to be conducted in atmospheric physics, geodesy and oceanography. The facility will be capable of being used for a wide variety of experiments on several flights, its core being complemented as required by kits of easily interchangeable mission-dependent equipment.

The Lidar consists essentially of two parts:
(a) a transmitter, composed of a pulsed laser (user provided) and an associated optic and power supply
(b) a receiver, composed of a telescope and an optical analyser (user provided) with alignment and calibration facilities between.

The contract for the Phase-B activities (definition) was awarded to MATRA, which will be conducting the study as Prime Contractor, with Dornier System as subcontractor, supported by Selenia. At the kick-off meeting, special emphasis was placed on the need to minimise Shuttle flight cost by optimising the facility's configuration in terms of volume and weight.

The Phase-B activities, which started on 31 July, will provide subsystem designs, system specifications and cost proposals for a facility concept designed to meet an agreed set of mission-model and scientific objectives.

OTS-2

OTS-2, launched in May and positioned at longitude 10°E is performing well. The satellite is being used on a time-sharing basis by the CEPT, as the first step in their planned use of the satellite, and by the Agency in its on-going Orbital Test Programme (OTP). Among other objectives, the OTP will ultimately assess the performance of all satellite subsystems and equipments, in preparation for the operational ECS programme.

At the present time, however, with the exception of parts of the Reaction Control Subsystem (RCS) which have not yet been tested, all the primary and redundant equipments on the satellite have been operated and found to be functional. Operation of redundant RCS equipment is scheduled for the near future.

ECS

The price negotiations for the main development contract for ECS-1 and 2 have been completed and signature of the contract is scheduled for later this year.

Significant efforts have been made to integrate the ECS and Marecs programmes, in view of the commonality between the two satellites. The same set of basic requirement specifications is being applied to the two contracts. Equipment and subsystem

MISSION INTERNATIONALE SOLAIRE POLAIRE

Dénomination du projet
Le Directoire de l'Agence a décidé que le projet précédemment dénommé Mission hors-écliptique (OOE), serait désormais appelé Mission internationale solaire polaire (ISPM), ce qui l'aligne sur la terminologie de la NASA.

Etat d'avancement
L'état d'avancement d'ensemble reste bon. Depuis la parution du dernier numéro du Bulletin, la Commission des Finances du Sénat des Etats-Unis a réinstitué pour l'exercice financier de 1979 les crédits budgétaires amputés par la Commission des Finances de la Chambre des Représentants. Des discussions sont en cours pour régler cette divergence de vues et une décision définitive est attendue dans un très proche avenir.

Charge utile scientifique
Les discussions se poursuivent avec chacun des expérimentateurs pour mieux définir les secteurs qui restent encore dans l'ombre. Le principal problème qui se soit posé à ce jour en ce qui concerne les matériels est une incompatibilité apparente entre l'expérience de Stone (GSFC) et le capteur de magnétomètre vectoriel à hélium incorporé dans l'expérience Hedgecock (Londres). Le problème a été discuté lors de la réunion de l'équipe scientifique début septembre.

Un autre problème concerne les chercheurs spécialistes des émissions radio-électriques qui demandent du véhicule spatial un potentiel technique supérieur à celui qui est prévu. Sur ce point encore le dialogue est engagé pour trouver une solution acceptable.

Appel d'offres pour la Phase B1
L'appel d'offres pour la Phase B1 du véhicule spatial de l'ESA a été lancé, comme prévu, le 24 juillet. Une réunion d'information pour l'industrie s'est tenue le 4 août et il y a été répondu à un certain nombre de questions posées par les soumissionnaires potentiels. La date limite pour la présentation des offres est fixée au 27 octobre.

Activités futures
Jusqu'à la réception des offres, fin octobre, il n'est pas possible d'avoir de contacts avec l'industrie. La principale activité, pour la période à venir, constituera donc à continuer de clarifier les impératifs des expérimentateurs et de chercher à remédier aux anomalies. Des travaux de conception de la configuration se poursuivent à l'Agence pour tenter de mieux cerner les besoins des expérimentateurs.

LIDAR

Le Lidar (Light Detection and Ranging) est conçu comme un instrument réutilisable, monté sur le porte-instruments du Spacelab et qui permettra d'effectuer des expériences de physique de l'atmosphère, de géodésie et d'océanographie. Cet instrument pourra être utilisé pour une grande variété d'expériences sur plusieurs vols, son élément central pouvant être complété pour les différentes missions par des équipements spécifiques aisément interchangeables. Le Lidar se compose essentiellement de deux parties:
(a) un émetteur, composé d'un laser pulsé (fourni par les utilisateurs) et de l'optique connexe ainsi que de l'alimentation en énergie;
(b) un récepteur, composé d'un télescope et d'un analyseur optique (fourni par les utilisateurs) avec des dispositifs d'alignement et d'étalonnage entre eux.

Le contrat couvrant les activités de Phase B (Définition) du Lidar a été confié à MATRA qui dirigera l'étude comme contractant principal, avec Dornier System comme sous-traitant, assisté de Selenia. Lors de la réunion de démarrage, l'accent a été tout particulièrement mis sur la nécessité de réduire au minimum le coût des vols de la Navette en optimisant la configuration de l'instrument en ce qui concerne son volume et son poids.

Les activités de Phase B, qui ont commencé le 31 juillet, auront pour objet la conception des sous-systèmes, la spécification du système ainsi qu'une proposition chiffrée pour un instrument conçu en vue d'effectuer une série de modèles de mission prévus et de répondre à des objectifs scientifiques approuvés.

OTS-2

Le satellite OTS-2, qui a été lancé en mai et mis à poste par 10°E, se comporte bien. Le satellite est utilisé en temps partagé par la CEPT, comme première étape de l'utilisation du satellite prévue par cet organisme, et par l'Agence, dans le cadre de son programme d'essais orbitaux en cours (OTP). Parmi les autres objectifs visés, l'OTP permettra finalement d'évaluer les performances de tous les sous-systèmes et équipements du satellite pour préparer le programme ECS opérationnel.

Pour le moment, à l'exception des éléments du sous-système de pilotage par réaction (RCS) qui n'ont pas encore été essayés, tous les équipements principaux et redondants du satellite ont été mis en fonctionnement et leur comportement a été jugé satisfaisant. Le fonctionnement de l'équipement redondant du RCS est prévu pour une date proche.

ECS

Les négociations portant sur le prix du contrat principal de développement d'ECS-1 et 2 se sont achevées et la signature du contrat est prévue pour la fin de cette année.

Des efforts importants ont été accomplis pour intégrer les programmes ECS et Marecs en tenant compte de la communauté de matériels qui existe entre les deux satellites. Les mêmes spécifications d'impératifs de base seront appliquées aux deux contrats. La réalisation de l'équipement et des sous-systèmes progresse conformément au calendrier. La définition des impératifs du secteur sol est également bien avancée.

development is proceeding on schedule and definition of ground-segment requirements is also well under way.

MARITIME SATELLITE

Maritime A and B
The negotiation with British Aerospace of the Marecs-A and B satellites contract has been completed and contract signature is expected in October. The spacecraft design was frozen at the Preliminary Design Review, which took place in June, and development work is progressing satisfactorily. Marecs-A is scheduled for launch on Ariane LO4 in October 1980, and Marecs-B during the second quarter of 1981.

Joint Venture for a Global Maritime System
The Agency offer for a global system of four satellites has been reviewed at several meetings of the 'Joint Venture', an assembly of representatives of the various nations interested in a global maritime satellite system (for further information see article on page 16). At the moment, the 'Joint Venture' favours a hybrid configuration made up of three Marecs and three Intelsat-V satellites with maritime payloads. The selection of this approach will be discussed further early in October.

HEAVY SATELLITE

The preliminary Phase-B contract has been proceeding according to plan and the next major milestone will be the Preliminary Design Review at the end of October. Thereafter activity in industry will be at a lower level until the end of the year, pending a decision on the start of the main development contract. Within the Agency, a further detailed study has been made of the growth potential of the H-Sat design and the role of the programme in the development of operational direct-broadcast satellite systems. The results of this work will be presented in the near future in support of the decisions to be taken on the next phase of the programme.

METEOSAT

Space segment
Meteosat-1, launched in November 1977, is performing very well. The spurious status changes due to surface discharges have become less frequent, as predicted, since their peak in April/May. The next peak in discharge activity is expected next spring. Meanwhile, simulated arcing tests are being performed on the satellite engineering model.

Meteosat-2 has completed its thermal vacuum testing. The vibration tests at Ariane levels will take place next year, after the modifications to the structure have been verified on the prototype and implemented on the F2 model.

Exploitation
The rate of distribution of meteorological facsimiles rose from 141 per day in April to 193 in August. The reliability of distribution, which was affected in June and July by problems connected with the processing system, rose to between 85 and 90% in August. As for the data-collection mission, about 20 requests for admission had been made by the end of June and others are under study. As regards these 20 requests, a few DCPs (Data-Collection Platforms) have been installed and have already transmitted reports, more or less intermittently. Only the ASDAR platforms on certain wide-bodied civil aircraft are transmitting quasi-operationally. The first interrogation tests conducted with a DCP set up in Greenland have been very valuable. Preparation of the software required for extracting the meteorological parameters is going ahead. The second wind-determination campaign (10-23 July) has given better results than the first campaign in April.

Demonstration/experimental activities
The Secondary Data User Station (SDUS) was successfully demonstrated in Athens and in Tunis towards the end of June. These demonstrations and the explanations of the Meteosat system have been followed with interest by the Meteorological Services. The second campaign covering Upper Volta, the Ivory Coast, Ghana, Morocco and Spain is being prepared for late September/early November.

Progress has been made with the use of images for television and the press. A sequence of images of the zone covered by Meteosat was generated on film and video-cassette for demonstration to television companies. The use of Meteosat in connection with the WMO 'Agrhymet' programme is also under study. The results will be presented to the WMO for approval and to the EEC for funding before the end of October.

GOES project
The equipment has been transported to Villafranca and most of it has been installed. Following the successful launch of GOES-3, GOES-1 has started its eastward drift and has come within sight of Europe. The first tests on the acquisition of VHF telemetry using Redu have been carried out satisfactorily. S-band acquisition by Villafranca is planned for the first week in September.

As regards the First GARP Global Experiment (FGGE), DFVLR (Germany), under a contract with the Agency, will process part of the data received, for the extraction of the winds, during the period 5 January – 5 March 1979, thus completing the processing carried out by the University of Wisconsin during the other months of the year.

SPACELAB

Software
Software Critical Design Reviews (SCDRs) have taken place at the Prime Contractor ERNO and at the co-contractors MATRA and BTM. The purpose of the SCDRs was to verify the software obtained in the design phase and compare it with the

SATELLITE MARITIME

Satellites maritimes A et B

Les négociations contractuelles avec British Aerospace pour les satellites Marecs-A et B sont achevées et la signature du contrat est prévue pour octobre. Lors de l'examen préliminaire de conception qui a eu lieu en juin, la conception du véhicule spatial a été gelée. Les travaux de développement progressent de façon satisfaisante. Marecs-A sera lancé par Ariane LO4 en octobre 1980. Marecs-B doit être lancé au cours du deuxième trimestre de 1981.

Association d'intérêts pour un système maritime mondial

L'offre faite par l'Agence d'un système mondial de quatre satellites a été examinée par l'Association d'intérêts au cours de plusieurs réunions rassemblant des représentants des divers pays intéressés par un système maritime mondial de satellites (pour plus de détails, voir article page 16). A l'heure actuelle, l'Association d'intérêts donne sa préférence à une configuration hybride constituée par trois satellites Marecs et trois satellites Intelsat-V avec charges utiles maritimes. Le choix de cette formule sera examiné de façon plus approfondie au début d'octobre.

SATELLITE LOURD

L'exécution du contrat préliminaire de Phase B se déroule conformément aux plans établis et la prochaine étape importante sera l'examen préliminaire de conception qui aura lieu à la fin d'octobre. Après cette date, l'activité de l'industrie sera maintenue à un niveau plus réduit jusqu'à la fin de l'année en attendant qu'une décision soit prise sur le démarrage du contrat principal de développement. Une nouvelle étude détaillée a été effectuée au sein de l'Agence sur le potentiel d'extension de la conception de H-Sat et sur le rôle du programme dans la réalisation de systèmes opérationnels de diffusion directe par satellite. Les résultats de ces travaux seront présentés prochainement à l'appui des décisions à prendre sur la prochaine phase du programme.

METEOSAT

Secteur spatial

Météosat-1, lancé en novembre 1977, fonctionne très bien. La fréquence des commandes intempestives provoquées par des décharges à la surface du véhicule spatial a, comme prévu, diminué depuis la pointe enregistrée en avril/mai; la prochaine pointe se situera vraisemblablement au Printemps de l'année prochaine. Entre-temps, des essais de claquage simulé sont effectués sur le modèle d'identification du satellite.

Les essais sous vide thermique de Météosat-2 sont achevés. Les essais de vibration au niveau du lanceur Ariane auront lieu l'année prochaine après que les modifications de structure aient été vérifiées sur le prototype et mises en oeuvre sur le modèle F2.

Exploitation

Le rythme de diffusion des fac-similés météorologiques est passé de 141 par jour en avril à 193 par jour au mois d'août. La fiabilité de la diffusion, qui a été affectée en juin et juillet par des problèmes liés au système de traitement, est remontée entre 85 et 90% en août. Quant à la mission collecte de données, une vingtaine de demandes d'admission avaient été formulées fin juin. D'autres sont en cours d'étude. De ces vingt demandes, quelques plates-formes de collecte de données (DCP) ont été installées et ont déjà transmis des rapports de façon intermittente. Seules les plates-formes ASDAR embarquées sur certains avions civils gros-porteurs transmettent de façon quasi opérationnelle. Les premiers essais d'interrogation réalisés avec une DCP installée au Groenland ont été fructueux. La préparation du logiciel nécessaire à l'extraction des paramètres météorologiques est en progression. La deuxième campagne de détermination des vents (10-23 juillet) a donné de meilleurs résultats que ceux de la première campagne d'avril.

Démonstration/Activités expérimentales

La station secondaire d'utilisateurs de données (SDUS) a effectué avec succès des démonstrations à Athènes et à Tunis à la fin du mois de juin. Ces démonstrations ainsi que les explications sur le système Météosat fourni à cette occasion ont été suivies avec intérêt par les Services Météorologiques. Une deuxième campagne couvrant la Haute-Volta, la Côte d'Ivoire, le Ghana, le Maroc et l'Espagne est en cours de préparation pour la période fin septembre/début novembre.

L'utilisation des données d'images pour la télévision et la presse a fait quelques progrès. Une séquence d'images de la zone couverte par Météosat a été générée sur film et sur vidéocassette aux fins de démonstration auprès des chaînes de télévision. Une étude d'utilisation de Météosat dans le cadre du programme de l'OMM 'Agrhymet' est en cours et sera présentée à l'OMM pour accord et à la CEE pour financement avant fin octobre.

Project GOES

Les équipements ont été transportés à Villafranca et sont pour la plupart installés. Après le succès du lancement de GOES-3, GOES-1 a commencé sa dérive vers l'Est et est parvenu en visibilité de l'Europe. Les premiers essais d'acquisition de télémesure en VHF avec Redu se sont déroulés correctement. L'acquisition en bande S par Villafranca est prévue dans la première semaine de septembre.

Pour la FGGE (1ère expérience du GARP), la DFVLR (Allemagne), dans le cadre d'un contrat avec l'Agence, traitera une partie des données reçues pour en extraire les vents pendant la période 5 janvier/5 mars 1979, complétant ainsi les traitements effectués par l'Université du Wisconsin pendant les autres mois de l'année.

Meteosat Secondary Data User Station (SDUS) on demonstration at the Tunis Meteorological Centre.
Station secondaire d'utilisateurs de données (SDUS) de Météosat installée au Centre Météorologique de Tunis.

requirements defined in the agreements between ESA, NASA and European industry. A NASA/ESA software interface control meeting clarified the Orbiter/Spacelab software interfaces.

Integration and testing
Essentially all engineering-model subsystem hardware has now been delivered to ERNO for integration and test.

Hardware, software and documentation has been prepared for the forthcoming system-level integration and test activities.

Schedule
NASA has indicated that postponement of the first two Spacelab flights will be inevitable if early Shuttle-flight planning has to be modified. A delay of several months seems likely for two reasons: firstly, the testing schedule for the Shuttle's main engine has slipped because of technical problems with the turbopump, and secondly, the Tracking and Data Relay Satellite System (TDRSS), an important link between Spacelab and the ground, has encountered development problems and its becoming operational will be somewhat delayed.

An agreement on the new target date for the first two Spacelab flights is expected in October, when ESA's Director General will meet with the NASA Administrator.

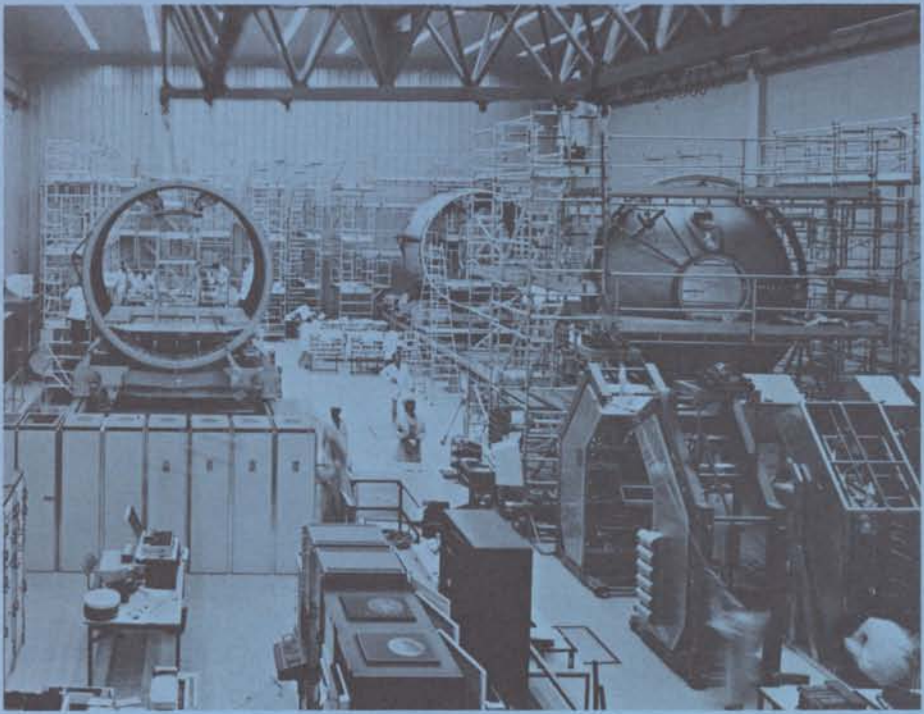
ARIANE

Second-stage tests completed
Following the propulsion-bay tests carried out in 1977, the next step has been development testing of the complete stage. The purpose of these tests, which have now been completed, has been:
- to validate the procedures for testing and operating the stage
- to verify proper behaviour of the structures: tanks, thrust-frame, skirts, water torus
- to check the flight-standard adjustments of the equipment
- to check the behaviour of the hardware in the exacting thermal and vibratory environment
- to verify the operation of the pressurisation system when fed by only three high-pressure helium bottles instead of four as originally planned
- to simulate a waiting period of the launch pad in Guiana, by heating the propellants to 22.5°C
- to study the different cases of propellant (UDMH, N_2O_4) and water depletion and to evaluate the corresponding thrust decays.

It will be recalled that the first static firing (M1) took place on 31 January, and lasted 138 s, the nominal operating time. The M2 stage was tested on 31 March, functioned nominally (138 s), and underwent a further test of 17 s on 10 April to study N_2O_4 depletion. M3 has been fired three times: on 14 August for the nominal duration of 138 s, which enabled simultaneous depletion of both propellants, and then on 18 and 29 August for two short-duration tests (17 and 23 s) terminated by the depletion of N_2O_4 and H_2O, respectively.

All of these tests, conducted at DFVLR's Hardthausen test centre, have proved very satisfactory, with no incidents of any kind reported.

Three other stages are now due to undergo qualification firings, in October (Q1), in December (Q2), and in February 1979 (Q3). Concurrently, tests with the engine adapted to vacuum conditions are continuing, and two qualification tests in vacuo are planned for early 1979.



Le modèle de definition du Spacelab en cours d'intégration et d'essais chez ERNO.
Spacelab engineering-model integration and testing activities at ERNO.

SPACELAB

Logiciel
Les examens critiques de la conception du logiciel se sont déroulés chez le contractant principal, ERNO, et chez les co-contractants, MATRA et BTM. Ils avaient pour objet de vérifier le logiciel obtenu au cours de la phase conceptuelle et de le comparer aux spécifications définies dans les accords entre l'ESA, la NASA et l'industrie européenne. Une réunion NASA/ESA a permis de préciser les interfaces du logiciel Orbiteur/Spacelab.

Intégration et essais
Presque tout le matériel des sous-systèmes du modèle d'identification a maintenant été livré à ERNO aux fins d'intégration et d'essais. Les matériels, le logiciel et la documentation ont été préparés en vue des activités futures d'intégration et d'essais au niveau des systèmes.

Calendrier
La NASA a fait savoir qu'un report des deux premiers vols du Spacelab serait inévitable si le calendrier initial des vols de la Navette devait être modifié. Un retard de plusieurs mois semble aujourd'hui probable et ce pour deux raisons. Tout d'abord, le calendrier d'essais du moteur principal de la Navette a été décalé, en raison des problèmes techniques au niveau de la turbo-pompe. D'autre part, le système de satellite de poursuite et de relais des données (TDRSS) a posé des problèmes de développement et ne sera opérationnel qu'avec un certain retard. Or il s'agit là d'une liaison importante entre Spacelab et le sol. On estime que lors de la réunion qui aura lieu en octobre entre le Directeur général de l'ESA et l'Administrateur de la NASA, un accord se fera sur les nouvelles dates prévues pour les deux premiers vols du Laboratoire spatial.

ARIANE

Achèvement des essais du deuxième étage
Après les essais des baies de propulsion, qui avaient eu lieu courant 1977, l'étape suivante consistait à effectuer des essais de mise au point d'étage complet. Les objectifs de ces essais, qui sont maintenant terminés, étaient les suivants:

- *valider les procédures de mise au banc et de mise en oeuvre de l'étage;*
- *vérifier le bon comportement des structures (réservoirs, bâti-moteur, jupes, tore d'eau);*
- *vérifier les réglages type vol des équipements;*
- *vérifier la tenue des matériels dans l'ambiance thermique et vibratoire sévère des essais;*
- *vérifier le fonctionnement du système de pressurisation à l'hélium alimenté à partir de seulement trois bouteilles haute pression (sur les quatre initialement prévues);*
- *simuler une attente sur rampe en Guyane (en portant la température des ergols à 22,5°C);*
- *étudier les différents types d'épuisement d'ergols (UDMH, N_2O_4) et d'eau et évaluer les queues de poussée correspondantes.*

Rappelons que la première mise à feu de l'étage M1 a eu lieu le 31 janvier et a duré 138 s, durée nominale de fonctionnement. L'étage M2 essayé le 31 mars, a fonctionné nominalement (138 s) et a subi un essai complémentaire de 17 s le 10 avril pour étudier l'épuisement N_2O_4. Enfin, l'étage M3 a été tiré trois fois: le 14 août pour une durée nominale de 138 s permettant un épuisement simultané des deux ergols, puis les 18 et 29 août pour deux essais de courte durée (17 et 13 s) s'achevant respectivement sur épuisement N_2O_4 et H_2O.

Tous ces essais qui ont été effectués au centre d'essais de la DFVLR à Hardthausen, se sont déroulés de façon très satisfaisante, et aucun incident n'a été enregistré.

Trois autres étages vont maintenant subir les tirs de qualification en octobre (Q1), décembre (Q2) et février 1979 (Q3). Parallèlement, le moteur adapté aux conditions de vide poursuit ses essais et deux tirs de qualification sous vide sont prévus début 1979.

Problems of Inflation and Exchange-Rate Fluctuations in an International Organisation

H. Frank, J. Vuagnat & H. Schullze, Directorate of Administration, ESA, Paris

The financing of International Organisations, and in particular of our own Agency, has become increasingly difficult in recent years, so much so that one can be left with the impression that the financial problems sometimes attract more interest than the 'real' problems that have to be faced in the development and launching of satellites. In the three-year period from 1975 to 1977, ESA's Member States and Executive tried to analyse the situation and negotiated specific and package solutions. Partial solutions were found by introducing monthly conversion rates for the evaluation of industrial tenders and the annual revision of GNP-based contribution scales, but no major breakthroughs were achieved. Consequently, at the end of 1977, the Director General proposed that the International Monetary Fund (IMF) be consulted on these questions with a view to securing neutral, expert advice.

It is understandable that Member States should be particularly concerned with ESA's finances when one realises that the 1978 contributions to the Agency include more than 900 MFF from France, nearly 400 MDM from Germany, 27 M£ from the United Kingdom and 50 Milliard Lire from Italy. The Agency's annual budgets have in fact increased substantially over the last fifteen years (Table 1), and at present ESA heads a budgetary league of International Organisations that leaves aside more political bodies such as the EEC and military organisations like NATO (Table 2).

Nevertheless, it would seem that the overall financial requirements of the Agency create fewer difficulties than the differing views of Member States on how the financial burden should be shared. Since 1974, the effects of the different rates of inflation in the various countries and of the fluctuations in exchange rates between the Accounting Unit and National Currencies have so distorted the Agency's financial management procedure that a complete reform has been thought necessary by Member States for some time.

The main criticisms may be summarised as follows:

- Countries with inflation rates below the average for all Member States should not be obliged to finance the inflation in countries with above average rates, bearing in mind that inflation in Member States varies from 2 to 20%.
- The use of the officially published statistics on national income and the conversion of GNP figures into Accounting Units at fixed conversion rates no longer takes into account the real economic status of the Member States.
- The retroactive adjustment of contributions due to variations in conversion rates in the course of the financial year results in hardship for countries with depreciating currencies.
- The accounting of the Agency's commitments and payments at fixed conversion rates favours countries with appreciating currencies and does not reflect the real costs of the Agency.

TABLE 2
Budgets of International Organisations for 1978

Organisation	Budget, M$
ESA	620
UN	417
WHO	172
UNESCO	112
FAO	106
IAEA	53
WMO	14

TABLE 1 – *Development of ESRO/ESA Annual Budgets (Nett Payment Appropriations in MAU)*

1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
5	17	33	44	54	56	64	76	85	106	190	336	465	488	549

REMEDIES PROPOSED BY THE IMF

Faced with the inflation, fluctuations in currency conversion rates, and widely varying national economic and monetary structures in the fifteen or so countries in which ESA's major financial transactions take place, the experts of the IMF are clearly not to be expected to propose any 'miraculous' solution to the Agency's problems. They have, however, been able to show that, depending on the objectives that the Member States assign, there are two possible approaches to the problem – an 'integrated' approach and a 'national' approach.

The *integrated approach* is based on the premise that the International Organisation was set up with the main aim of enabling its Member States to undertake jointly a series of programmes generating common benefits, each programme being funded jointly by all the Member States in the light of their individual contributive capacities. In such a case, the funding of expenditure is shared in fixed or predetermined proportions; ideally, these fixed proportions would be respected if the daily expenditures were converted into accounting units at the rates of the day and the contributions called up each day on the basis of these fixed proportions and the daily conversion rates. This is of course the extreme solution, which the experts recognise to be impracticable, but a simplified version of which they propose in a form that will be described below.

The *national approach*, on the other hand, is based on the premise that the main objective of the international body is to co-ordinate national projects decided by the national authorities in the light of their own priorities and funded on a national basis. In this case, each country limits its contribution to the amount of expenditure incurred in its own currency. There are then no exchange gains or losses and the accounts can be kept with the aid of any accounting unit one wishes.

The latter approach is not, however, feasible for all of the organisation's expenditure, a fraction of which will necessarily be 'common', if only that relating to coordination activities for the various national projects. It is moreover an approach that would perhaps entail national contributions fluctuating widely from one year to the next, since the timing and sizes of calls for contributions should in principle coincide with the payments made for work done, whereas such work does not in fact evolve linearly. The national approach is also one with which it would seem difficult to evaluate correctly the effect of reallocating certain work from one country to another during the course of a programme, and its implementation would undoubtedly give rise to considerable administrative complications.

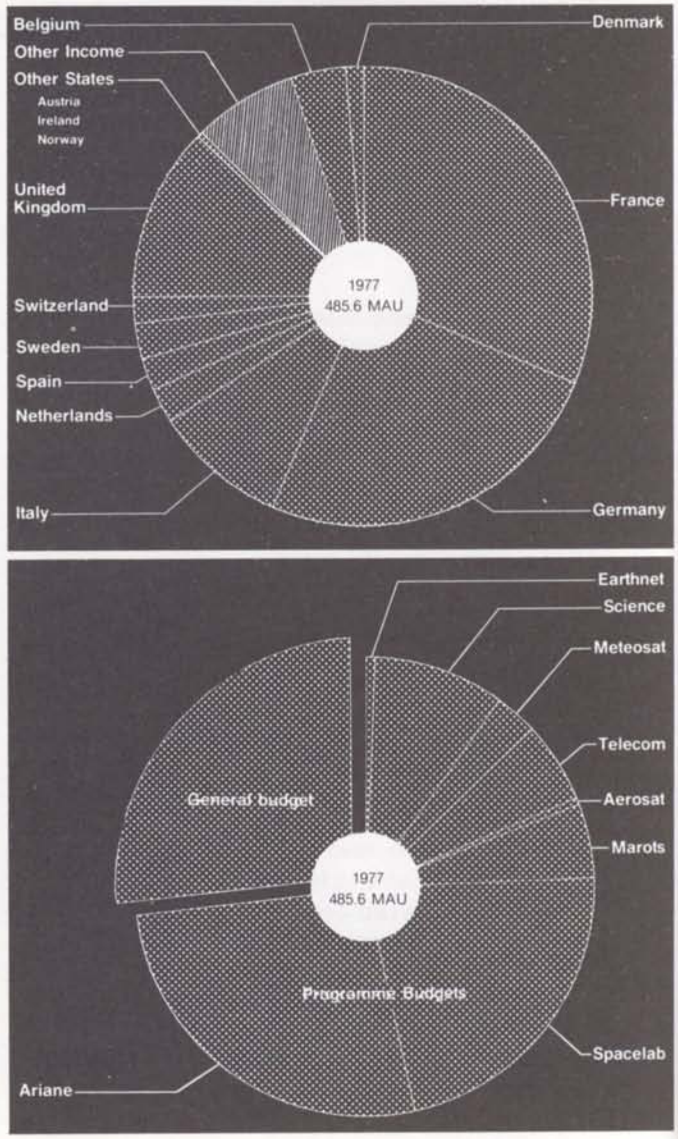


Figure 1 – Total ESA net income and payments for 1977, broken down on the basis of contributing Member States and Programme Expenditures respectively (retroactive budget decisions taken in 1978 not included in these representations).

The integrated approach on the other hand, the premise of which seems more in keeping with the raison d'être of an international body, can be put into effect without real difficulty, at least in its simplified version, which would mainly involve:

– expressing expenditure proposals initially with conversion rates for national currencies and the accounting unit as close as possible to the end of the year preceding that of execution, the daily (or monthly) rates being envisaged for the latter;

- incorporating, in these expenditure forecasts, estimates of projected price rises during the year of execution, and of reserves to cover any shortfalls that may result from the appreciation of certain currencies in the course of the year compared with the initial set of conversion rates;
- allocating among countries the funding of this expenditure on a joint basis, the scale for which could either be national income or any other basis agreed among countries, the conversion into national currencies of such funding being effected using the initial set of conversion rates;
- calling up this funding by States (contributions) in its entirety at the very outset of the financial year, and converting immediately into the 'deficit' currencies any surplus of currencies received, this being done on the basis of an estimate of the probable distribution of expenditure in national currencies.

In the case of ESA, such measures would undoubtedly bring about an improvement in its present Financial Rules; budgets, which would be implemented in current prices, would cope better with the economic situation of the moment, and Member States' contributions would no longer need to be adjusted retroactively to take account of conversion-rate fluctuations, while exchange losses would in all likelihood be reduced to a minimum.

For the Agency, and for any similar International Organisation, such procedures should enable annual costs to be allocated among its Member States in a consistent and administratively workable manner, without any of its Members being given particularly favourable or particularly unfavourable treatment.

All these measures are currently being analysed by a Working Group set up by the Council of the Agency at its meeting in July 1978 and consisting of representatives of each of the Member States. At its first meeting last September, the Working Group unanimously recognised the merits, at least in principle, of the IMF experts' proposals. Different points of view naturally emerged as to the practical arrangements for applying these IMF recommendations, some of which would raise real difficulties for a number of Member States. A case in point is the recommendation that Member States pay from the outset of the financial year the whole of their contributions for that year. However, in view of the many points of agreement already achieved and the constructive spirit shown by the members of the Working Group, there is every reason to hope for a favourable outcome to the work by the end of this year.

IMPLICATIONS FOR OTHER INTERNATIONAL ORGANISATIONS

The IMF study broaches the question of whether the problems that it deals with are specific to ESA, or whether similar ones have also been met by other International Organisations. In its broadest sense, the notion International Organisation refers to entities in international law emanating from interstate agreements which have been made for the achievement of common aims. As about 200 major organisations of this kind exist and it is obviously not possible within the framework of this article to consider the specific financial problems which all of them have undergone in respect of inflation and fluctuations in exchange rates, we will restrict ourselves here to scientific/technical organisations which can be compared with ESA on the basis of their particular field of activity. A short summary of the situation prevailing in the European Communities will be included because, like ESA, it expresses its budgets in terms of a European accounting unit and its financial procedures contain some elements that appear in the IMF's recommendations to ESA.

The 'sister organisations' that can be considered comparable to ESA are:

- in the field of atomic research, the European Organisation for Nuclear Research (CERN) in Geneva, and the International Atomic Energy Agency (IAEA) in Vienna;
- in the field of astronomical research, the European Organisation for Astronomical Research in the Southern Hemisphere (ESO) in Munich;
- in the field of biological research, the European Molecular Biology Laboratory (EMBL) in Heidelberg.

At first sight, a budgetary comparison with these organisations shows ESA to be by far the largest. Furthermore, none of these 'sister organisations' has to deal with major development contracts to be executed in a large number of different countries; on the contrary, these organisations – with the exception of IAEA – spend the major part of their funds in the currency in which their budget is expressed, and which corresponds to the currency of the organisation's headquarters.

TABLE 3

Organisation			Budgetary volume 1977
ESA			488.4 MAU
CERN	646.2 MSF	=	238.3 MAU
IAEA	60.4 M $ US	=	55.0 MAU
ESO	40.6 MDM	=	14.3 MAU
EMBL	33.0 MDM	=	11.7 MAU

From this it follows that CERN, ESO and EMBL are in a much less complex position than ESA in terms of inflation and variations in exchange rates, and that consequently much simpler procedures could be used to effect solutions. By expressing their budgets in a national currency and obliging Member States to pay their contribution in this currency, CERN, ESO and EMBL in effect charge their Member States with the risk resulting from a possible depreciation of their own national currency. For the organisation itself, problems of exchange gains or losses arise neither on the income side, nor on the expenditure side, in so far as payments are made in the currency of the budget. The only factor that has to be taken into account in this case is the inflation rate of the country of the organisation's headquarters. This is a well-known problem which can either be resolved by inclusion of open reserves in the budget, by supplementary budgets, or by applying pre-estimated inflation factors to the expenditure side of the budget.

The situation at IAEA, whose budget is expressed in US $, is somewhat more complicated, as it spends about 75% of its funds in Austrian Schillings, Deutsche Marks and Swiss Francs. Conversions from US $ into one or other of these currencies are accounted for on the basis of the official 'United Nations operational rate of exchange', which is fixed monthly. Because these rates follow the market rate closely, no major exchange gains and losses result from their application. At the end of each month, cash and balances of bank and other accounts kept in currencies other than US $ are adjusted to the United Nations rates for the following month; differences are charged to an 'Exchange gains and losses account', the balance of which is entered into the budget by the end of the financial year. The IAEA budget contains a special reserve to cover losses that might follow further US $ depreciations.

For their payments in nonbudgetary currencies, CERN and ESO use procedures similar to those of IAEA except that they do not apply the UN rates, but rather their own monthly rates, fixed internally by their respective finance administrations. EMBL uses daily market rates for its conversions.

As long as these organisations are able to maintain a national currency as their budgetary currency, the ideas contained in the IMF report will not be of particular interest to them. This will change, however, if one day they are obliged to use an accounting unit as budgetary currency, as ESRO had to do in 1969.

A change of this nature took place last January when the largest of the European organisations, the European Communities, with a budget 20 times greater than that of ESA, took the European Accounting Unit as its budgetary currency. There, the following IMF report principles are applied:

– strict discipline in respect of transfer of the so-called 'own resources', which replace the major part of Member States' contributions to the Communities
– utilisation of monthly (in the future, daily) rates for the execution of the budget, both income and expenditure.

It should not be overlooked that the 'rate of the day' system creates some difficulties because it requires additional effort from the accountants, and makes it more difficult for management to follow programme expenditure due to the 'permanently floating accounting unit'. However, this is the price that the European Communities are prepared to pay for a financial system that, in principle, offers fair and adequate solutions for equal treatment of all Member States. □

Insurance of Satellites

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In view of the operational nature of a number of the Agency's current satellite programmes and the fact that reduced budgets and rising costs make the replacement of any 'lost' spacecraft, whether applications oriented or scientific, through the process of 'self-insurance' a less and less realistic proposition for European governments, the commercial insurance of satellites, their successful launching and their successful operation is beginning to play an increasingly important role in the funding scenario of ESA's space projects. The destruction of the Agency's own OTS-1 communications satellite by the explosion of its American Thor-Delta vehicle last year and the subsequent recovery through insurance of $29 million towards the cost of its replacement by OTS-2 served as an unwelcome reminder of the merits of such protection.

Figure 1 – The Underwriting Room at Lloyd's.

Unlikely though it might seem, to begin to trace the early history of insurance one has to begin at an 18th-century coffee-shop in the city of London owned by a certain Edward Lloyd. It was he who organised among his regular customers the first 'gambling' on merchant ships returning to London, with those who wished to cover the risk of the non-return of a ship having to 'underwrite' a document. The risks included both the hazards of the sea and any enemy action.

In the course of the 18th century, the 'gambling' in Mr. Lloyd's coffee-shop turned into a more sophisticated business based on a systematic mathematical approach, and in 1760 Lloyd's Register of Shipping came into existence. The Register contains information on all ship movements and serves to inform underwriters of their fortunes and misfortunes, and allows them to calculate the risks involved.

The Lloyd's market is a perfect example of the early insurance concept of spreading the risk, so that any loss 'lighteth rather easilie upon many, than heavilie upon fewe'. Lloyd's has also been noted over the years for the imagination and enterprise of its individual underwriters, who have pioneered often revolutionary forms of insurance cover (Fig. 1).

HISTORY OF SATELLITE INSURANCE

When the Russians launched Sputnik 1, the Columbus of space, on 4 October 1957, there was no question of insurance or of investors sitting in a coffee-shop and anxiously waiting for news of their investment. By the early 1960s, however, the United States had taken up the space challenge, appointing NASA as the responsible government agency for launch services. Private businesses soon entered the arena also, and COMSAT, for example, assumed responsibility for and had to face considerable risks in connection with the establishment and maintenance of communications satellite systems as a private venture. Not surprisingly, therefore, the first basic concepts for satellite insurance were developed and applied in the USA.

Figure 2 – Destruction of OTS-1 with the explosion of its Thor-Delta launcher.

Europe's development of scientific satellites, for subsequent launch by US vehicles, did not at this time involve any direct commercial interest. The governments participating in these programmes through the European Space Research Organisation (ESRO) took rather a distant attitude with regard to insurance, rather favouring the deep-rooted governmental concept of 'self-insurance'. This approach presupposes, however, that the funds needed for any replacement in case of failure can be made available. This assumption became subject to question in the context of ESA's activities with the introduction of special programmes, which fixed the financial obligations to a ceiling not taking into account any catastrophic failures. A noticeable change occurred in the attitude of ESA's Member States towards the risks involved from 1975 onwards, as it became evident that funding limitations were becoming increasingly severe, so that the 'self-insurance' principle no longer really applied and the lack of appropriate insurance coverage was jeopardising any satellite replacement that could prove necessary.

Another aspect is coverage of the risks to third parties. With the launching of thousands of satellites, public opinion has become more and more concerned by the thought that a deficient spacecraft might hit Miami Beach, Cologne, or some other densely populated area. The recent somewhat spectacular crash of a nuclear-powered Russian spacecraft and Skylab's potential descent to Earth in the coming years have reinforced these fears and speculations.

The United Nations Treaty on Outer Space has established liabilities for accidents attributable to satellites, and on the basis of this the US Government obliges NASA's customers to cover liabilities connected with any launch from a US range by an insurance. The problem of third-party liability will be equally valid for launches by ESA's own Ariane vehicle from Kourou, French Guiana.

Against this background, the Executive of the Agency was obliged to consider the possibility of insurance more closely and to draw the attention of the appropriate Committees to the various aspects.

RISKS TO BE INSURED

Four different areas of risk can be distinguished which correspond to four distinct types of insurance:

Pre-launch insurance
This insurance covers, inter alia, the transport of the satellite from the contractor's premises to the launch site, and the subsequent period until the launch attempt, including the mating of the satellite with the launch vehicle.

In view of contractual arrangements with the contractors responsible for the delivery of the satellite, ESA assumes neither title nor custody during the period up to launch ignition. The risk of physical loss or damage during this period is with the contractor and is of no direct concern to ESA. Insurance of this type has therefore not been taken out by the Agency in the past.

Third-party-liability insurance
Third-party-liability insurance covers the owner of the satellite and, if required, the launching authority, for their legal liability to third parties arising out of the launch and principal launch activities and the satellite's behaviour once it has been launched. This insurance enters into force with the arrival of the satellite at the launch site, and generally provides coverage for up to three years after launch.

ESA takes out a third-party-liability insurance, which gives reasonable coverage to the Agency and NASA, these two parties being the assured under the terms of the policy for the risk in question. The amount to be covered in accordance with the contract provisions is $ 100 000 000, this coverage being obtained for the relatively modest premium of $ 25 000 per launch, under a general policy for ESA launches.

ESA is presently considering how its third-party liability should be covered for Ariane launchings from Kourou. It appears likely that a policy similar to the one used with NASA will be taken out, with the insured sum perhaps being further increased beyond the $ 100 million limit considered satsifactory for US launchings; other organisations have already subscribed to third-party-liability insurances extending to $ 300 million.

Launch insurance
Launch insurance covers loss of and damage to the satellite and launch vehicle from the moment of ignition until the 'successful' injection of the satellite into its correct orbit, success being judged on the basis of the meeting of a certain number of predetermined criteria within an agreed period after launch. Typical criteria might be that the satellite has enough fuel and power to operate for its designated lifetime, or that a certain number of repeater channels are functioning correctly. Since the determination of whether or not such criteria are met takes place in the weeks after launch, this type of insurance, depending of course on the specific terms of the policy, embraces certain aspects of in-orbit insurance.

The Agency considered and decided to take out launch insurance for the first time on the occasion of the OTS-1 launch. A tender action was undertaken with a view to giving insurance companies in all the Agency's Member States a chance to bid, but the proposals subsequently received from the various companies quoted identical premiums, demonstrating that the market for such insurance is not one in which a tender action is meaningful, because of the close interconnection of the different companies (they did in fact state in their tenders that they had consulted each other). Although there is no 'Lloyd's Register on the launching of satellites', the premiums quoted very accurately reflect the failure rate of launchings on Thor-Delta vehicles.

In practice, the coverage to be obtained is always expressed as a capital sum and it is up to the customer to decide whether the full replacement value or only a partial value is to be insured. In the case of OTS-1 the sum insured was markedly below the total replacement cost of satellite and launch, because some of the equipment to be replaced was already available. In the case of Meteosat, a sum corresponding only to the launch services was insured, because a second satellite prototype was already available as a back-up.

A typical insurance premium would be 10% of the insured value, of which 33.3% would be returned in the event of no loss. In this case, the effective premium rate would amount to 6.67%. It is also possible to further guarantee the 'no-loss return', by insuring this amount at a premium of 15%, which leads in turn to an effective premium of 7.2% of the insured value. ESA has in the past always reinsured the 'no-loss return'.

For the insurance of OTS and Meteosat, ESA selected a broker in the UK with underwriters in all Member States and with specific experience in the field of satellite insurance. The $ 29 million payment made to ESA by these insurers within two weeks of the spectacular explosion of the Thor-Delta launch vehicle carrying OTS-1 in fact wiped out approximately two-thirds of the premium income built up by companies participating in satellite insurance during their first 12 years of activity! For those companies, particularly in ESA Member States, who were insuring this type of risk for the first time, the loss of OTS-1 constituted a very bad start, and a number of them have subsequently withdrawn from satellite insurance. Nevertheless, the insurance companies maintained their original quotation with regard to the Meteosat launch and it was only thereafter that a modest increase was noted, in that the no-loss return was reduced from 33.3% to 25%. This resulted in a guaranteed rate of 7.9% for the OTS-2 launch, leading to a premium of $ 3.8 million for an insured sum of $ 50 million.

In-orbit insurance
This type of insurance covers the satellite during its operation for, for example, correct functioning of communication transponders, power and/or fuel systems or other subsystems for a specified period of time. It is designed to cover the possible financial consequences involved in:
- the replacement value of the satellite, including the cost of further launch services
- the loss of revenue that may result from a deficiency in the satellite.

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The Geostationary Satellite as an Aid to Very-Long-Baseline Interferometry (VLBI)

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From its inception in 1967, very-long-baseline radio interferometry (VLBI) has proved to be a powerful tool in the study of the physics of radio sources and in recent years the technique has also shown great promise in the areas of geodesy, geophysics and astrometry. In radio astronomy the need for the very high resolution provided by VLBI extends from radio observations of the Sun to the furthest objects known in the Universe, and the information being sought is crucial to our understanding of the origin and evolutionary processes of many astrophysical phenomena, particularly as the formation of images with these resolutions will not be possible in other spectral domains for many years to come. The feasibility of high-resolution visual and infrared interferometry in space has just started to receive attention and its development requires high-level technology and large structures in space. It is conceivable that VLBI stations could be developed in the same time scale.

Geophysical interest in VLBI stems mainly from the use of an inertially fixed, rigid reference frame of unresolved, very distant radio sources, which allows the relative displacements of points and reference frames located/fixed to various points on the Earth's crust to be measured with great accuracy. The latter should provide a key to a breakthrough in our understanding of the complex dynamics of the Earth's interior and, more importantly in the shorter term, the Earth's crust.

From an astrometric point of view, VLBI promises the most accurate determination of radio-source positions by making possible studies of parallax and proper motion, of galactic structure and rotation, relative to fixed, distant extragalactic sources. The accuracy attainable is at least comparable with that expected from the space astronomy mission planned by ESA, although the latter will observe a much larger number of stars.

Although the VLBI technique clearly has applications in a wide variety of scientific endeavours, work so far has been limited if one considers VLBI's potential capabilities. Detailed investigations in different fields are, of course, difficult to co-ordinate and the present data-reduction techniques are both complex and time-consuming. It was the recognition of the existence of these problems that led to the formation of an ESA Study Group to investigate the scientific objectives and development of a major new instrument, namely a real-time satellite-linked VLBI system, for Europe. This instrument should be capable both of exploiting the full potential of the technique and of providing wide-ranging scientific returns to the European user community.

THE RATIONALE BEHIND SATELLITE-LINKED VLBI FOR EUROPE

The discrete sources of celestial radio emission have angular extents ranging from several degrees to less than one thousandth of an arc second. The corresponding surface brightness ranges over more than 16 orders of magnitude, which means that instruments of somewhat different designs are needed in order to work across this entire range.

For the larger sources, filled-aperture or other pencil-beam instruments are used to obtain angular resolutions approaching a minute of arc, which is comparable to that of the naked eye. For resolutions approaching one second of arc, phase-coherent aperture synthesis arrays are used, with the connected elements spaced over several kilometres. For the higher resolutions, however, the spacings between the elements must be very large, and their physical connection over the intervening hundreds or even thousands of kilometres via land-based lines is very difficult, if not impossible.

The problem of transmitting the signals received at these widely-spaced elements to a central location for correlation can be solved in two ways. The first solution, dating from 1967, employs independent tape recordings of the signals and independent local oscillators at each element, and correlations are made in post-real-time. This is currently the standard method of performing VLBI in Europe and North America. The second possibility is to use a geostationary satellite as a relay, and successful

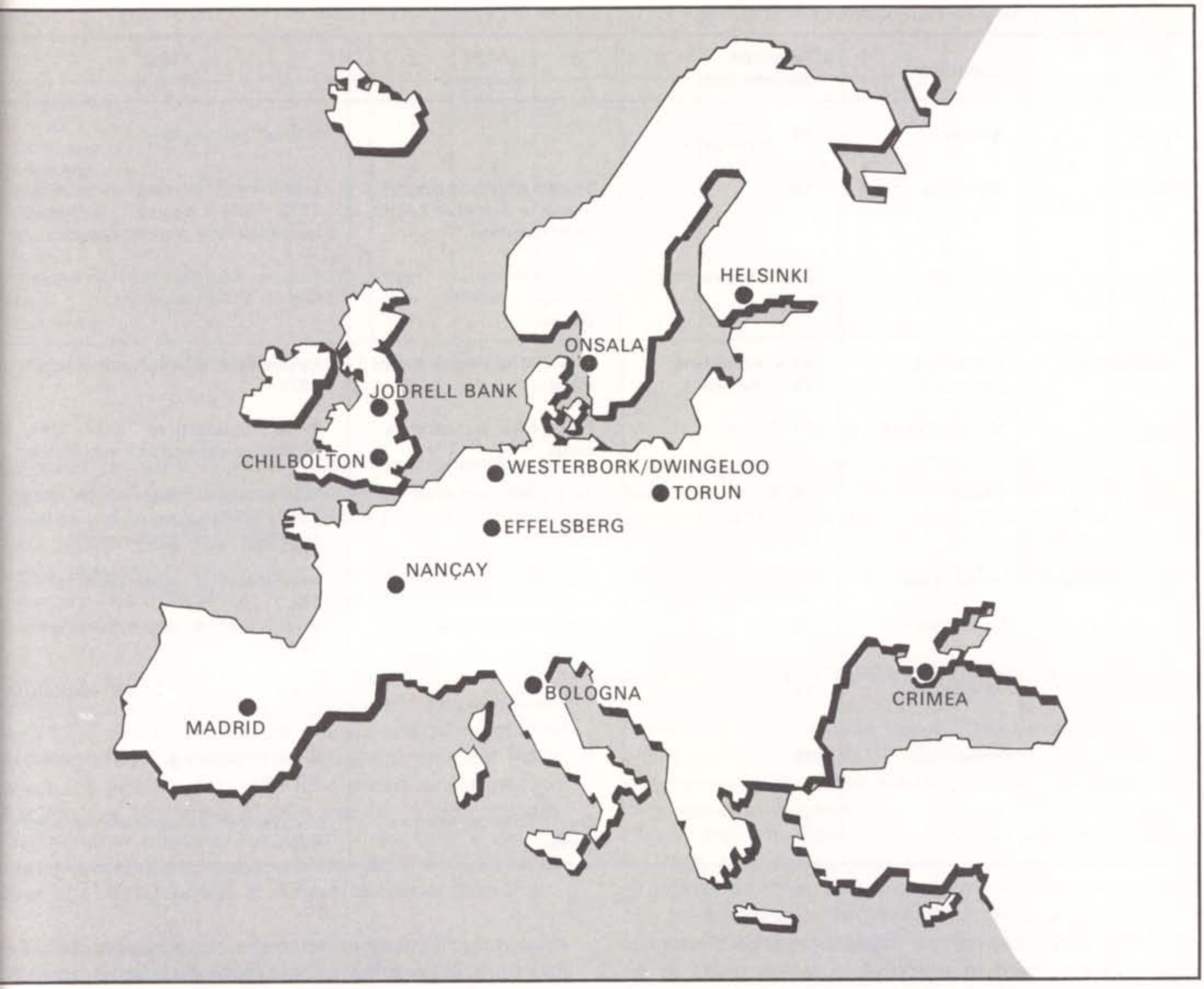


Figure 1 – Observatories that could take part in VLBI observations.

tests have already been carried out using the CTS satellite to link a radio observatory in the USA with one in Canada.

Although remarkably high resolutions have already been achieved with the existing technology, a number of problems have limited VLBI's full exploitation, namely:

- The logistics of distributing and processing the large number of magnetic tapes, with the time- consuming replaying very often taking much longer than the observations themselves (particularly for multiple baselines).
- The lack of real-time information on the performance of the telescope array because the correlations are made weeks, or even months, after the observations. Consequently, there is no possibility to make changes in the observing programme to compensate for problems in array operation or to follow up interesting results obtained early in the programme.
- The absence of adequate phase stability in the independent local oscillators prevents the formation of true images on milliarcsec to tenth-arcsec scales. This lack of stability has also prevented the full potential of VLBI for geodetic and astrometric work from being realised.
- The small bandwidth recorded (2 MHz) limits sensitivity for continuum observations.

POSSIBLE DEVELOPMENTS IN VLBI TECHNOLOGY

An improved tape-recorder system, using instrumentation

TABLE 1a. *Summary of Potential VLBI Facilities*

Country	Observatory	Telescope diameter (m)	VLBI equipment	VLBI activities
France	Nançay	94 (equivalent diameter)	–	Interest, but no plans.
Germany	Effelsberg	100	Three 2 MHz recording terminals; a 3-station 2 MHz VLBI correlator	Involvement in observations since 1973. Will procure an instrumentation tape-recorder terminal.
Italy	Bologna	25, 25,8 (proposed)	Instrumentation tape-recorder terminal (proposed)	Proposal submitted to Italian authorities for a VLBI capability.
Netherlands	Westerbork/ Dwingeloo	93.5 (equivalent 25 diameter)	One 2 MHz recording terminal	Involvement in observations since 1976.
Spain	Madrid (NASA)	64, 26, 26	One 2 MHz recording terminal	Some observations with USA. Available observing time very limited.
Sweden	Onsala	26, 20	Two 2 MHz recording terminals	Involvement in observations since 1969. Will procure an instrumentation tape-recorder terminal.
United Kingdom	Jodrell Bank	76, 25, 25	One 2 MHz recording terminal	Involvement in observations since 1967.
	Chilbolton	26	One 2 MHz recording terminal	Involvement in observations since 1973.
Finland	Helsinki	15	–	Plans to build a 2 MHz recording terminal.
Poland	Torun	15	–	Plans to borrow a 2 MHz recording terminal.
USSR	Crimea	22	One 2 MHz recording terminal	Involvement in observations since 1968.

recorders and more stable independent oscillators, is under development in the USA, and the gains to be expected are threefold:

- Bandwidth can be greatly increased, to 56 MHz or perhaps 112 MHz, giving an order of magnitude or more improvement in sensitivity.
- The stability of modern hydrogen-maser oscillators is such ($\Delta\upsilon/\upsilon \sim 10^{-15}$) that the main source of phase error on time scales of an hour is due to atmospheric path-length variations from the radio source to the telescope, rather than local oscillator instabilities.
- A suitable real-time check on the performance of the various interferometer elements is possible by observing a strong source at the beginning of a session and transmitting the data via conventional commercial telephone lines using limited bandwidth.

There nevertheless remain two major deficiencies in the use of such a system for a major VLBI facility.

The first is the logistic problem of transporting the large volume of magnetic tape to the processing centre and the subsequent redistribution to the observatories. In a full day's operation at maximum bandwidth (tape speed 120 inch/s), 144 tapes will be recorded per station. Not all recordings will be made at maximum bandwidth (e.g. spectral line observations), but over 2000 tapes per week will still have to be redistributed from the processing centre for a five-station network. Although it may be possible to organise this aspect efficiently enough to make it essentially invisible to the user scientist and to provide calibrated data within a week or so, such logistics must be seen as a major handicap in the use of tape recorders for a full-time research facility. Their part-time use for a few years is nevertheless seen as an essential step in understanding the problems associated with a satellite-linked VLBI system.

The second shortcoming of the independent-station VLBI system is the insufficient stability of the independent local oscillators for geodetic and astrometric work. To make full use of the potential of VLBI, the interferometer phase must be measured with an accuracy of less than ~1 rad. For the imaging of radio-source structures, it may be

TABLE 1b. *Wavelengths of the Radio-Astronomy Receivers at The Various Observatories in Europe*

(cm)	1.3	2	3	4	5	6	13	18	21	50	75	100
Chilbolton	+		+			(+)						
Crimea	+		(+)			(+)						
Dwingeloo			?			+		+	+		(+)	(+)
Effelsberg	+	+	+	(+)		+	(+)	+	+			+
Helsinki	+											
Jodrell Bank	+		(+)			+	+	+	+	+	+	+
Madrid (NASA)		+		+			+					
Nançay								+	+			
Onsala	+			+	+	+	+	+	?			
Torun						(+)		(+)	?			
Westerbork			?			+		(+)	+	+		(+)

+ available (+) will be available ? may be available

sufficient to make relative phase measurements with respect to a nearby unresolved source often enough to calibrate phase excursions due to the oscillators and the atmosphere. The new hydrogen-maser oscillators are stable enough for this type of measurement, although there may be difficulties in finding appropriate nearby reference sources.

However, to place the radio structure on the sky with milliarcsec accuracy, and to make geodetic measurements with 1 cm accuracy, absolute phase must be maintained for the period over which the measurements are made, which is typically a day. Hydrogen-maser oscillators have stabilities of 10^{-15} over 1000 s and 10^{-14} over one day. The nominal phase accuracy of 1 rad over a day, at centimetre and decimetre wavelengths, requires stabilities one to two orders of magnitude better than this.

A VLBI system in which a geostationary satellite is used as a communications link for clock synchronisation and for wideband signal transmissions in real-time, can overcome the two deficiencies just noted; it obviously overcomes the logistic problems involved in returning a large volume of magnetic tape to the Data Processing Centre and the subsequent redistribution, but it also allows the phase of the oscillators at each station to be monitored continuously, an important factor.

A satellite-linked system must be considered a major new instrument capable of work of great value in astrophysics, geophysics and astrometry. The requirements for such a system are:

- a space segment consisting of a geostationary satellite carrying VLBI communications' transponders with a capacity of up to 1000 MHz for up to ten wideband signal transmissions and for clock synchronisation;
- a ground segment consisting of up to ten radio telescopes, each with a ground station, as well as a Data Processing Centre with its own ground station.

The space segment can be considered in terms of (i) the host satellite, and (ii) use of the satellite link for clock synchronisation and signal transmission. The ground segment can be divided into three sections: (i) radio observatories, (ii) ground stations, and (iii) the Data Processing Centre.

POSSIBLE VLBI OBSERVATORIES IN EUROPE

Figure 1 shows the radio observatories in Europe which could be used for VLBI observations, while Table 1 summarises the facilities available and the VLBI activities in progress or planned, on a country-by-country basis. Clearly, from the tables, there is strong interest in Europe in VLBI techniques, and there is a solid nucleus of expertise, facilities and measurement programmes that can be drawn upon in the setting up of a co-ordinated European VLBI programme using space techniques.

The baseline geometry presently available in Europe is an important feature of the network, lending itself well to the mapping of small-scale radio structures once the phase can be satisfactorily measured. Referring again to Figure 1, it can also be seen that the baselines connect many of the countries in Europe so that accurate determinations of their lengths and orientations would be a very useful contribution to a unified global reference system to which all national and continental data could be related.

STEPS TOWARDS AN OPERATIONAL SATELLITE-LINKED VLBI SYSTEM

There is a considerable amount of technical development to be done and experience to be gained in using the new equipment and in handling the data. In both the technical and data-handling areas, considerable software effort will be needed early in the development of the system.

There are a number of preliminary steps to be taken which would be invaluable in improving the performance of the final VLBI system.

Step 1: Two stations with linked local oscillators
Evaluation of the clock-synchronisation scheme using a 40 or 120 MHz channel on the Agency's OTS satellite and simple ground stations would constitute the first step. Preparation for such an evaluation is already in the early planning stages. Each observatory needs to procure ground-station equipment and satellite time is required for testing clock synchronisation, and of course for subsequent astronomical and geophysical measurements. OTS would be used from time to time in this step.

Step 2: Four or five stations with linked local oscillators
When the two-station local-oscillator synchronisation is operational, it should be expanded to four or five stations for improved image-forming capability and to allow significant geodetic and astrometric measurements to be made. One central station (not yet designated) can record the phases of the out-station oscillators. The 2 MHz recorders can continue to be used until Step 3.

This step constitutes the first operational phase for a satellite-linked system and significant science can be conducted. If the interferometer phase can be maintained for the full track of a radio source, an improvement in sensitivity by a factor of 10 to 15 can be expected purely on the basis of longer coherent integration times (12 h versus 5 min).

At this stage, experience must be gained in correcting for the effects of troposphere and ionosphere on phase during the path from radio source to radio telescope, which is likely to be the ultimate limit on the accuracy of VLBI for astronomical, geodetic and astrometric measurements.

Step 3: Linked local oscillators with wideband instrumentation tape recorders
By 1980 – 81 at least two observatories in Europe are expected to have wideband recording terminals compatible with the American system now under development, namely the observatories of Effelsberg and Onsala. Dwingeloo/Westerbork may also possibly obtain a terminal. These new terminals would replace the 2 MHz recorders entirely by end 1982, and continue in use until launch of the first satellite carrying a wideband VLBI transponder. Initially, correlation would have to be done in the USA, until the European Data Processing Centre were available (Step 4).

Step 4: Design and building of the Data Processing Centre
At the time when the wideband instrumentation recorders come into use in Europe, there will be a need for a processing centre to correlate the wideband signals, from the tape recorders and from the satellite down link. Detailed design could begin in 1980, with the end of 1982 as the target date for building completion.

Step 5: Signal transmission and clock synchronisation via satellite
The design and construction of the VLBI transponder should be geared to allow a launch by 1985, and thereafter operation of the VLBI system in Europe would be via a satellite link for both wideband signals and clock synchronisation. It is anticipated that the extra telescopes would gradually be incorporated into the system during the first year of operation.

Step 6: Dedicated radio-telescope network
The final phase of a satellite-linked VLBI system would be to have a fully dedicated system on the ground as well as a dedicated transponder in space. New telescopes could be built at optimum locations, and these would be available continuously for VLBI system operations. Such investment would only be made if there were to be a continuing space segment extending beyond the one launch of a dedicated transponder.

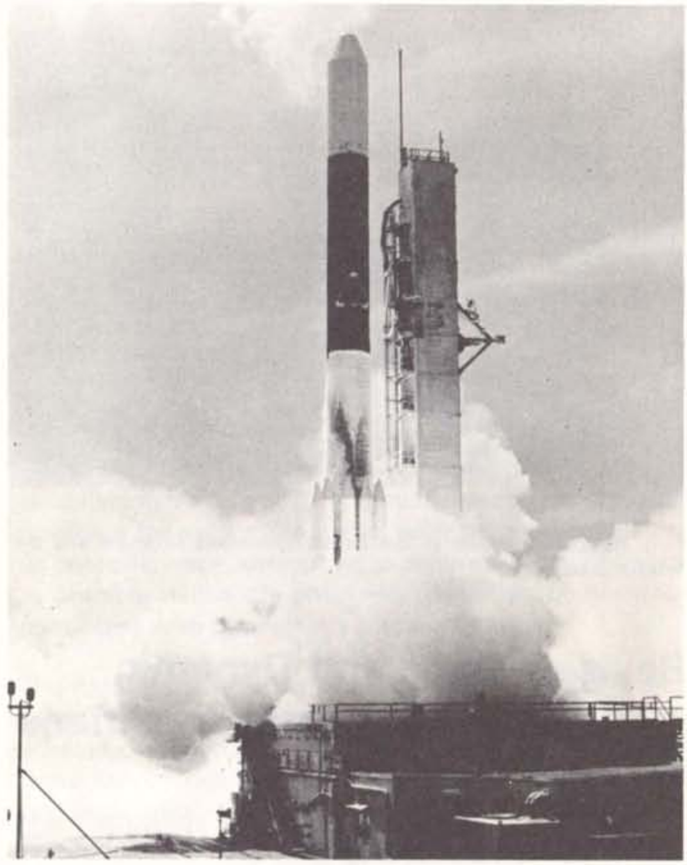
The first series of experimental measurements using a clock-synchronisation scheme via satellite in conjunction with tape recordings of the data could be carried out on a part-time basis using a geostationary satellite already in orbit or in the planning stage, with OTS as first choice. OTS's position at 10°E longitude and its Eurobeam coverage of Europe make it a preferred candidate. Astronomers and geophysicists would already like to start using OTS on an intermittent basis, and significant new radio-astronomy observations could be performed after the first phase of tests, before the end of 1980. □

In Brief

ESA Technical Director Appointed

At its 27 July meeting, the ESA Council took the decision to create a new post of Technical Director of the Agency, to be located at ESTEC and combining the functions of Director ESTEC with the major part of those of the Agency's Technical Inspector. The Council also nominated Professor Massimo Trella, the then Technical Inspector, to this new post with effect from 1 August. □

ISEE-3 Launched



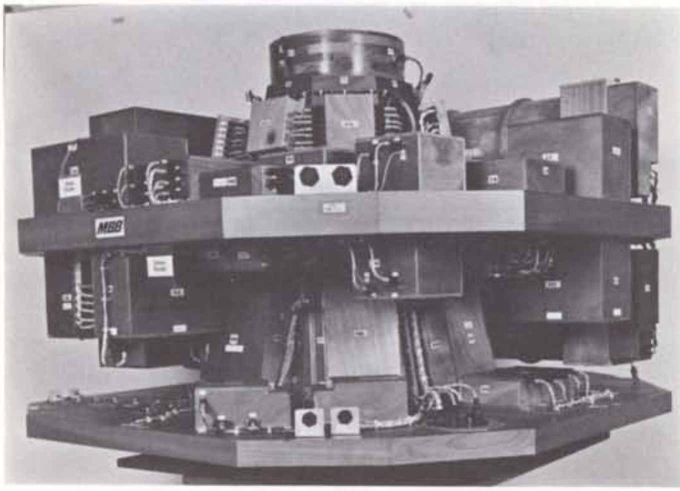
Launch of ISEE-3 from Cape Canaveral on 12 August, at 11.12 am EDT, aboard a Delta-144 vehicle.

ISEE-3, the US satellite that forms the third element of the ISEE programme, was launched from Cape Canaveral on 12 August. ISEE-1, supplied by NASA, and ISEE-2, developed and built by ESA, were launched in tandem on 22 October last year into a highly-eccentric orbit and have already been supplying novel data on magnetospheric phenomena, their fluctuations, their effects on the Earth's environment and, in particular, their velocity and directional characteristics in space and the separation of spatial from temporal variations. (The preliminary results from ISEE-1 and 2 and are described on page 23 of this issue).

A scientific requirement for ISEE-3 is that it should observe the solar-wind conditions that subsequently affect the magnetosphere from a point far enough away from the Earth not to observe waves and/or particles generated by or reflected from the magnetosphere, and on this basis this third spacecraft falls into a different orbital category from its highly-eccentric orbiting sister satellites.

ISEE-3 is therefore stationed in a halo orbit between the Sun and the Earth at a libration point, 1 500 000 km from Earth, where the various interplanetary forces balance.

Three European experiments form part of ISEE-3's payload, namely:
- an investigation of protons in interplanetary space (Imperial College, London/Space Research Laboratory, Utrecht, Netherlands/Space Science Department of ESA)
- a study of the composition of solar particles (Max-Planck Institute, Garching, Germany)
- a study of magnetic field-lines emanating from the Sun (Paris Observatory, Meudon, France). □



Early wooden mock-up of the Exosat spacecraft structure and the satellite subsystems.

Revised Static and Dynamic Acceleration Loadings for Ariane

As a result of an editorial oversight, the combinations of low-frequency static and dynamic accelerations quoted for critical flight events during an Ariane launch in the last issue of the Bulletin (No. 15, top of page 42) were not the latest figures available. For the benefit of those of our readers expressly interested in this aspect of Ariane's performance, an updated version of the table concerned is repeated below:

Development Contract for Exosat entrusted to COSMOS Consortium

The contract for the development (Phases C and D) of the scientific satellite Exosat, worth a total of 46.5 MAU, has been awarded to the European COSMOS Consortium, led by Messerschmitt-Bölkow-Blohm of Germany, with ETCA (Belgium), Aérospatiale (France), Marconi Space and Defence Systems (United Kingdom) and Selenia (Italy) as co-contractors.

Exosat, a three-axis-stabilised orbital observatory able to measure the position, structures and spectral and temporal characteristics of X-ray sources, will carry four experiments – two imaging telescopes for low-energy X-rays, and a large-area proportional counter array and a gas-scintillation spectrometer for medium-energy X-rays – developed mainly by European industry under the direction of ESA's Space Science Department, with the collaboration of the Max-Planck Institute (Germany), Mullard Space Science Laboratory and Leicester University (UK), the University of Palermo and the National Research Council, Milan (Italy), the Cosmic Ray Working Group of Leiden and the Utrecht Space Research Laboratory (Netherlands), and ESA's own High-Energy Astrophysics Division of Space Science Department.

Exosat will be launched in the second quarter of 1981 on an Ariane vehicle. □

TABLE 1 – *Low-Frequency Static and Dynamic Accelerations*

Flight events	**Longitudinal axis** (g)			**Lateral axis** (g)		
	Static	Dynamic	Total	Static	Dynamic	Total
Maximum dynamic pressure (85th second)	−1.9	±1.5	−3.4	±0.1	±1.9	±2.0
First-stage burnout	−4.3	±1.5	−5.8	±0.2	±1.5	±1.7
Second-stage burnout	−4.7	±2.0	−6.7	±0.4	±1.5	±1.9

CONTINUED FROM PAGE 67

It does not, by definition, cover the risks related to the launching and it comes into effect either upon termination of the prior launch policy or upon the spacecraft's achieving its designated orbit under the required conditions.

This kind of insurance is relatively recent, the first policy not being issued until 1976 in the United States. ESA is considering this insurance for its future projects and activities, but has not so far needed to cover itself against this type of risk.

With regard to the definition of such a policy, a particularly relevant consideration is the point in time at which a failure occurs. In the case of a satellite with a seven-year lifetime failing in its third year, insurance payment for a full replacement having a capacity of another seven years would allow the insured to benefit from a further three years of operational capacity beyond his original expectations. In principle, therefore, the insured sum reduces during the life of the policy.

The other relevant consideration is the definition of partial failure (which in certain cases might also be pertinent to the launch policy if that insurance includes coverage for certain failures for several weeks after launch!). In the case of communications satellites, partial failure can be defined on the basis of the proportion of malfunctioning transponders. If, for example, one transponder were to fail but the satellite were still capable of fulfilling its role entirely with the remaining capacity, no insurance compensation could be expected.

Some essential factors to be taken into account when considering in-orbit insurance for commercial satellites are:

- When does the loss of a transponder or channel result in loss of revenue?
- What proportion of the insured sum is properly payable in relation to the failure identified?
- At what point does the satellite cease to be profitable, i.e. when is it to be considered a total loss?

The rates chargeable for in-orbit insurance are of course very much dependent on the nature of the particular satellite. At present, coverage of the first three years of operation attracts a premium of between 5 and 6%; subsequent periods can be covered at a later stage, possibly at similar rates, depending on the expected future performance at the time of extension.

FUTURE PROSPECTS FOR SATELLITE INSURANCE

There is no doubt that satellite insurance will play an increasingly important role in the coming years as far as ESA is concerned, particularly in view of certain forthcoming operational programmes. Close contact has already been established with the highly specialised insurance market and the recurring task is one of establishing the criteria for the most appropriate insurance coverage for each programme, with particular emphasis on cost efficiency, attempting to minimise premiums as far as possible whilst still obtaining the maximum coverage consistent with the Agency's requirements.

The natural trade-off is, of course, between the launch reliability on the one hand and the nature of the insurance scheme on the other. The effective premium for Thor-Delta launchings of 7.2%, for example, reflects their statistical reliability, which is around 93%. The direct effect of the OTS-1 explosion was an increase of less than 10% in effective premium. This implies that the original charge was most reasonable and could not be reduced further under a simple one-launch insurance scheme. A further reduction in premiums is only possible by covering a series of launchings. For three satellites for a given operational system, for example, one could question whether the possibility of every launch being a failure is not so remote as to make it unjustified to insure against having to pay for three new satellites, the premium normally being assessed on the total insured value.

One attractive alternative is to insure all planned launches in such a way that only one failure would be reimbursed. Another alternative is to assume responsibility for the first failure, so that only the second and any subsequent failures would be reimbursed by the insurers ('excess of one failure deductible' scheme). It is only by developing such schemes that substantial savings on premiums will be possible. □

ESA Publications

The documents listed here have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table inside the back cover and using the Order Form on page 87.

ESA Journal

The following papers were published in Vol. 2, No. 2:

Uranie et Cassandre: La coopération européenne dans l'Espace/Urania and Cassandra: European Co-operation in Space, *by H. Curien*

Material Sciences in Space, *by G. Seibert*

ESA's Field-Emission Electric Propulsion Programme, *by H.A. Pfeffer, C. Bartoli & H. von Rohden*

The European Synthetic-Aperture-Radar (SAR) Processor for Seasat- A, *by J.P. Guignard*

Trajectory Analysis for Interplanetary Missions, *by J.W. Cornelisse*

Etude paramétrique d'un amortisseur d'extrémité contenant deux liquides non miscibles faiblement visqueux, *by H.T. Huynh*

Clock Recovery from a Nonlinear Channel, *by F.M. Gardner*

ESA Reports

SPECIAL PUBLICATIONS

ESA SP-134 *EARTH OBSERVATION FROM SPACE AND MANAGEMENT OF PLANETARY RESOURCES/ OBSERVATION SPATIALE DE LA TERRE ET GESTION DES RESSOURCES TERRESTRES, PROC INTERNAT CONF TOULOUSE, FRANCE, 6-11 MARCH 1978 (JUN 1978)*
PLEVIN, J./HOOD, V./GUYENNE T.D. (EDS)
PRICE CODE E4

ESA SP-135 *EUROPEAN SOUNDING-ROCKET, BALLOON AND RELATED RESEARCH, WITH EMPHASIS ON EXPERIMENTS AT HIGH LATITUDES, PROC CONF AJACCIO, CORSICA, 24-29 APRIL 1978 (JUN 1978)*
HALVORSEN T./BATTRICK B./ROWLEY C. (EDS)
PRICE CODE C3

ESA SP-136 *FIRST ESTEC SPACECRAFT ELECTROMAGNETIC COMPATIBILITY SEMINAR, PROC SEMINAR NOORDWIJK, THE NETHERLANDS, 24-26 MAY 1978 (JUL 1978)*
BACHMANN H./BATTRICK B./ROWLEY C. (EDS)
PRICE CODE C2

ESA SP-137 *SPACE OCEANOGRAPHY, NAVIGATION AND GEODYNAMICS ('SONG'), PROC EUROPEAN WORKSHOP SCHLOSS ELMAU, GERMANY, 16-21 JANUARY 1978 (APR 1978)*
HIEBER S./GUYENNE T.D. (EDS)
PRICE CODE C2

ESA SP-1007 *REPORT PRESENTED BY THE EUROPEAN SPACE AGENCY TO THE 21ST COSPAR MEETING, INNSBRUCK, AUSTRIA, JUNE 1978 (APR 1978)*
WILLS R.D./BURKE W.R. (EDS)
PRICE CODE E2

ESA SP-1008 *ESA SATELLITE CHECKOUT – INTRODUCTION (JUL 1978)*
DATA HANDLING AND SIGNAL PROCESSING DIVISION, ESTEC/TMTR SERVICES LTD., UK
NO CHARGE

ESA SP-1009 *CATALOGUE OF ESA PUBLICATIONS IN 1977 (SEP 1978)*
BATTRICK B. (ED)
NO CHARGE

ESA SP-1010 *APPLICATIONS OF EARTH RESOURCES SATELLITE DATA TO DEVELOPMENT AID PROGRAMMES (SEP 1978)*
PLEVIN J./GUYENNE T.D. (EDS)
PRICE CODE C1

SCIENTIFIC AND TECHNICAL MEMORANDA

ESA STM-201 *A COMPUTER PROGRAM FOR THE SIMULATION OF THE REPLENISHMENT PROCEDURE FOR A SATELLITE BASED COMMUNICATION SYSTEM (APR 1978)*
VIEHMANN H./KRISTENSEN B.L.
PRICE CODE C1

ESA STM-203 *ELECTROSTATIC SIMULATION TEST OF THE IMPROVED OUTER ALUMINISED KAPTON LAYER AS PROPOSED FOR THE OTS VHF SHIELD (APR 1978)*
BOSMA J.
PRICE CODE E1

ESA STM-204 *EVALUATION OF A CONDUCTIVE ADHESIVE SYSTEM FOR THE GROUNDING OF ALUMINISED KAPTON TAPE (JUN 1978)*
BOSMA J./FROGGATT M./GOURMELON G.
PRICE CODE C1

ESA STM-205 *HYBRID ANALOG COMPUTER TECHNIQUES: THEIR USE IN DESIGNING AND ASSESSING THE PERFORMANCE OF NONLINEAR TRANSMITTERS UNDER MULTICARRIER OPERATION (APR 1978)*
BLANKE M./MCELHONE T.P.
PRICE CODE C1

SCIENTIFIC AND TECHNICAL REPORTS

ESA STR-201 *A HEAT-TRANSPORT SYSTEM EMPLOYING A VAPOUR-PRESSURE PUMP (JUN 1978)*
TAMBURINI P.
PRICE CODE C1

PROCEDURES, STANDARDS AND SPECIFICATIONS

ESA PSS-30 (ISSUE 1) (FRENCH VERSION) *REDACTION DES GAMMES D'OPERATIONS (JAN 1978)*
DIVISION STRUCTURES ET CONTROLE THERMIQUE DE L'ESTEC
PRICE CODE C1

ESA PSS-45/TTC.A.01 (ISSUE 1) *PCM TELECOMMAND STANDARD (APR 1978)*
DATA HANDLING AND SIGNAL PROCESSING DIVISION, ESTEC
PRICE CODE C1

ESA PSS-46/TTC.A.02 (ISSUE 1) *PCM TELEMETRY STANDARD (APR 1978)*
DATA HANDLING AND SIGNAL PROCESSING DIVISION, ESTEC
PRICE CODE C1

CONTRACTOR REPORTS

ESA CR(P)-959 *MINIMETSAT (MMS) – PREFEASIBILITY STUDY. PART 1: SUMMARY (APR 1977)*
MBB, GERMANY

ESA CR(P)-961 *MODIFICATION OF THE LOUVER ACTUATOR SYSTEM DEVELOPED UNDER ESTEC CONTRACT NO 1550/71 HP (MAR 1977)*
PETER REUSSER AG, SWITZERLAND

ESA CR(X)-964 *ETUDE D'AMELIORATION D'ALIMENTATION DU SOUS-SYSTEME ELECTRIQUE POUR LE SECOND MODELE DE VOL DU SATELLITE 'METEOSAT' / VOLS 1 AND 2 (JUIN 1977)*
ETCA, BELGIUM

ESA CR(X)-965 *STUDY OF THE LIFETIME OF NICD CELLS FOR SPACE USE – FINAL REPORT (JUN 1977)*
NAT DEFENCE RES INST, SWEDEN

ESA CR(P)-968 *RAPPORT D'ETUDE D'UN DEMODULATEUR POUR UN DECODEUR DE TELECOMMANDE EMBARQUE (JUIN 1977)*
THOMSON-CSF, FRANCE

ESA CR(X)-982 *STUDY OF SPAMAC/CAMAC INTERFACE FOR THE SPACELAB PROGRAM (OCT 1976)*
OESTERREICH STUDIENGES F ATOMENERGIE GMBH, AUSTRIA

ESA CR(X)-987 ACCELERATED LIFE TEST ON A TELDIX DOUBLE-GIMBALLED MOMENTUM WHEEL (DEC 1976)
ESTL-UKAEA, UK

ESA CR(X)-995 *PRELIMINARY WORK TO MODIFY AN EMI 4-STAGE IMAGE INTENSIFIER TO BE SUITABLE FOR SPACEBORNE ASTRONOMICAL INSTRUMENT ON L.S.T. (MAY 1977)*
EMI ELECTRONICS LTD., UK

ESA CR(P)-996 *THE OPTIMISATION OF SATELLITE TRAJECTORIES/VOL 1: STUDY REPORT/VOL 2: THEORY/VOL 3: PROGRAMME DESCRIPTION AND USER'S GUIDE (AUG 1977)*
HSD, UK

ESA CR(P)-997 *LIFE TESTS OF THE TELECOMMUNICATIONS SATELLITE HEAT PIPES (JUL 1977)*
IKE, GERMANY

ESA CR(P)-998 *FIELD EMISSION ELECTRIC PROPULSION SYSTEM STUDY – FINAL REPORT VOLS 1 AND 2 (SEP 1977)*
SEP, FRANCE

ESA CR(X)-999 *PARALLEL DISCHARGE OF NICD BATTERIES – FINAL REPORT (JUN 1977)*
FOA, SWEDEN

ESA CR(P)-1003 *ETUDE DE LA MESURE DU BILAN RADIATIF*

ATMOSPHERIQUE PAR L'INTERMEDIAIRE DE LA PRESSION DE RADIATION (JUL 1977)
MET NAT/ONERA/CERGA, FRANCE

ESA CR(P)-1005 *A SURVEY ON ROUNDING EFFECTS IN FLOATING-POINT ARITHMETIC (MAY 1977)*
ACM SCHAENIS AG, SWITZERLAND

ESA CR(X)-1006 *ETUDE DE SYNTHESE DES ACTIONS DE PROPRETE ENGAGEES POUR LA REALISATION DU RADIATEUR CRYOGENIQUE PASSIF DU RADIOMETRE DU SATELLITE METEOSAT (AOUT 1977)*
BERTIN ET CIE, FRANCE

ESA CR(P)-1007 *REACTIVE DOWN CONVERTERS WITH CLOSE INPUT AND OUTPUT FREQUENCIES (MAY 1977)*
GTE TELECOMUNICAZIONI SPA, ITALY

ESA CR(P)-1012 *THERMAL CYCLING TESTS ON SOLAR CELL PANEL SAMPLES UNDER VACUUM CONDITIONS (JAN 1977)*
DFVLR, GERMANY

ESA CR(P)-1013 *ETUDE PRELIMINAIRE D'UN ENREGISTREUR DE DONNEES D'UNE MEMOIRE A BULLES MAGNETIQUES (OCT 1977)*
LETI – CENTRE D'ETUDES NUCLEAIRES DE GRENOBLE, FRANCE

ESA CR(P)-1014 *EVALUATION DU MARCHE ACCESSIBLE A L'INDUSTRIE SPATIALE EUROPEENNE (JUIN 1977)*
EUROSPACE, FRANCE

ESA CR(P)-1019 *LES SERVICES NOUVEAUX DE TELEVISION ENVISAGEABLES EN EUROPE A L'AGE DU SATELLITE DE TELEVISION DIRECTE/VOLS 1 ET 2 (SANS DATE)*
EUROSPACE, FRANCE

ESA CR(P)-1020 *APPLIED RESEARCH PROGRAMME ON LUBRICATION OF TITANIUM BOLTS – REPORT ON IVD ALUMINIUM (OCT 1977)*
SPS LABORATORIES, IRELAND

ESA CR(P)-1021 *THERMAL VACUUM TEST ON A PROTOTYPE TELDIX DOUBLE-GIMBALLED MOMENTUM WHEEL (SEP 1977)*
ESTL/UKAEA, UK

ESA CR(P)-1022 *HIGHLY RELIABLE RANDOM ACCESS SEMICONDUCTOR MEMORY FOR THE ON-BOARD COMPUTER – FINAL REPORT (BREADBOARD MODEL) (AUG 1977)*
BAC, UK

TECHNICAL TRANSLATIONS

ESA TT-417 *EXPERIMENTAL AND THEORETICAL STRESS ANALYSIS OF A FIBER REINFORCED PLASTIC TENSILE SPECIMEN WITH A HOLE IN IT*
SCHUETZE, R./KHARADI, H., DFVLR, GERMANY

ESA TT-418 *INFLUENCE OF MICROSTRUCTURE ON FATIGUE CRACK PROPAGATION RATE OF ALUMINIUM ALLOYS*
ALBRECHT, J./LUETJERING, G., DFVLR, GERMANY

ESA TT-420 *THE INFLUENCE OF THE JOURNEY'S TIME OF DAY ON THE DE- AND RESYNCHRONIZATION OF THE 24-HOUR RHYTHM OF BODY AND TEMPERATURE AFTER TRANSATLANTIC FLIGHTS*
SONDERFELD, A., DFVLR, GERMANY

ESA TT-421 *ANALYTICAL SOLUTION OF THE GENERALIZED HELMHOLTZ WAVE EQUATION FOR COMPRESSIBLE SUBSONIC FLOW AND CALCULATION OF THE UNSTEADY PRESSURE DISTRIBUTIONS ABOUT OSCILLATING SPHEROIDS*
CHAO, K.-L., DFVLR, GERMANY

ESA TT-426 *UNSTEADY PRESSURE MEASUREMENTS ON WING-STORE COMBINATIONS IN INCOMPRESSIBLE FLOW*
TRIEBSTEIN, H., DFVLR, GERMANY

ESA TT-432 *SOME EXPERIMENTAL RESULTS ON SELECTIVE ABSORBING SURFACES FOR LOW TEMPERATURE SOLAR COLLECTORS*
GOERLER, G., DFVLR

ESA TT-437 *STRESS CORROSION AND REPASSIVATION BEHAVIOUR OF AUSTENITIC STAINLESS STEELS IN BOILING MGC12 SOLUTION*
BUHL, H./KUHN, P., DFVLR, GERMANY

ESA TT-438 *INTENSITY, ANGULAR DISTRIBUTION AND POLARISATION OF SPONTANEOUS MOLECULAR LIGHT SCATTERING*
STURSBERG, K., DFVLR, GERMANY

ESA TT-446 *LITHERGOL DUAL PROPULSION FOR CRUISE MISSILES*
LIPS, H./SCHMUCKER, R., DFVLR, GERMANY

ESA TT-448 *HYBRID PROPULSIVE SYSTEMS. TECHNOLOGY AND APPLICATION*
SCHMUCKER, R./LIPS, H., DFVLR, GERMANY

ESA TT-449 *INVESTIGATION ON THE DISTRIBUTION OF THE LIQUID IN AN EVAPORATING JET IN-*

JECTED PERPENDICULARLY TO AN AIR FLOW
BUSCHULTE, W., DFVLR, GERMANY

ESA TT-451 *INVESTIGATIONS ON CATALYTIC DECOMPOSITION OF HYDRAZINE-AMMONIA MIXTURES*
KOCH, H./KAEMPFER, F., DFVLR, GERMANY

ESA TT-452 *PRIMARY AND SECONDARY COMBUSTION CHAMBER IN COMBINATION PROPULSION WITH BORON AS PROPELLANT*
BOUSSIOS, A., DFVLR, GERMANY

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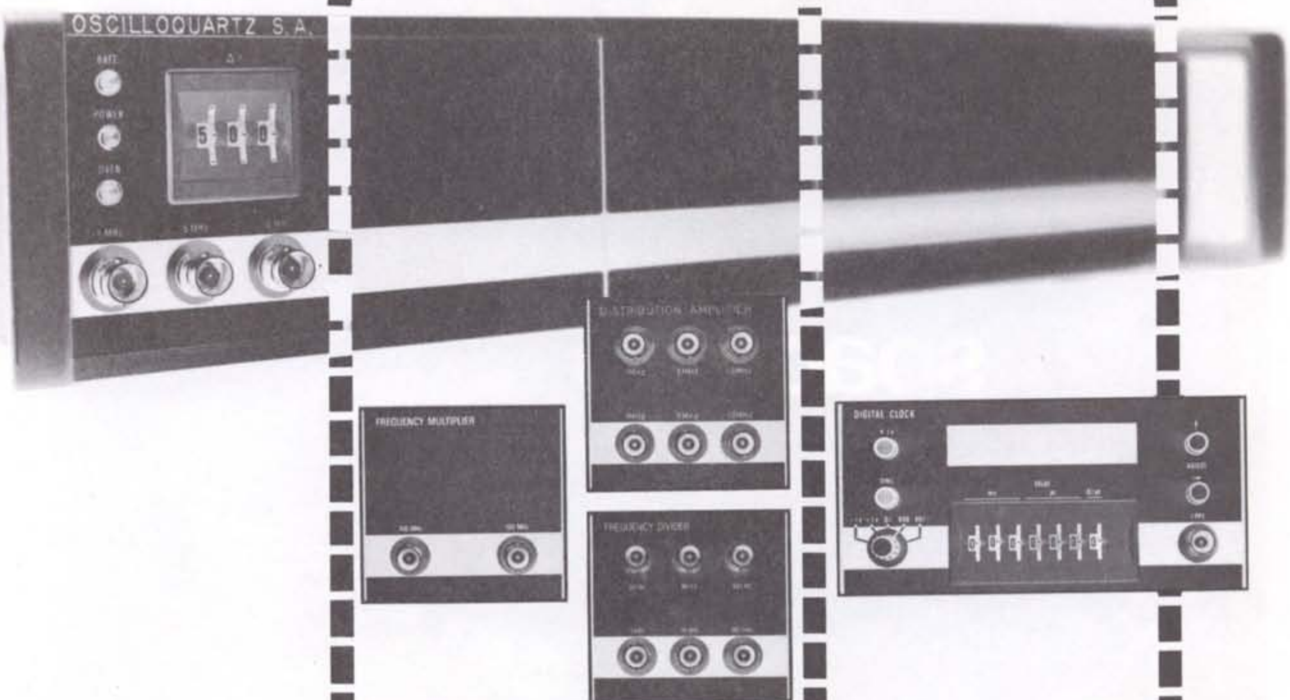

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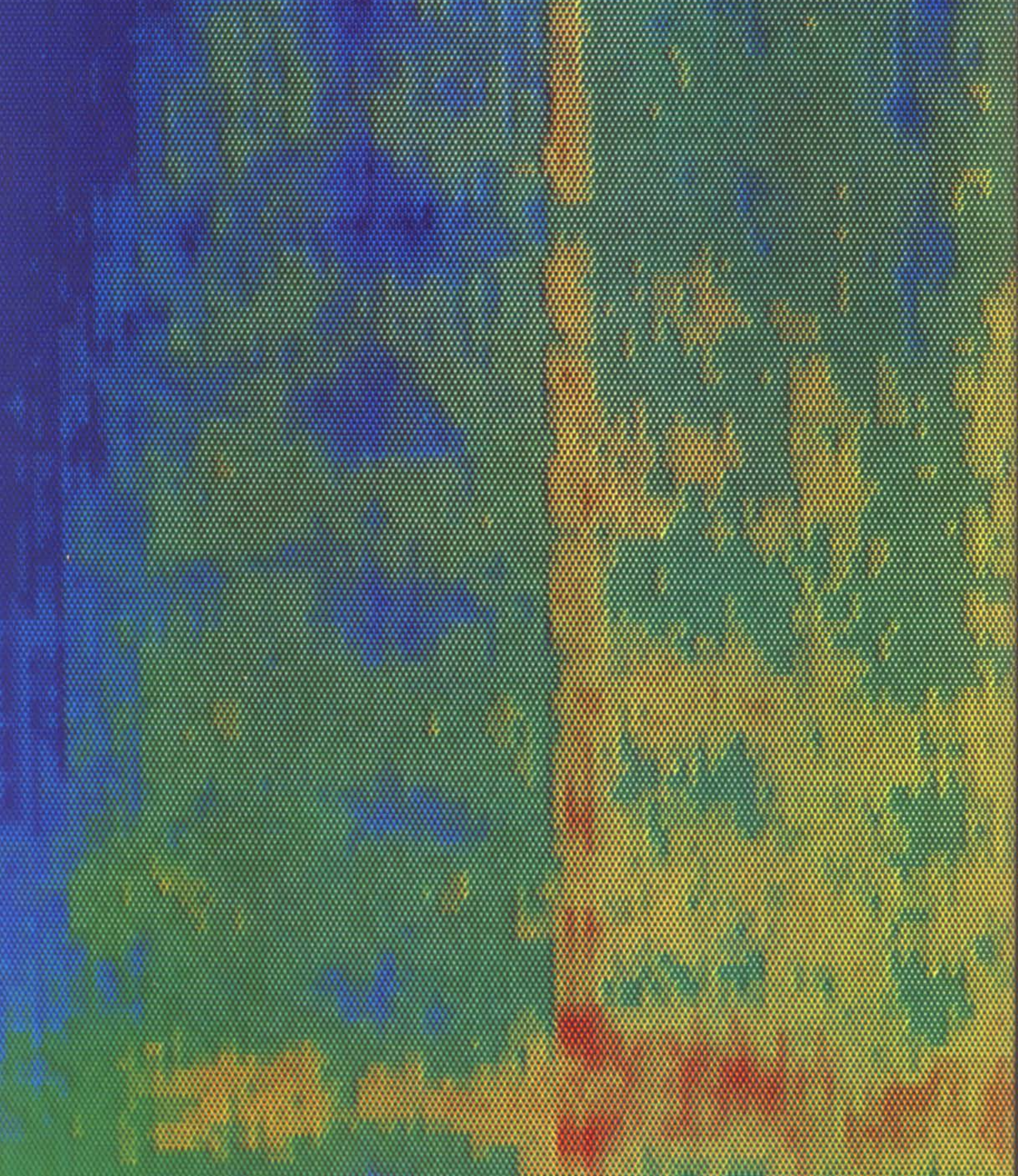

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