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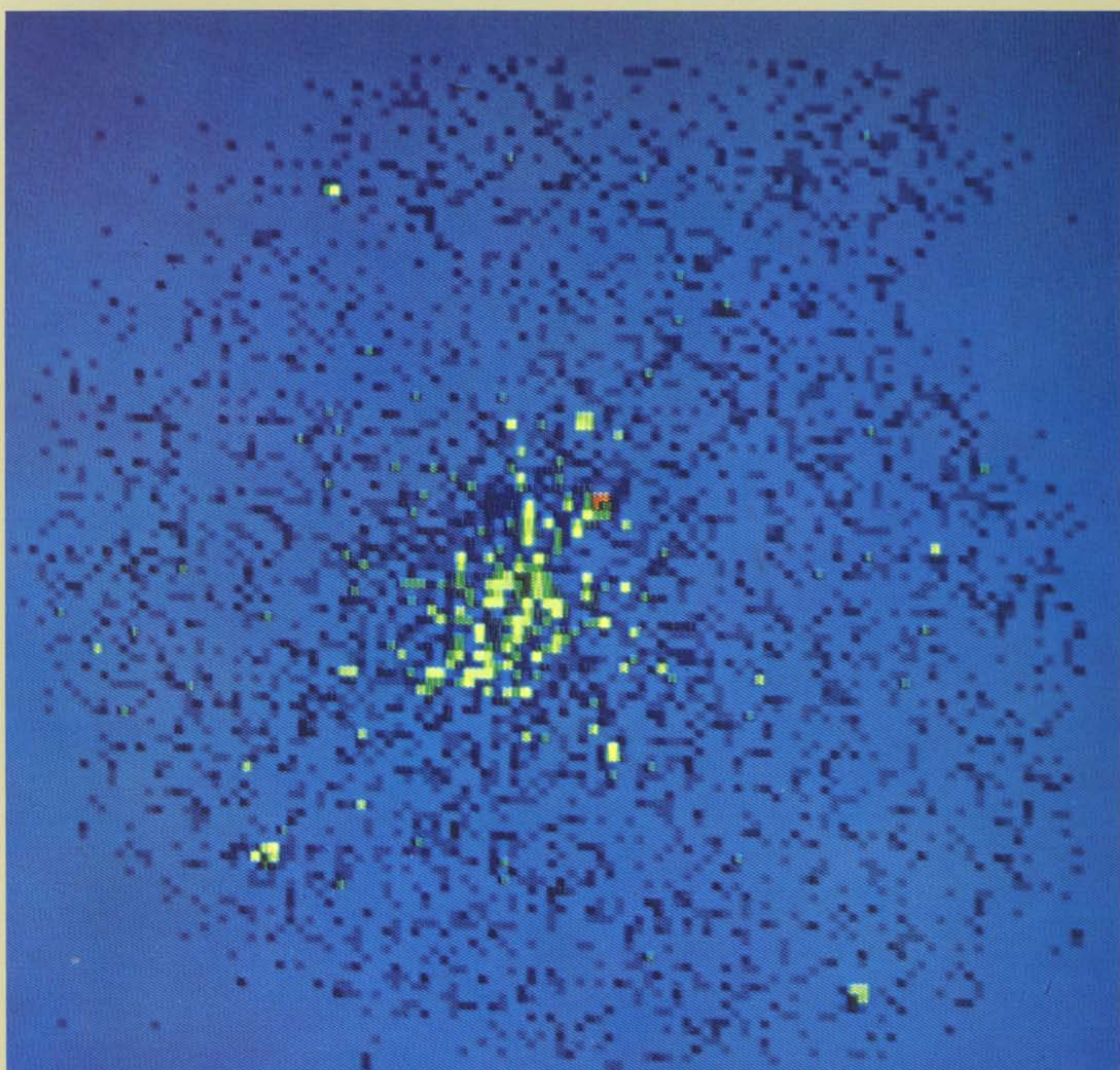

european space agency

The European Space Agency was formed out of, and took over the rights and obligations of, the two earlier European Space Organisations: the European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). The Member States are Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Ireland has signed the ESA Convention and will become a Member State upon its ratification. Austria, Canada and Norway have been granted Observer status.

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

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

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

The Directorate of the Agency consists of the Director General; the Director of Planning and Future Programmes; the Director of Administration; the Director of Scientific Programmes; the Director of Applications Programmes; the Director of the Spacelab Programme; the Technical Director and the Director of ESOC.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: Mr. J. Stiernstedt (Sweden).

Director General: Mr. R. Gibson.

agence spatiale européenne

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

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

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(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

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ESRIN, Frascati, Italie.

Président du Conseil: M.J. Stiernstedt (Suède).

Directeur général: M. R. Gibson.

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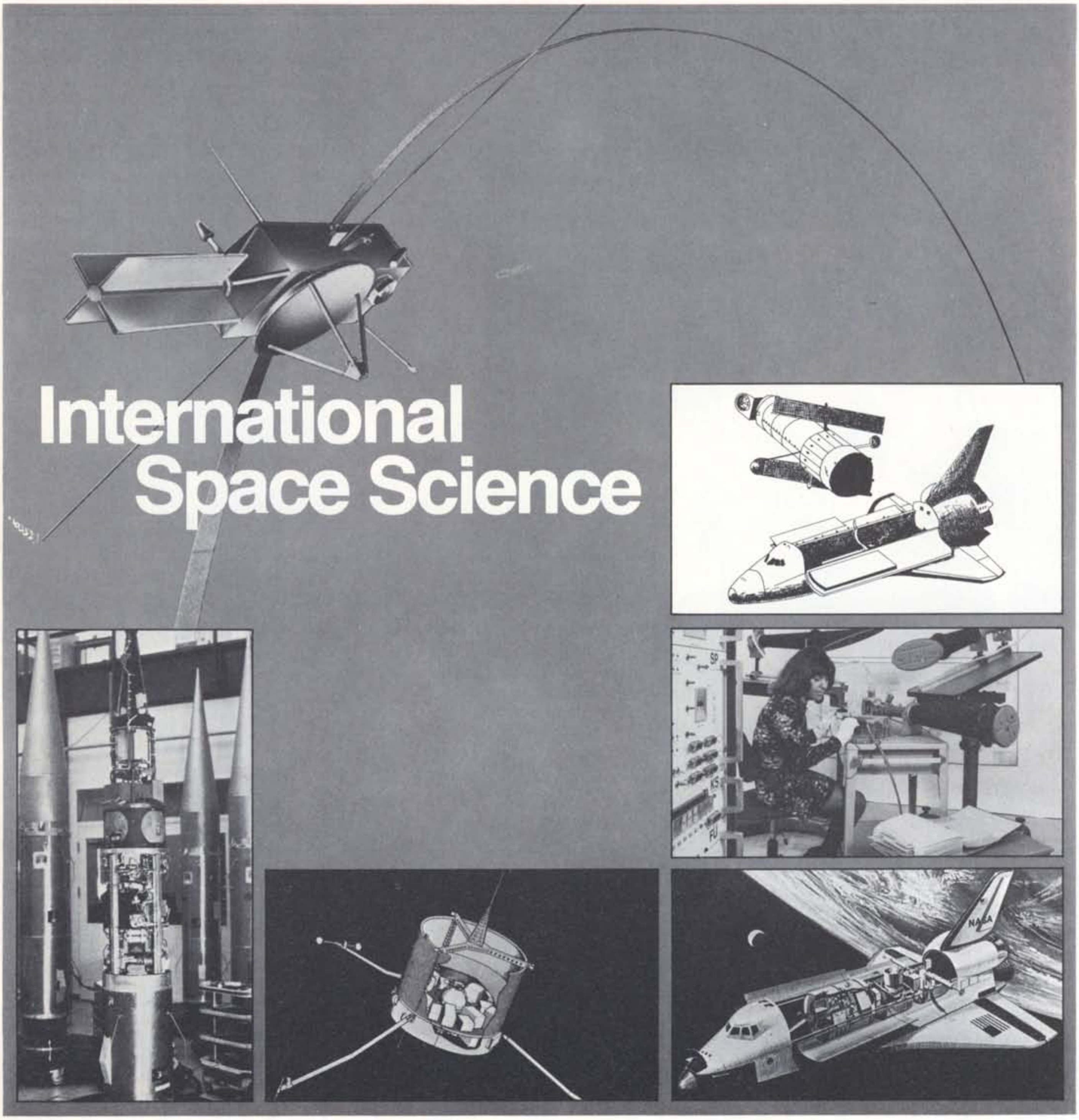

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OTS's First Year in Orbit

R.C.L. Collette, E.W. Ashford & C.D. Hughes
ESA Communications Satellite Department, ESTEC, Noordwijk, The Netherlands

The European Space Agency's Orbital Test Satellite, OTS, launched on 11 May, 1978 has now successfully completed the first year of its three-year design life in orbit. Built for ESA by a European consortium led by British Aerospace, OTS was conceived to demonstrate and validate in space the advanced hardware and communications concepts to be used later on satellites of the European Communications Satellite (ECS) Programme, and to provide pre-operational non-revenue-earning capacity. It is located in a geostationary orbit, approximately 36 000 km above the equator and at 10°E longitude, from which its antennas can communicate with all of Western Europe and North Africa, as well as Iceland to the north-west and the Canary Islands to the southwest.

Introduction

An extensive programme of tests and demonstrations has been carried out with OTS during the past year by ESA and the European National PTT Administrations (now represented by the Interim EUTELSAT Organisation), covering many aspects of satellite communications. These range from purely scientific measurements, to telephony, television and data-transmission demonstrations which have shown the potential of this type of satellite to substantially augment communication facilities within and around Europe. The early phase of this programme was under the responsibility of ESA and relied primarily on Agency earth-station facilities. The experiments then rapidly expanded to involve the many National Administrations which have brought their own earth stations into the test programme. All elements of this overall system are operating satisfactorily, the use of the OTS capability currently being administered on the basis of an Agreement between Interim EUTELSAT and ESA signed on 11 January 1979.

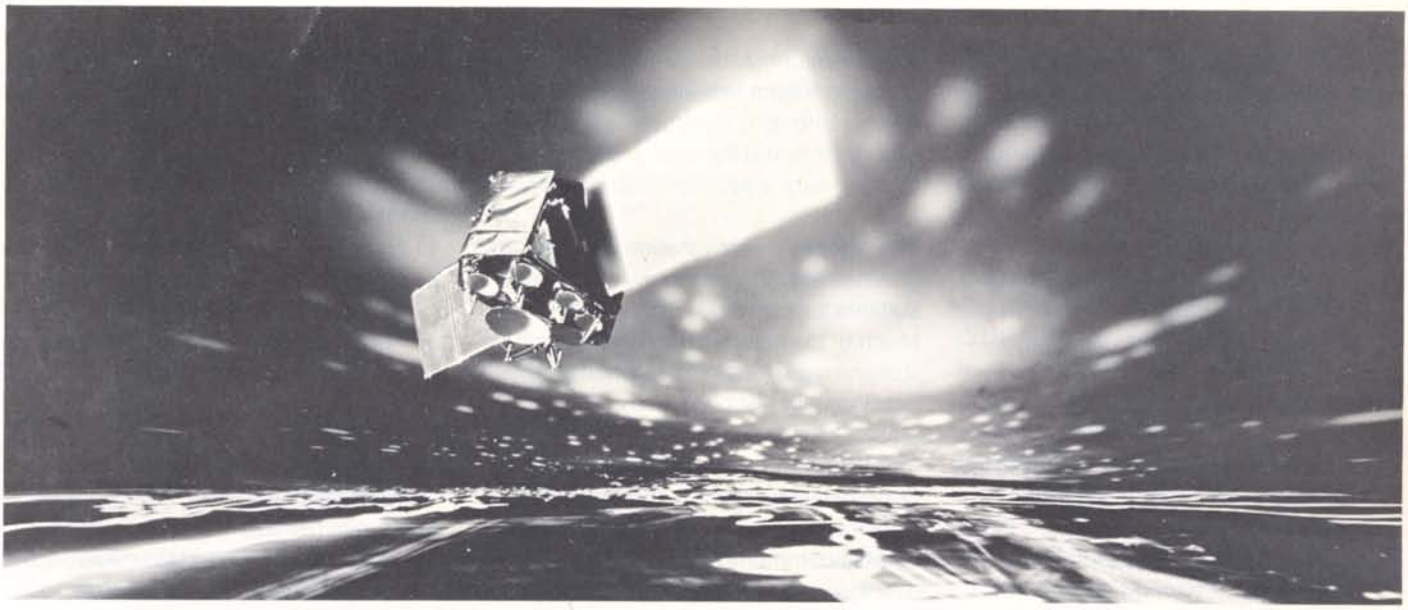
Both the ESA/Telespazio station at Fucino (Italy) and the French earth station at

Table 1 – OTS demonstrations organised by ESA and/or PTT Administrations

Location	Date	Signals	Stations used
Farnborough Air Show (UK)	3-10 September 1978	TV	Fucino (SCTS) and Ferranti 3 m TV receive terminal
Goonhilly earth station (UK) opening ceremony	4 September 1978	TV	Goonhilly in loop
International Broadcasting Convention, Wembley UK	18-19 September 1978	TV + Telefax	Goonhilly plus Ferranti 3 m terminal plus IBA 3 m transmit terminal
Conference on Role of Space Technology for Development, Cairo	6-11 October 1978	TV + Telefax	Ferranti 3 m terminal in Cairo
Opening of Louvain earth station, Belgium	11 December 1978	TV	Fucino plus Louvain terminal
Rabat, Morocco	June 1979	TV + Telefax	Bercenay, Fucino and 3 m receive terminal
International Television Symposium, Montreux	June 1979	TV	3 m transmit/receive terminal

Figure 1 – OTS, ESA's telecommunications satellite

Figure 2 – The 19 m antenna of the earth station at Goonhilly Downs, UK

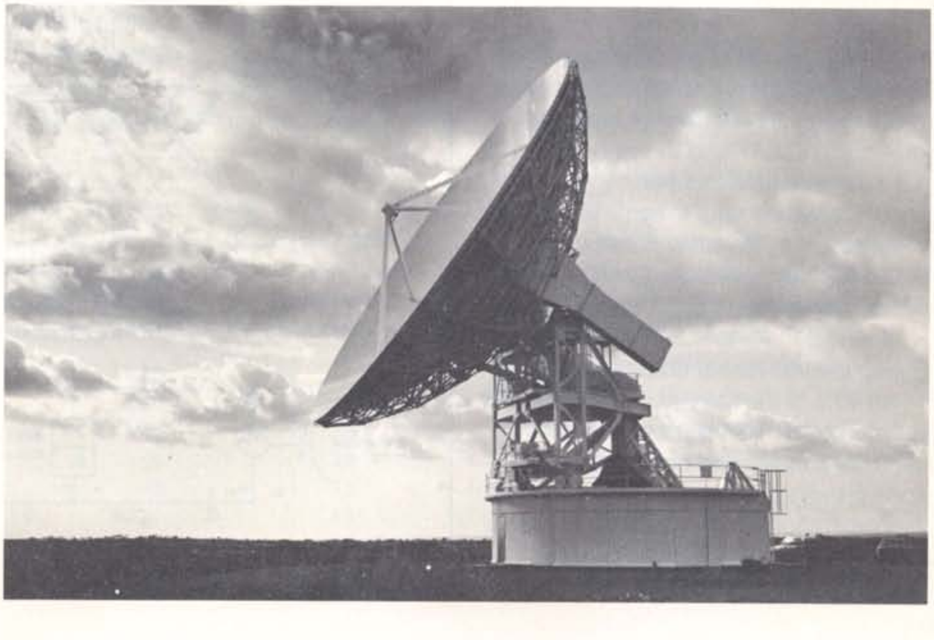


Bercenay-en-Othe, southeast of Paris, have been carrying out testing activities through the satellite since it was first put into geostationary orbit. Within a few months of launch two more large stations, at Usingen in Germany, and at Goonhilly Downs (Fig. 2) in the United Kingdom, joined the test programme. Eight small stations owned by various national PTT Administrations, educational bodies, scientific establishments and ESA have been transmitting and receiving test signals through the satellite as part of the propagation experiments. In addition, thirty small receive-only stations have been measuring beacon signals from the satellite on a regular basis within the framework of the extensive propagation measurements that form part of the Orbital Test Programme (OTP).

In addition to these experiments within Western Europe, during OTS's first year a number of demonstrations of the satellite's capabilities and versatility have been made to the international community. These demonstrations (Table 1), some of which have been organised by ESA, some by PTT Administrations, and some jointly, have included experimental transmissions of both data and television from Europe to Cairo and Rabat. The transmissions to Cairo and Rabat are worthy of particular mention, since they involved slewing the satellite about its roll and pitch axes to repoint the Spotbeam by approximately 2°. Regular scheduled use of the satellite to transmit television programmes from France to Tunisia is also now taking place.

All the demonstrations given have provided excellent results and have received unanimously favourable comment.

All the activities concerning the utilisation of the satellite are coordinated within the framework of the Orbital Test Programme (OTP). The OTP is considered a major end product of the satellite's development and construction. The programme includes many experiments to demonstrate the capabilities of the satellite and to measure the overall performance of the communications system. Individual tests and demonstrations within the programme are the responsibility of ESA, individual PTT administrations (members of Interim EUTELSAT), organisations such as the



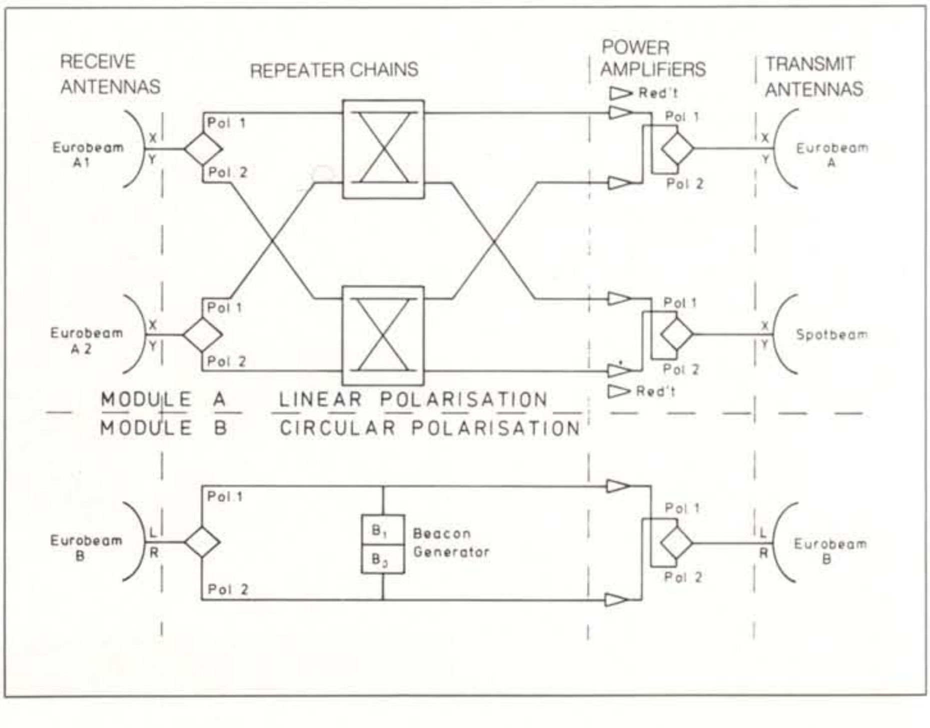


Figure 3 – OTS: payload block diagram (simplified)

European Broadcasting Union, various universities and technical centres.

The Orbital Test Programme contains a number of elements which can be broadly classified as follows:

- Performance-assessment tests, i.e. the large number of exhaustive performance tests, involving both the satellite and the associated earth segment, generally defined prior to the launch of OTS, which serve to determine or verify the performance of all spacecraft hardware and of the communications systems design envisaged for the operational European Communications Satellite (ECS) system, now under development, and for the Marecs maritime communications satellite.
- Special ad-hoc tests, defined by the Agency and designed principally to investigate any anomalous behaviour of the satellite.
- Special demonstrations of the capabilities of OTS to members of the international communications community.
- Transmission tests related specifically to ECS's implementation.
- Measurements of propagation effects in the 11/14 GHz frequency channels.
- Experiments related to new applications.

The Agency's part of the programme has concentrated mainly on the evaluation of in-orbit satellite performance, whereas Interim EUTELSAT and the other users have concentrated more on communications tests. In some areas, complementary tests have been carried out by each organisation. Only the results of the Agency's tests are considered here.

During the first year of OTS operation, about 40% of the satellite's repeater time was devoted to ESA tests, with the remainder being used by the PTT Administrations and others. In the future, the percentage of time available to Interim EUTELSAT will increase as more user earth stations are added to the OTS experimental network and as emphasis shifts more from satellite performance measurements to communications experiments and the exchange of pre-operational traffic.

The Agency's earth-station facilities

ESA has established a network of earth stations for use for OTP measurements. Much of the critical hardware for such stations was not available when satellite development first began, since OTS employs the 11/14 GHz frequency bands, frequency re-use by polarisation discrimination, and very high speed digital transmission, all new technology areas for satellite communications. The Agency was therefore obliged to take the lead in encouraging industry and the National Administrations to develop and exploit the more advanced system concepts of OTS in respect of earth-station hardware.

The Fucino Satellite Control and Test Station (SCTS)

The SCTS, built by AEG-Telefunken and completed in September 1977, is the largest of the ESA stations. It is owned jointly by the Agency and Telespazio, the latter's part of the station being leased by the Agency for its tests.

The station employs two antennas, a 17 m diameter antenna and associated equipment which operates in conjunction with the OTS Module-A repeaters (i.e. the 40 and 120 MHz bandwidth channels), and a 3 m diameter antenna and associated equipment which operates with the OTS Module-B repeaters (i.e. the two narrow bandwidth channels).

Fluxmeter stations

The Agency procured four small receive-only earth stations which are located at Stockholm (Sweden), Dublin (Ireland), Villafranca (Spain), and Milo (Sicily). These locations, chosen to be close to the 4 dB contour of the OTS Spotbeam coverage, are used for measurement of the flux received from all OTS repeaters and for propagation measurements. Two antennas with associated equipment are employed at each location, one for flux measurement proper, and the other for simultaneous measurement of sky noise temperature.

The ESTEC earth station

This station provides a further flux-

Table 2 – OTS saturated EIRP levels measured at Fucino (SCTS) shortly after payload switch-on

Repeater chain	Expected value from pre-launch data, dBW	Measured in orbit, dBW
2/A	39.1	39.6
2/B	39.4	39.7
4	47.0	47.2
$\bar{4}$/A	46.3	46.5
$\bar{4}$/B	46.3	46.4
RL	42.7	42.6
LR	42.5	42.0

measurement capability, but in addition is able to measure the cross-polar performance of the satellite antennas as seen from The Netherlands. The station also has a transmit capability and can measure up-path polarisation discrimination as part of the satellite antenna in-orbit test measurements.

The earth-station facilities of other users

The Bercenay-en-Othe station

This French PTT station, completed in January 1978, is used within the OTP for experiments and demonstrations with Module-A repeaters. The station employs a 14.5 m diameter antenna with dual linear polarisation.

The Goonhilly earth station

This British PTT station, completed in September 1978, is also used within the OTP for measurements and demonstrations through Module-A. It employs a 19 m diameter antenna with dual polarisation.

The Usingen earth station

The German PTT station at Usingen employs a 17 m antenna with dual polarisation. It was completed in November 1978 and is currently carrying out a programme of tests and demonstrations via Module-A.

Propagation earth stations

There are currently nine propagation stations that have transmit and receive capability operating through OTS: Martlesham (United Kingdom), Fucino (Italy), ESTEC (The Netherlands), Gometz-la-Ville (France), Nederhorst-den-Berg (The Netherlands), Stockholm (Sweden), Aflenz (Austria), Copenhagen (Denmark), and Oslo (Norway).

There are also some 30 receive-only stations which are making propagation measurements using the Module-A beacon (linearly polarised) and the Module-B beacon (circularly polarised) of OTS.

Demonstration terminals

Three small transportable earth terminals are in use on an intermittent basis for television and data-transmission demonstrations at exhibitions and conferences. These terminals have been used both by ESA and by various administrations and broadcasting entities.

Table 3 – OTS noise figures measured at Fucino (SCTS)

RX antenna	Receiver	Polarisation	Noise figure, dB	Pre-launch noise figure, dB
Eurobeam A	A	X	4.0	4.0
Eurobeam A	B	X	4.3	4.2
Eurobeam A	A	Y	4.3	3.9
Eurobeam A	B	Y	4.5	3.9
Eurobeam B	–	RL	4.0	4.5
Eurobeam B	–	LR	3.7	4.1

Noise figure specified: 5.0 dB

Results of ESA tests and demonstrations

The ESA tests during the first year of OTS operation have concentrated on measuring the radio-frequency characteristics of the satellite and its overall performance.

Classical repeater tests

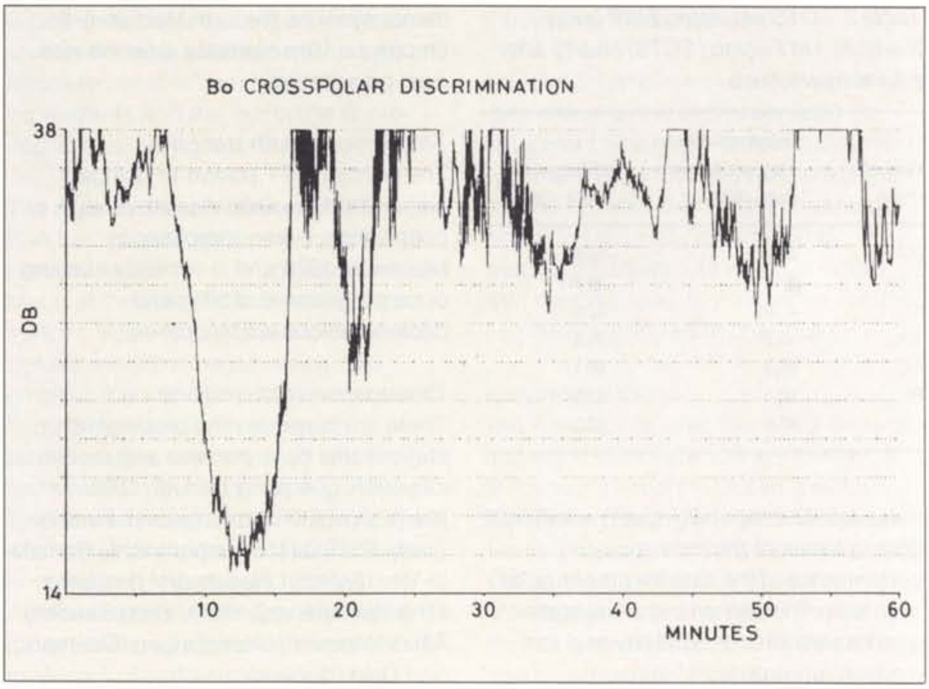
On 16 May 1978, while still in drift orbit, OTS came within the acquisition range of the SCTS earth station. The SCTS locked onto the satellite's telemetry beacon and it was then possible to transfer the tracking, telemetry and command (TTC) from the VHF network to the SCTS at SHF. After some checking of the TTC functions, the payload switch-on procedure, aimed at exercising all elements of the payload including redundant units and making outline performance measurements at each stage of the operation (e.g. power output, gain steps, etc), was commenced. All elements of the payload (Fig. 3) were shown to be operating fully to the required standard and at the end of the test the satellite was readied for service (i.e. all six repeaters plus the beacon signals on).

As an additional part of the initial setting-up procedure, test signals were transmitted from Fucino and Bercenay-en-Othe simultaneously to fill all six repeaters, to check that no unexpected problems would arise from full satellite loading or interference between channels. All measurements were entirely consistent with predicted performance.

Measurements of the satellite power output (EIRP) were then made from Fucino, with the results shown in Table 2. The values recorded were well above specification. The SCTS station in Fucino also measured the satellite noise figure for each of the satellite receivers of Modules-A and B (Table 3). The values recorded were very close to the pre-launch predictions and all were better than specification.

The power output, amplitude stability, spectral density and frequency stability of

Figure 4 – OTS: an interesting propagation event, showing a deep fade coupled with a severe reduction in cross-polar discrimination



all satellite beacon signals were also checked from Fucino. All were as predicted. Beacon amplitude and frequency stability measurements were continued throughout the year as part of the routine testing. During this period a 3 dB degradation in the power output of one of the redundant Module-B beacons, an experimental beacon based on Impatt diode technology, was noted, but this has now stabilised and no impact on the satellite mission is expected.

In total, some seventy separate payload test sequences have been performed by ESA during the first year of OTS operation. While too detailed to be reviewed here, they will be included in a complete technical report to be published later this year.

Satellite-antenna measurements
The in-orbit performance of the six OTS antennas has been evaluated through a series of tests designed to measure:
- gain and gain stability
- beam shape
- polarisation purity
- relative alignment of the various antenna polarisation planes.

The full network of ESA earth stations and some of the user earth stations, coordinated by Interim EUTELSAT, have been involved in these tests. Simultaneous measurements have been made at all locations over periods of at least 24 h, with the satellite manoeuvred over an east-west and north-south grid pattern.

The final results from these particular tests are not yet available, but it can already be said that no significant anomalies have been detected, the gains of all receive antennas are nominal under both hot (night) and cold (day) conditions, and worst-case cross-polarisation performance within the measured sectors is approximately as expected from pre-launch predictions.

Polarisation planes have been measured for all linearly polarised antennas and across all available channels for selected directions; in any one direction

Maximum spread	: ±3/4°	(–37 dB)
Maximum deviation from TM beacon	: 1 1/2°	(–31 dB)
Maximum day/night variation	: 1°	(–35 dB)

As expected, there is evidence of some diurnal beam-swing and beam-broadening (of the order of 0.1–0.2° and a few percent for the Spotbeam). Further analysis to evaluate this as accurately as possible for all antennas is presently underway.

Digital ranging tests
Accurate ranging is possible through the SHF communications payload of OTS using the high-speed digital equipment of the SCTS. Tests have been carried out by ESA to explore this possibility for use on future operational satellites, with very encouraging results.

Incentive-scheme measurements
Every six months the Agency measures the flux received from the OTS repeaters at the earth's surface at critical points in the coverage to determine the extent of any incentive payment to the satellite manufacturer. This measurement exercise involves the fluxmeter stations and the SCTS. Two such measurement campaigns have been conducted to date, with the flux levels from all channels well above the incentive thresholds at all locations, except for channel $\overline{2}$ in which a TWT amplifier, one of eight on board the spacecraft, failed after several weeks of operation.

Satellite platform tests
An extensive series of tests has been carried out to evaluate the in-orbit performance of the OTS platform, i.e. all those satellite subsystems that do not form part of the repeater/antenna payload. The data from these tests have shown consistently good results, with most platform equipments exceeding their specified performances by comfortable margins, clearly demonstrating the validity of the design concepts upon which the OTS and ECS platforms are based. The few on-board anomalies that have occurred are not expected to have an impact on the OTS mission itself, but have nevertheless provided valuable information in terms of improvements to

be introduced into future ECS and Marecs platforms. The present status of OTS's on-board subsystems is in fact such that the spacecraft can be expected to outlive its design lifetime – it still has sufficient fuel, for example, to maintain its correct geostationary position and orientation for another five years.

Propagation experiments
A coordinated programme of propagation measurements involving many earth stations is currently in progress. The receive-only stations are measuring atmospheric attenuation and depolarisation in the downlink (i.e. 11 GHz band). Figure 4 shows a remarkably deep fade, measured at Fucino in August 1978, which illustrates the type of propagation events that, although occurring very rarely, can strongly influence communications in this frequency band. As the OTS communications Module-A (linear polarisation) and Module-B (circular polarisation) both contain beacon generators, it is also possible to make comparisons between the two types of polarisation. Some stations therefore have facilities for simultaneous reception of both beacons. Those propagation earth stations that have transmit facilities as well are participating in the up-path beacon experiment, which enables attenuation and depolarisation in the up-path (i.e. 14 GHz band) to be measured. The Fucino station collects all down-path signals resulting from the up-path beacon experiments and records the data on magnetic tape for subsequent analysis.

ESA has also been conducting a test, in cooperation with Telespazio, from the SCTS, which will correlate the variations in bit error rate on 180 Mbit/s digital signals transmitted through the satellite with those predicted from beacon signals measured at the same time.

Special investigations
Where on-board equipment anomalies have occurred during the first year of OTS operation, ESA has undertaken special investigations to analyse them in depth, in particular to make sure that any implications for future satellite design are well understood and acted upon. Most of the anomalies identified are indeed now well understood and, with the exception of the TWT amplifier failure, are of negligible consequence for the future mission of OTS itself. The results of a selection of special tests are summarised in the following paragraphs.

Repeaters
The repeaters have, as has been said, performed nominally, with all parameters above specification and with sufficient margins to give high confidence that the specified lifetime will be exceeded. The only notable exceptions have been:

(i) On a number of occasions in two of the OTS channels the output Travelling-Wave-Tube Amplifiers (TWTAs) have switched off due to their own protection circuitry without command from the ground. When commanded back on, they have operated again without difficulty. This unscheduled switch-off condition has occurred twice in one of the channels and has not re-occurred. In the other channel the switch-off has occurred more frequently. It has been found, however, that the effect can be eliminated by taking care at the earth stations not to overdrive this particular satellite channel or to uplink rapid transients of too high an amplitude, and this is acceptable for OTS. Steps have been taken to eliminate the problem altogether in future spacecraft.

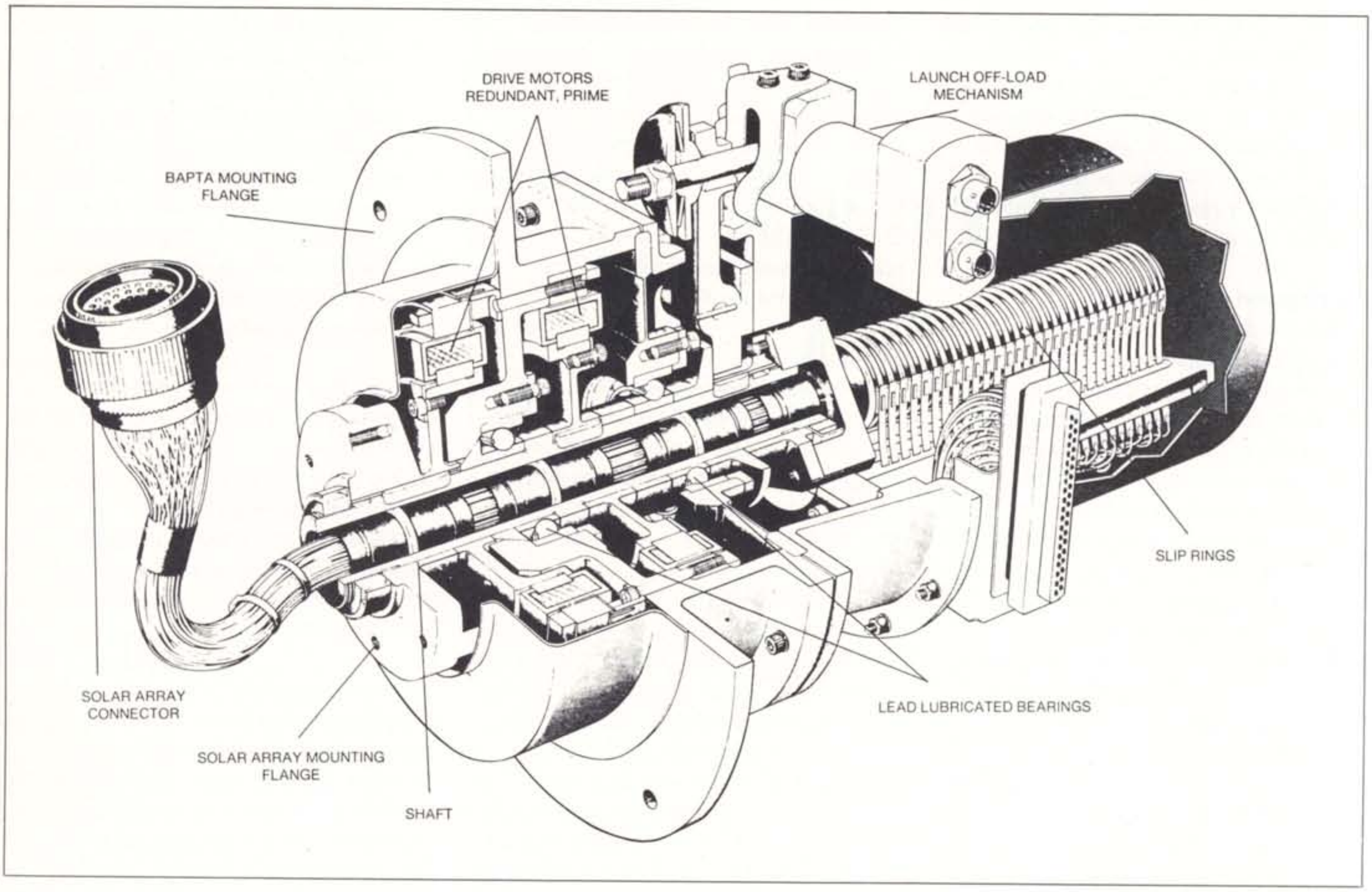
(ii) A problem of a more serious nature is affecting the TWTA in one of the two 40 MHz bandwith channels (channel $\bar{2}$) which, after several weeks of trouble-free performance, began to exhibit a spurious automatic switch-off phenomenon. In this case, however, the interval between such events decreased progressively until finally the TWTA could not be maintained in an operational state for long enough to be useful. Extensive trouble-shooting and analysis have determined that the most probable cause of this failure was high-voltage arcing outside the tube, possibly in the cathode circuitry, initiating shutdowns via the TWTA protection circuits. This arcing is likely to be the result of a defect in the potting around the high-voltage leads entering the TWTA, a situation made progressively worse by the successive switch-offs.

The fact that this failure mode has occurred on only one of the eight TWTAs on OTS and had never been experienced during ground testing, indicates that it is a random failure. Nevertheless, modifications to the potting, quality inspection, and test procedures are being incorporated in the manufacture of future TWT amplifiers.

Antenna subsystem
In general, both the VHF and SHF antenna systems have operated satisfactorily. However, the SHF antennas have a white paint finish for which rapid degradation is inevitable, antenna temperatures have risen markedly since launch, although no detailed analysis has yet been conducted. A direct comparison between autumn and spring equinox temperatures, taken six months apart, showed rises of up to 20°C on the Spotbeam antenna dish in the period; the summer solstice values for 1979 are currently awaited to obtain a one-year comparison with 1978 figures. The highest temperature yet seen on a reflector is about 67°C, a long way under the qualification upper limit of 135°C.

Power subsystem
The performance of the power subsystem has been excellent, generating more power than was specified during all mission phases. The sole anomaly noted has been in the performance of one of the BAPTAs (Bearing and Power Transfer Assemblies) driving one of the two solar-array wings (Fig. 5). This showed an apparent reduction in torque level during periods around the winter solstice when, due to its position relative to the sun, the

Figure 5 – OTS: cut-away drawing of the Bearing and Power Transfer Assembly (BAPTA) manufactured by British Aerospace, UK



south BAPTA saw its highest temperatures.

The causes of such behaviour are now well understood (mainly insufficient preloading of the bearing assembly) and corresponding design- procedural modifications on units to fly on subsequent spacecraft are being made to preclude the occurrence of such an anomaly in the future.

Infrared sensors
OTS has two functionally redundant infrared earth sensors, each one based on a different concept. One unit (IRES-A) has been found to be susceptible to random internal switching between its four bolometers, a phenomenon due both to internal reflections of the sun's rays at certain times of the year and to electromagnetic interference. This switching has, on certain occasions, been mistakenly interpreted by the on-board logic as a failure, and caused unnecessary switching to redundant AOCS equipments and/or operating modes.

Changes have been introduced into the design of this particular IRES which should eliminate such occurrences on future satellites. On OTS, to avoid undesirable spurious mode switching, this earth sensor is presently being used off-line as a monitoring unit.

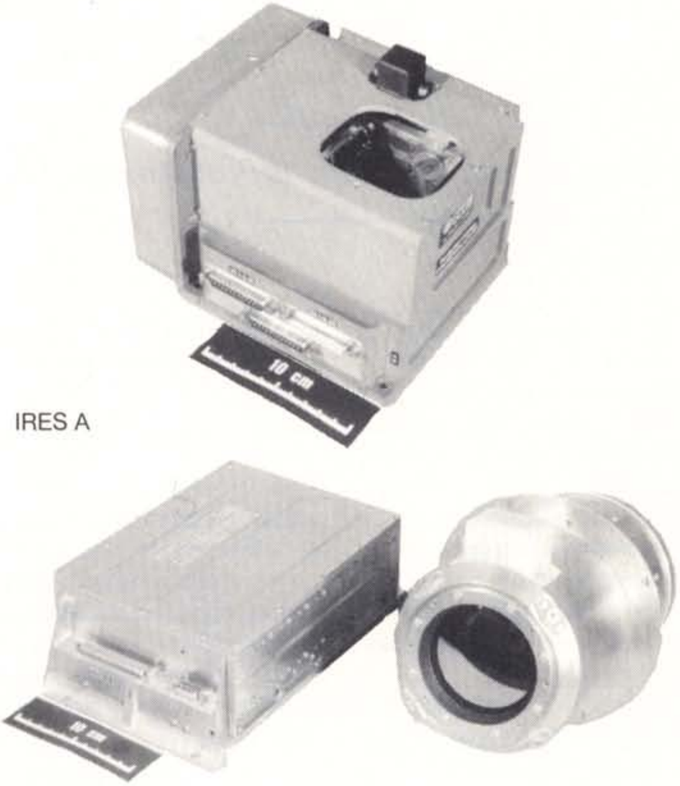
The second earth sensor (IRES-B) has performed quite satisfactorily. It has been found, however, to be more sensitive than expected to the seasonal variations in the earth's infrared profile and to stochastic variations due to localised weather conditions. Hence its accuracy is somewhat less than that of IRES-A (Figs. 6a, b).

Thruster system
The reaction-control thrusters have exhibited three types of unforeseen phenomena:
- Spurious disturbance torques on the spacecraft due to impingement of the thruster's plume on the solar arrays during some north-south orbit manoeuvres.
- Apparent generation of gas in the hydrazine system which, when thrusters are not used for a long period of time, leads initially to low thrust levels when a new train of pulses is commanded.
- On relatively rare occasions last year, one of the thrusters apparently produced an impulse when none had been commanded. Here the cause has not been unequivocally determined.

Procedural changes have, however, been

Figure 6a – Infrared earth sensor IRES-A, manufactured by Officine Galileo, Italy.

Figure 6b – Infrared earth sensor IRES-B, manufactured by Sodern, France.



(a) IRES A

(b) IRES B

incorporated so that these effects have no operational consequence.

Thermal subsystem

Initial interpretations of thermal telemetry data appeared to indicate that the general temperature of the satellite was too high. Later, however, a more detailed analysis showed this not to be the case and, with few exceptions, equipments are operating well within their specified temperature limits. Several equipment items are operating slightly outside their previously predicted temperature limits, but this is not considered serious, as they are still inside limits to which they have been previously qualified. The reasons for the differences between predicted and actual temperatures are now well understood, and steps have been taken to avoid such discrepancies in the future.

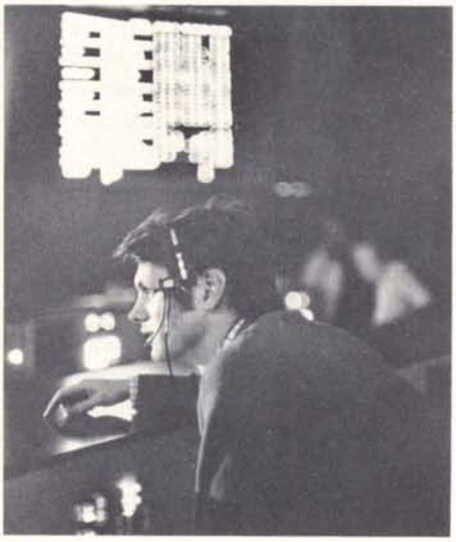
Conclusions

The Agency has now completed all the major OTS performance measurements. Routine performance checks and incentive scheme measurements will continue to be carried out at regular intervals. The PTT Administrations have made good progress in their transmission tests and it can be concluded that the OTS system is generally operating above specification in almost every aspect.

The emphasis in the Orbital Test Programme is now moving away from the more basic measurements that have been described, towards experiments that involve the communication system aspects of future satellite communications in Europe. Notable among the experiments foreseen are:

- Multi-earth-station high-speed TDMA experiments using 60 Mbit/s and 120 Mbit/s signals.
- The STELLA data experiment which involves transmission of scientific data to and from small terminals at scientific establishments. Three earth stations are already being constructed for this experiment and will commence operation in September 1979.
- The SPINE experiment, which involves small earth stations located at ESA establishments and those at other interested bodies such as the Royal Aircraft Establishment in the United Kingdom. This experiment will include high-speed facsimile transmission, computer-to-computer data transfer, and video conferencing. The experiment will commence in January 1980. Three earth stations are in the course of construction and several existing stations are being converted to participate in the experiment.
- Television experiments of the European Broadcasting Union.

In general, for the Agency OTS continues to provide valuable information for the design of future communications satellites. For the growing number of users, OTS is giving an opportunity to experiment with communications systems techniques that can be directly applied to the operational systems of the 1980s, such as ECS.



The Use of Satellites for Informatics

S. Hanell, Directorate of Applications Programmes, ESA, Paris

The development of data-processing systems points to a time when their use will no longer be the prerogative of the specialist and they will be at the disposal of society as a whole. The traditional division of telecommunications systems according to category of service will be a thing of the past, being replaced by integrated services in which the flexibility of digital data traffic will be exploited to merge various types of traffic, both conventional narrow-band and the emerging wide-band or high-speed services, into a single digital network. The satellite link possesses unique properties as a data-transmission medium and the early use of such links in conjunction with earth stations located close to the premises of the users could offer the best near- to medium-term possibilities for providing an integrated-service digital network in Europe. As the terrestrial networks grow, the satellite link's uses would become increasingly specialised and in the long term might well be centred around new face-to-face interactive telecommunications services, such as video teleconferencing.

'Informatics' is a comparatively young science that has developed in the wake of the explosive evolution of data processing over the past twenty years. The exact definition of informatics tends to depend on circumstances, but broadly speaking it can be described as the science of information processing using computers. When informatics systems are connected to communications systems, the overall system becomes a 'tele-informatics' or, as suggested by Nora & Minc*, a 'telematique' system. Tele-informatics, as a science, is not limited to technical elements, but includes the utilisation and the relevant socio-economic and political aspects of the systems considered. In fact, it is a merging of several technical and nontechnical disciplines, the predominant technical discipline being information processing and communications.

Traditionally, information processing using computers treats information represented by bits or bytes as opposed to the analogue wave forms carrying the speech information in the telephony network. The flexibility of digital information and the peculiar characteristics of data traffic make such traffic especially suited to store-and-forward types of communications systems, these being the main reasons behind the current trend to handle digital data traffic in specialised networks separated from the telephony network.

The data-communications network differs from the traditional circuit-switched network in that it contains processor-controlled (intelligent) traffic nodes that not only route the traffic, but also share a number of data-handling tasks with the computer equipment connected to the network.

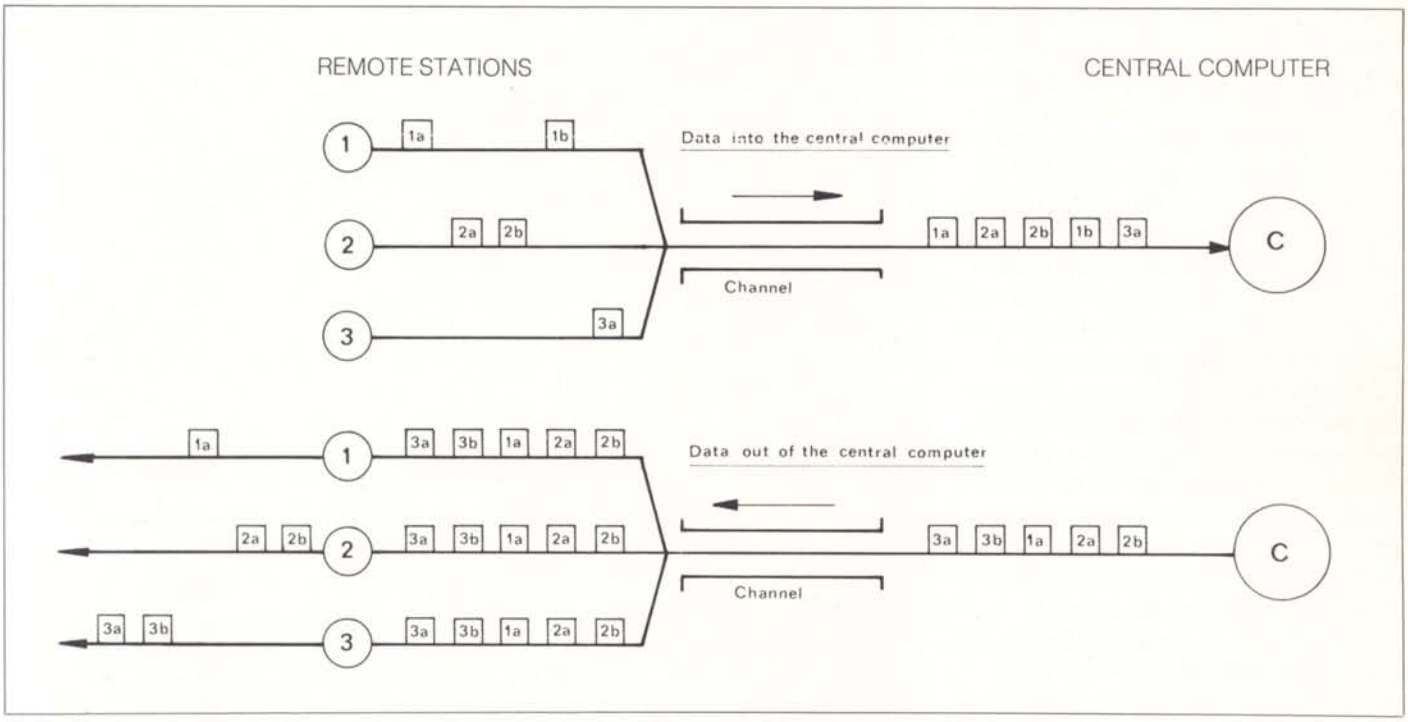
Consideration of the use of satellite links in the context of data-communications networks began in the USA almost with the birth of the first packet-switched data-communications network. Despite the European origin of informatics, data-communications techniques emerged in the USA and the present state-of-the-art in Europe reflects the pioneering efforts made there.

The flexibility of digital data traffic leads to the design of data communications networks that differ from the ordinary telephony network and makes the data traffic especially suited to a satellite link. Although the latter possesses many features that appear attractive for data traffic, its future roles must, however, be seen in the context of growing terrestrial networks. New advanced public data networks are emerging in Europe; these include both national and international networks, such as the recently opened Transpac network in France, and Euronet, which is scheduled to become operational in September.

Today's demand for transmission facilities is dominated by the need for terminal-generated interactive operations requiring a rather modest rate of information transfer compatible with voice-grade channels adapted for data communications. The existing planning for European data-transmission satellite systems would emphasise the complementary nature of the satellite and

* *L'Informatisation de la Société (La Documentation française, 1978)*

Figure 1 – Principle of the ALOHA system



the terrestrial networks. The satellite network could be designed, for example, to carry traffic that is difficult to serve with terrestrial networks, such as the high-speed transfer of large volumes of data.

The evolution of high-speed data communications, on the other hand, may be closely related to the development of terrestrial public wideband networks based on optical and waveguide techniques as well as on the development of bi-directional cable-TV networks, capable of relaying and routing digitised voice and video signals in addition to a large variety of digital data signals. The future may see the realisation of the digital integrated services network handling multiplexed digital traffic with different speeds and operational requirements. The future roles of the satellite link would reflect this evolution and the growing capabilities of the infrastructure of terrestrial networks would lead to increased specialisation in the use of the satellite link.

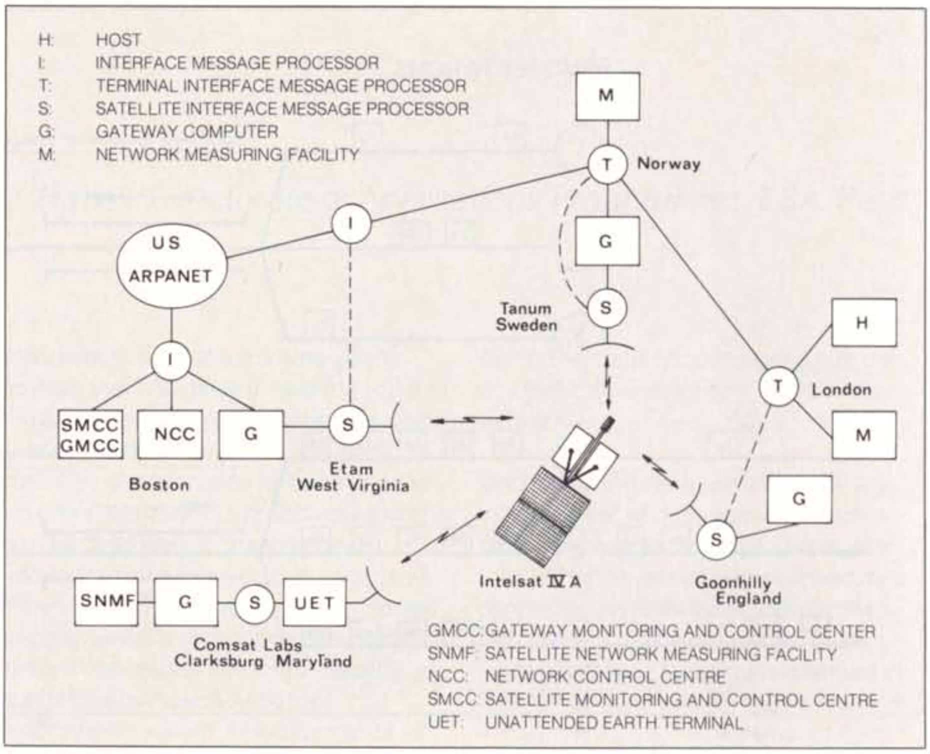
Background
The unique properties of a satellite link for relaying and routing digital data in the context of computer communications networks was first recognised with the ALOHA system, developed by the University of Hawai under a research project sponsored by the Advanced Research Project Agency (ARPA) and supported by contracts from NASA and the US Airforce Office of Aerospace Research.

The ALOHA system is a packet-switched computer network that uses terrestrial UHF radio channels to relay data packets between several remote stations and a central computer. The multiple access to the radio channel is almost random because the system is designed not to require complicated and expensive techniques to synchronise the transmissions from the remote stations. Interference caused by overlap of simultaneous transmissions is detected by all participating stations and the interfered with messages or data packets are simply retransmitted. The only synchronisation or timing control in the network is associated with the time slots inside which transmission is permitted, i.e. the Slotted ALOHA system.

The ALOHA system relies on two separate broadcast channels (Fig. 1) to serve its remote stations; one is used to carry data into the central computer, and the other to transmit it out again. As all the remote stations transmit their data packets in the same channel to the central computer, each station automatically multiplexes its data onto the channel at the time of transmission. It has in fact been suggested that in the ALOHA system 'the medium is the multiplexer'.

The ALOHA system is designed around the properties of a UHF terrestrial data broadcast channel. The only difference in principle between the terrestrial UHF channel and the satellite channel is the coverage, which is limited by the radio horizon in the terrestrial case, but the satellite link is limited only in terms of the part of the earth that is visible from geostationary orbit, i.e. one third of the earth's surface. The use of directional antennas on board the satellite could, of course, limit that coverage.

Figure 2 – The trans-Atlantic packet satellite experiment



In 1970, an experimental and at that time advanced computer communications network, developed by ARPA, became operational in the USA. This was in fact the first computer communications network to employ packet-switching techniques, which are especially suited to the peculiar statistics of digital data traffic. The network is characterised by a new kind of communications system in which the path of the traffic is not established in advance, but instead each messge or data packet carries an address and can choose one of several paths decided by the instantaneous availability of routes in the network. The nodes in the network are equipped with processors that monitor the status of the network and decide the paths or routes that are available to the individual message or data packet. Messages normally traverse several nodes in the network in going from source to destination. The network has a store-and-forward system in which copies of the messages are stored at the nodes until they are correctly received and acknowledged by the following node.

The ALOHA system is especially suited to networks connecting a large number of geographically separated users, each user generating a rather low traffic volume. When there are many stations or users that want to transmit simultaneously, the delays caused by queuing and the channel utilisation limit of 36% (Slotted ALOHA) tend to make the ALOHA system inefficient.

To improve the efficiency of data distribution via radio channels such as satellite links and to permit different types of data traffic to be transmitted simultaneously in the network, ARPA proposed a capacity 'reservation' system similar to Time Division Multiple Access (TDMA) in concept. The reservation system divides the channel into time slots and organises those time slots into frames and bursts. Each frame contains one or more time slots, which are subdivided into shorter time slots that are used to reserve capacity in subsequent frames.

The reservation system is of particular interest because of its applicability to satellite data-transmission networks interfacing with terrestrial networks at traffic nodes or other points where the traffic is large or concentrated to an even data stream. This type of access technique appears well-suited for future European satellite networks complementing terrestrial data communications networks. The technical feasibility of the simplified TDMA system based on the principles of the reservation system has been studied and validated by European industry as part of the Agency's forward-looking activities.

The ARPA network is at present connected experimentally to the UK and Norway via Intelsat channels (Fig. 2).

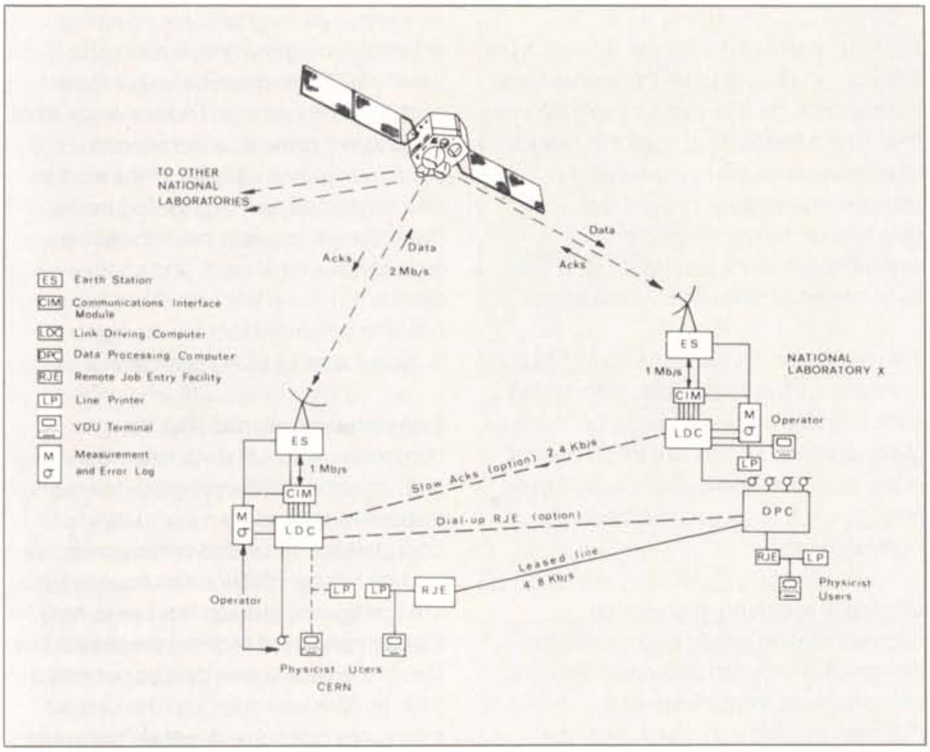
During the Spring of 1977, IBM, COMSAT and the French Telecommunications Administration undertook a computer communications experiment using the Symphonie satellite. Earth stations were located at Comsat Labs, Clarksburg, Maryland, IBM, Gainthersburg, Maryland and at IBM, La Gaude, France. The outcome of the experiment demonstrated the technical feasibility of efficient high-speed computer communication via satellite. The measurements conducted provided experimental data on link throughput and CPU (Central Processing Unit) resource utilisation and showed how these factors are affected by protocols, operating parameters and transmission link quality.

Other experiments are now being planned using ESA's OTS communications satellite. One of these, the STELLA experiment is an on-going project aimed at exploring the usefulness of high-speed data communications in the context of high-energy-physics research in Europe. It is partly financed by the Commission of the European Communities in Brussels and will use OTS to relay large volumes of data from CERN in Geneva to collaborating national high-energy-physics laboratories (Fig. 3).

A second experiment, with the acronym SPINE (Space Informatics Network

Figure 3 – The experimental STELLA system

Figure 4 – Equipment used in the SPINE experiment



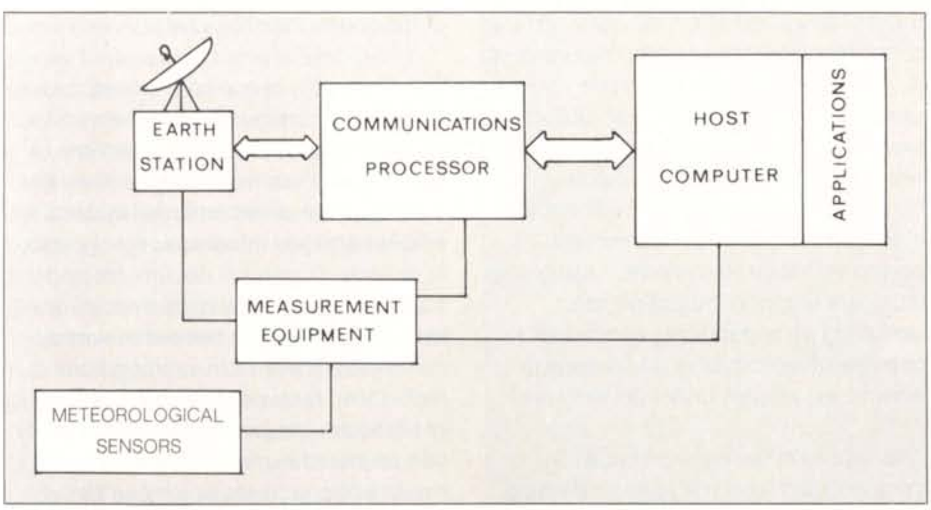
The role of high speed in the development of data communications in Europe

The discussion of the evolution of telecommunications and informatics, whether it concerns earthbound or space systems, cannot be separated from considerations and forecasts of the future needs of the users of telecommunications systems. In fact, the driving forces behind the evolution of communications technology are an ever-increasing need to communicate and the interplay between the growing needs of the users and the capabilities offered by new technologies.

The advent of data communications – an integral part of tele-informatics – is the result of the evolution of data-processing equipment pointing to a growing need to communicate with and between machines such as computers, having characteristics and requirements different from the ordinary telephone. When these new requirements became apparent to telecommunications administrations early in the 1960s, research and development work commenced, leading to the development of trial or pilot networks specially designed to carry data traffic either integrated with or separated from the ordinary telephony network. Although these early networks are being replaced by public data networks in many European countries and international data traffic will soon be routed via Euronet, the telephony network will remain the obvious and the most economic local network through which to access specialised data networks.

The speed limitation imposed on data communication by the characteristics of the telephony channel is not a severe constraint because communications between manually operated terminals and computers dominate the use of today's networks. The speed range offered by the network is adequate for manually operated terminals because the man-machine interface is limited by the human operator's ability to input and extract

Experiment), is proposed by ESA in collaboration with the Royal Aircraft Establishment (RAE) in Farnborough and DFVLR in Germany. This experiment will use OTS's Module-B repeaters to complement the STELLA project by providing information that can be used directly in the design of future operational satellite data communications systems. Most of the areas proposed to be investigated are concerned with the network aspects of satellite data communications systems, particular emphasis being given to communications and applications-oriented protocols. In order to explore the transparency of the satellite communications systems, a range of applications with different operational and transmission requirements will be tested (Fig. 4).



information – namely a typing speed of 50 or so words per minute and a reading ability of a few hundred words per minute. Most of today's data networks, including Euronet, are therefore designed mainly to carry traffic generated by man-machine operations. The need for high-speed ($\geqslant$ 48 kbit/s) data communication is still small, and this is reflected in the present limited capability for carrying this type of traffic in specialised data communications networks.

The present trend in data-processing equipment points to cheaper digital processing and storage, accompanied by decreasing component and equipment sizes. Even small pocket computers can now be programmed to process substantial volumes of input data. The cost for communications on the other hand, tends to remain fairly constant, the major milestone being the introduction of packet switching techniques.

Computer peripherals such as disks and magnetic-tape drives are capable of operating with input/output speeds exceeding 1 Mbit/s, while the natural speed of the CPUs themselves ranges from 1 Mbit/s to several megabits per second. In fact, the mismatch in natural speed between the computer equipment and the available networks is becoming more and more evident as the call for machine-to-machine types of communication increases.

In the longer term, the characteristics of machine-to-machine types of transmissions will change the requirements for data-communications networks drastically. The trend towards such transmissions is already visible in the current growth in the market for intelligent and buffered terminals, which contain logic circuits and memories to arrange and edit messages prior to transmission. Any interaction with the human operator takes place off-line and the subsequent on-line transmission to a distant terminal or computer is done automatically.

The need for high-speed data communication is by nature a function of the volume of data to be transmitted and the importance of a short transmission time. The need for that speed to reduce transmission time is not yet well established because today's users are conditioned by the characteristics of available networks and have adjusted their modes of operation accordingly.

It is difficult if not impossible to forecast or estimate the future need for high-speed data communication services because so many areas of society are involved and many potential applications would only emerge once such services became commonplace.

Generally speaking, high-speed communication would encourage the design of distributed processor systems using various combinations of mainframes and minicomputers; the processing load would be distributed not only functionally, but also geographically between distant computers.

Areas that would benefit from high-speed data communication

A number of areas that would benefit especially from the use of high-speed data communication can already be identified. The present growth in facsimile systems in Europe, for example, clearly reflects the interest and willingness of business organisations to install even the rudimentary electronic mail system offered by today's facsimile equipment connected to voice grade channels. It is not unrealistic to assume that high-speed communications will be required to cope with the traffic generated by future document transmission and electronic-mail-type systems. In fact, computer-controlled facsimile equipment using laser scanners and non-impact printers operating at megabits per second and capable of reproducing an A4 page in about 1 s is already under development.

The future will see electronic-mail computerised facsimile systems develop as integral parts of office automating systems, aiding the preparation and handling of documents along with text and word processors. Today's embryonic systems will grow and high-speed communications will give an impetus to new advanced techniques. Electronic methods will, for example, increasingly replace the use of cash and cheques, and electronic fund-transfer systems will become commonplace as an aid to business and banking operations.

It has been mentioned that the predominant use of data networks such as Euronet is characterised by interactive transmissions between manually operated terminals and central computers or data bases. Today's database systems are configured around files containing bibliographic and factual references. The files of the data bases can be searched from remote terminals and the desired references retrieved. However, the primary document referenced is usually not archived at the data base, but in a library distant from both data base and user. The search for a reference may be concluded in less than half an hour, but it may be several days before the user has the referenced document in his hand, because of the need to use the ordinary postal service to acquire it. The short and often cryptic references contained in today's data bases are, of course, the result of efforts to minimise search time while remaining within the characteristics of the communications network.

The availability of economic wideband or high-speed communications networks could drastically improve the services of data bases. Priority would most likely be placed on the development of systems for efficient and fast transmission of extended summaries of primary documents and the transmission of the primary document itself. The equipment needed is already commercially available, ranging from high-speed facsimile to video. The latter is of particular interest because documents can be stored in microfiche or holographic archives which can be

Figure 5 – A microfiche retrieval system

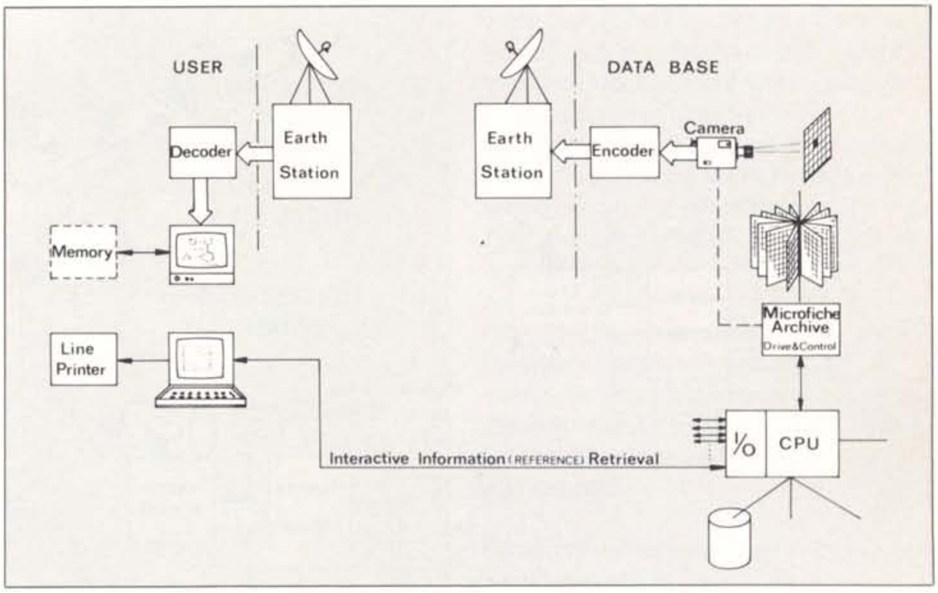
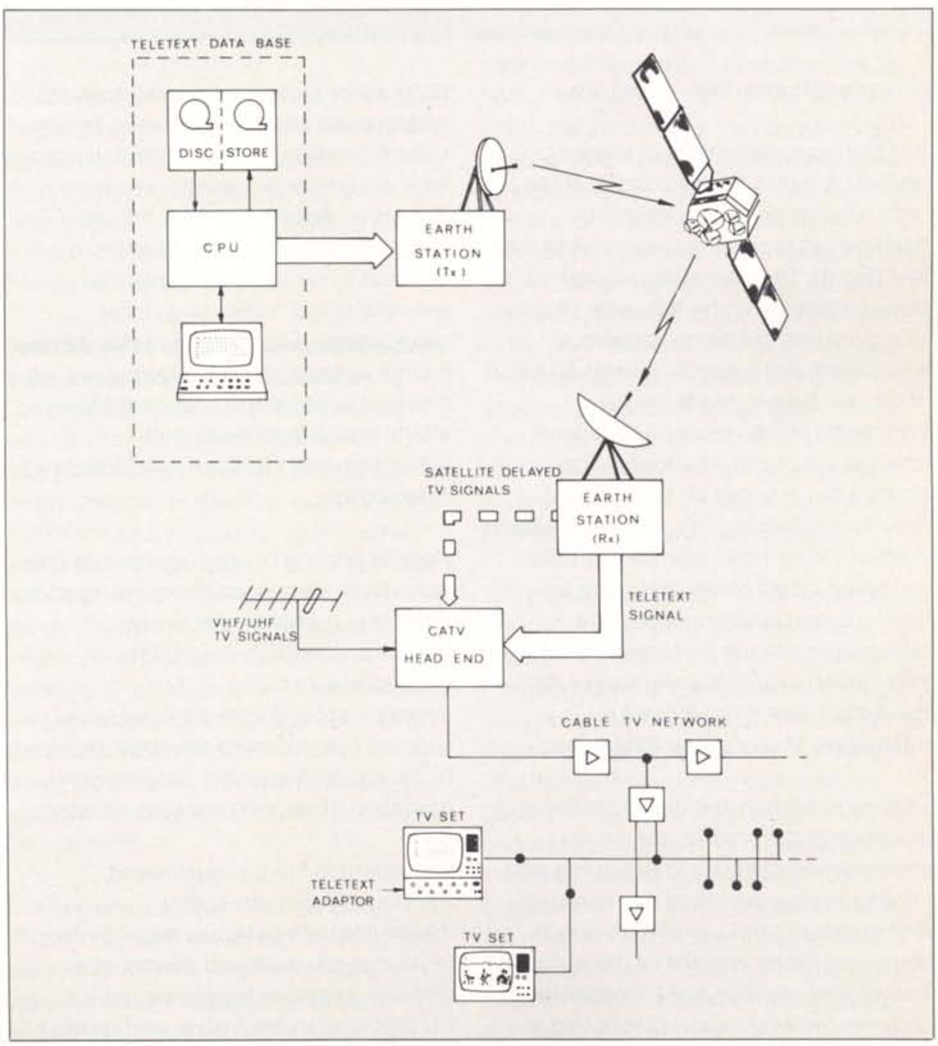


Figure 6 – A wideband teletext system



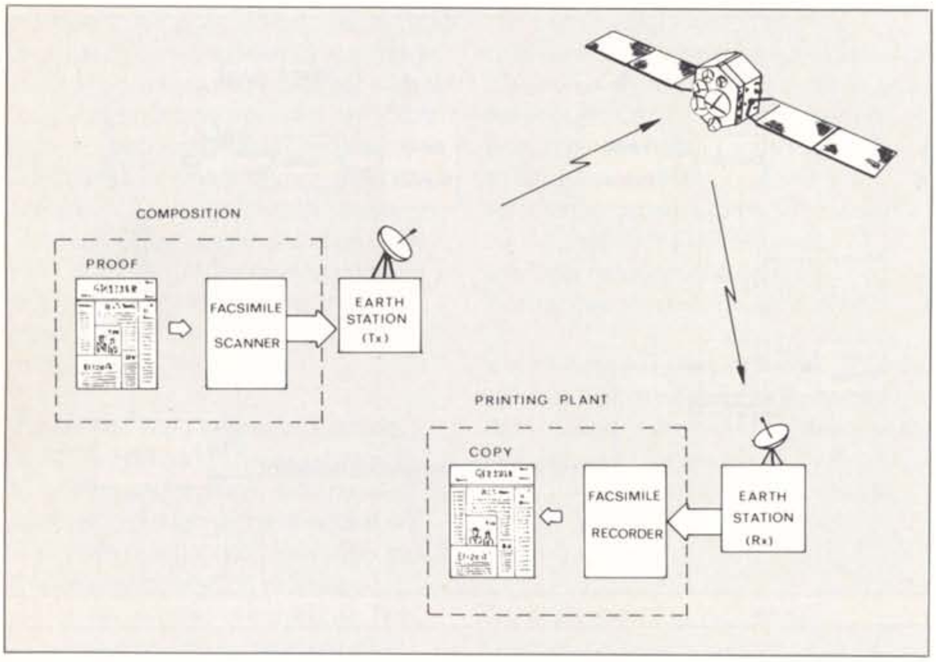
searched remotely, using video technology to transmit images (Fig. 5). Efficient and economic methods of archiving and transmitting photographs may lead to the development of new data bases containing files of primary documents, graphical material and pictures which can be searched in the same way as today's interactive data bases.

Updating is another area of data-base services that could be improved by the availability of high-speed communications facilities. In addition, data-base load and resource-sharing systems – in the context of distributed data-base systems requiring the high-speed transfer of files between geographically distant locations – may emerge once high-speed communications become an economic and useful addition to today's networks.

The teletext system is in its infancy today, but it may well develop into a widely used 'home informatics' system. The early systems (e.g. Ceefax, Oracle, etc.) led to the development of the Viewdata system in the UK, which is now attracting international interest under its new name 'Prestel'. The Prestel system is an interactive data base service using the public switched telephony network to communicate with the teletext data base. The teletext signal can be displayed on the screen of an ordinary television receiver using a teletext adaptor connected to the telephony network. A simple keyboard terminal is required to interrogate the data base. The success of such teletext systems depends entirely on the use of the ordinary telephony network, because the system can then benefit from the deep penetration of this network to reach a large population of customers.

Because the teletext system requires the telephony network for its proliferation, the role that high-speed communications could play here is not obvious. Nevertheless, any future connections between teletext data bases in different countries exchanging and updating files

Figure 7 – Remote printing via satellite



could benefit from high-speed links.

A rather specialised form of teletext system transmits the full content of the data base at high speed (e.g. 6 to 7 Mbit/s), while continuously rotating the files (Fig. 6). The user selects a desired page for display on his television receiver using a 'frame-grabbing' technique associated with a special teletext adaptor. The basic system needs the full bandwidth of the television broadcast channel and its future evolution depends on the use of vacant channels in cable television networks. This particular system is attractive for news agencies or other specialised data bases that serve an international user community, the advantages lying in the large volume of information available instantaneously to the distant user without need to interrogate or search the data base.

Today's publishers are making more and more use of data banks and computerised methods in preparing and printing newspapers, and this may itself lend impetus to the use of high-speed communications systems by this industry. These networks may make it possible to organise the information processing in such a way that expensive production systems can be shared between several distant newspaper offices, thereby making local and regional newspapers more economic. Access to edited articles on national and international events archived in central data banks, for example, could relieve small local newspapers of the burden of maintaining a large editorial staff. The local newspaper could then concentrate its efforts on the local news and advertisements that form the backbone of its existence.

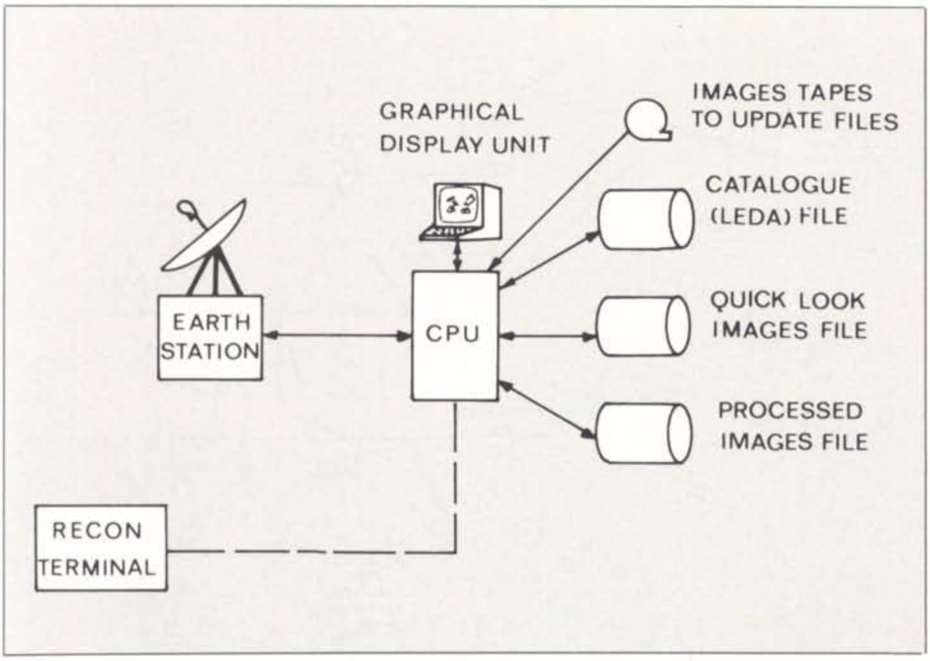
Remote printing of newspapers and other periodicals composed at central locations is another growing category of application for high-speed data communications (Fig. 7). The development of the new flatbed laser scanner has improved the state-of-the-art of page facsimile and is capable of operating at megabit per second rates.

In addition to the areas reviewed, applications for high-speed communication networks might be found in various research and development activities. High-energy physics and nuclear-research activities are just two areas that traditionally generate large volumes of data in the context of complex experiments. The availability of high-speed data communications may in the long term change the methods of conducting such research, resulting in more economic deployment of manpower and computing resources.

Space research activities are another area that generates large volumes of digital data. In particular, scientific space projects and earth-observation projects generate large volumes of data over regular periods. The practical use of information collected by earth-observation spacecraft is now well recognised and the need to disseminate it efficiently well established (Fig. 8). The present system of relying largely on postal services is inadequate for such a task. The satellite data can be used to monitor and predict the progress of agriculture, the varying conditions of oceans and rivers, the melting of snow in mountainous areas, etc. and the timing of the delivery of such data to the user is obviously important for its efficient use. Data of this sort can be used to predict catastrophies such as avalanches, droughts and floods.

Although the potential applications for high-speed data communications are numerous, few would provide immediate benefits to the users if they were introduced today. The reason is, of course, that high-speed data communications add new dimensions to communications and open up new possibilities for organising systems according to new rules, which may lead ultimately to more economic use of communications channels and data-processing equipment. It is inevitable that high-speed communications will be more complex and expensive than those at the rather moderate data rates offered by today's networks. The architecture of existing systems will probably have to be adapted for the use of high-speed links and the conversion of relevant parts of the data communications market will be a long-term process.

Figure 8 – Earth-resources data distribution via satellite



The exploitation of the potential advantages offered by high-speed data communications is not only a question of technical matters, but depends also on the ability of the user organisations to adjust their overall methods of operation such that the cost of high-speed data communications is outweighed by the economies that it brings in conducting their business.

It is quite possible that the evolution of (video) teleconference services and high-speed data communications services will converge. The advancing state-of-the-art in communications technology points to a time when wideband systems such as fibre-optics and waveguide systems will become practical elements in public networks providing digital integrated service facilities, whilst the technical compatibility between digital video transmissions and data communications services supports the convergence of (video) teleconference and data communications. The future systems may provide the users with high-capacity digital links, the utilisation of which would differ from user organisation to user organisation as well as over the twenty-four hour daily cycle. Flexible integrated service networks of this sort, accessible at the premises of the users, are already in sight in the USA, a development encouraged by the near-term prospects for economic satellite links offering a wide range of combinations of business-oriented services.

Possible roles of European satellite links in the evolution of tele-informatics

The developments around domestic satellite communications systems in the USA point to the use of the satellite link as an integral part of the inter-establishment communications networks of industrial and business concerns. The siting of the earth stations on the user's premises makes the satellite link an independent medium with respect to terrestrial networks. The users of the satellite service are offered a flexible, transparent, digital communications network capable of relaying various types of multiplexed digital traffic according to their varying requirements.

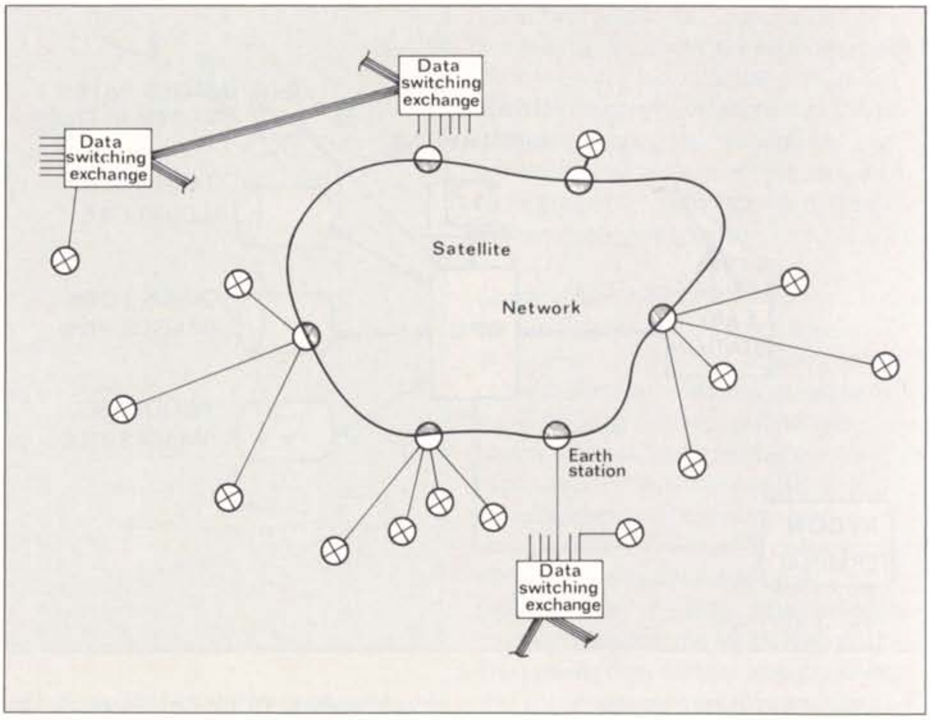
The prevailing situation is now being reviewed by both the telecommunications authorities and the large potential user organisations in Europe. It is already evident that the systems being developed in the USA cannot be directly transferred to the European environment. In fact, both the institutional and technical features of the systems must be adapted to conditions in Europe, where public-service telecommunications, for example, are the vested prerogative of the Post and Telecommunications (PTT) Administrations.

Nevertheless, the prospective roles of the European satellite link as a data-communications medium can be broadly identified and it is clear that such systems will be implemented in Europe during the next decade.

It was mentioned earlier that in Europe the capabilities of the growing terrestrial networks must be taken into account and as a result the satellite and the terrestrial data-communications networks should be complementary. One of the ways in which the satellite link can complement existing data-communications networks is by providing for high-speed applications that are difficult to serve in today's specialised networks. This implies that the satellite system should not rely heavily on terrestrial networks to connect the users to the earth stations. The length of lines, for instance, that must be provided especially to access the satellite network should be kept to a minimum. On the other hand, economic considerations point to the use of the same earth station by several users whenever possible.

The problems of earth-station location and the connection of the user then become matters of trade-off, considering the geographical distribution of the user population with the aim of minimising the distance between a majority of the users and the earth stations. It can easily be concluded that the earth stations should be located close to or in business and industrial centres such as large cities, because the users who will require and will be able to afford the initial satellite service are likely to be organisations with establishments or offices throughout a country or with substantial international

Figure 9 – Integrated satellite and terrestrial data communications



relations. It is quite conceivable, however, that several large user organisations could generate enough traffic to justify an earth station on their own premises

Terrestrial radio links tend to focus on large cities, where the problems of coordinating satellite and terrestrial networks are accentuated. Because of the importance of locating the earth station close to the user, the satellite system should operate in frequency bands that are not shared with terrestrial fixed and mobile systems. The limited 12.5 – 12.75 GHz frequency band may be suitable for an early system, since it is close enough to the 11 GHz downlink bands of the forthcoming ECS satellites to allow the satellite repeater technology already developed for ECS to be utilised.

In the long term, the growth of the satellite data-communications system may require the addition of links operating in the 20 and 30 GHz frequency bands. Narrow pencil beams covering cities or heavily industrialised areas would be required to counteract the varying atmospheric attenuations in these frequency bands and to facilitate frequency re-use systems.

The earth stations of the satellite system could be designed for automatic operation and a small computer in the station would make the logic decisions to counter the effects of malfunctioning components. The design of the earth station would include duplication of critical components and automatic activation of stand-by units should the operational units fail.

The earth station would be equipped with an antenna with a diameter of 3 to 5 m. The smaller size would be compatible with a fixed pointed antenna, whilst the larger antenna would require a step-track system to maintain satellite pointing; in other words no expensive precision auto-track systems would be required.

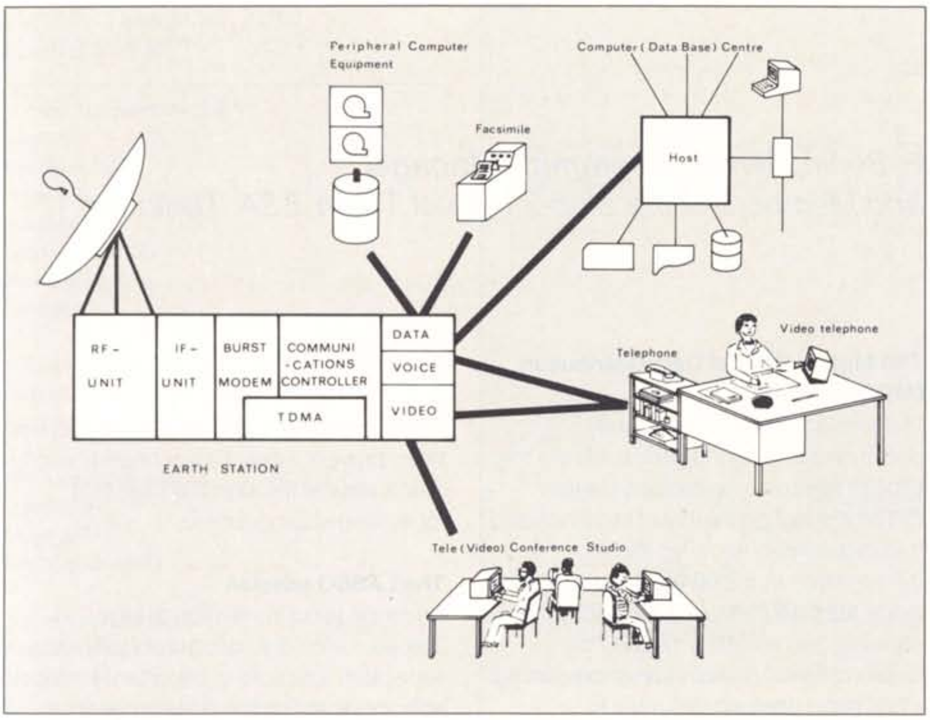
The sensitivity of the earth-station receiver would be determined by the characteristics of a low-noise receiver front end, such as an uncooled parametric amplifier, whilst the transmitter power would be in the range 100–500 W, depending on the characteristics of the satellite repeater.

The nominal bit rate through the satellite repeater would be in the range 25 – 60 Mbit/s, and forward error correction codes would be used to increase quality by reducing bit error rate in the digital transmission.

An important element of the system is the satellite multiple-access system. This can be a rather simple TDMA system, based on the reservation system developed by ARPA, which is specially designed to handle data and digitised analogue traffic. Its operation is characterised by the sharing of repeater capacity by allocating different time slots to different users according to their traffic demands. The users share the resources of the satellite network rather like the sharing of resources in a packet-switched data communications network. This property of the satellite network is therefore well suited to a charging structure based on the volume of the traffic the user transmits through the network. The distance independence and the multiple destination capability of the satellite link could be exploited to the advantage of the users.

It is advantageous to regard the satellite network as an independent network that can be added to the terrestrial data communications network without special alterations to either. The satellite network can in fact complement the terrestrial network not only by providing services that are difficult to serve in the terrestrial network, but also by adding flexible capacity and traffic-routing capabilities. The star-shaped configuration of the space network in which the satellite acts as a central traffic node is complementary to the typical configurations of terrestrial data networks. A further reason for pursuing this 'complementary' approach is the requirement for unbalanced circuits in high-speed bulk data transfers; i.e. signalling and control data can be transmitted at lower speed using the terrestrial network, while the high-speed

Figure 10 – Digital and integrated services satellite system



data transfer proceeds via the satellite link.

The obvious interfaces between the satellite and the terrestrial networks would be at the switching exchange concentrators or multiplexers in the terrestrial network, depending on the status of the area served by the earth station in terms of the hierarchy in the terrestrial data-communications network (Fig. 9).

In addition to earth stations with transmit and receive capabilities, small receive-only earth stations could become valuable complements to the network. The receive-only earth station would be located at the premises of the user, while taking advantage of the multidestination capability of the satellite link to receive various types of bulk data transmissions. The user could employ the public telephony, telex or data networks to transmit data requests or acknowledgements to the data-originating earth station.

An important aspect of future operational satellite data-communications systems is the coding or scrambling of the digital transmission through the satellite network. Privacy as well as traffic flow security to protect against volume and pattern analysis would be necessary because the design of the satellite system might be such that it would be comparatively easy to access the raw data being transmitted.

The satellite network could provide a digital integrated-services network (Fig. 10) with the character of an inter-city network. Although its advantages are most evident for a satellite link relaying high-speed data traffic in the context of tele-informatics systems, digital voice and video transmissions will probably predominate in the early satellite systems. The requirements for voice communication will correspond to those for the leased-line networks presently in use. In addition to various data and voice applications, the services provided by the satellite network will include teleconference services requiring the digital transmission of broadcast-standard television pictures and video telephone signals.

The Sirio-2 Programme

P. Berlin, Sirio-2 Programme Manager
and Members of the Sirio-2 Project Team, ESA, Toulouse

In 1977, Italy expressed interest in re-using the spare flight model of the successful domestic Sirio-1 telecommunications satellite for application on a broader European basis. ESA then examined its 'catalogue of needs' and – in consultation with national services and with the World Meteorological Organisation – produced a proposal to fly two payloads on the Sirio-2 platform, one for Meteorological Data Distribution (MDD), and one for Laser Synchronisation from Synchronous Orbit (LASSO).

After successful completion of Phase-A (study phase) and Phase-B (definition phase) studies, which were performed throughout 1978, the proposal for the Sirio-2 programme was accepted by the Agency's Council in December 1978 and the development phase (Phase C/D) was started at the end of January last.

Sirio-2 will be placed in a geo-synchronous orbit by Ariane, either in the first half of 1981 together with Marecs-B (nominal solution), or at the end of 1981 together with ECS-1. In either case, use will be made – for the first time – of the Ariane double-launch facility 'Sylda', which was described in some detail in ESA Bulletin No. 15 (August 1978).

The Meteorological Data Distribution (MDD) mission

Meteorological data is presently distributed on a world-wide basis via the Global Telecommunications System (GTS), consisting mainly of landlines and microwave links allowing data transmission in the 50-9600 baud range. Since the GTS in Africa often lacks the capacity and reliability needed for meteorological research and forecasting, it has been deemed desirable to overcome these deficiencies by exploiting space-relay techniques.

The MDD transponder carried by Sirio-2 will enable the various meteorological centres to communicate with each other directly using simple, robust and inexpensive receive/transmit stations. The satellite will permit 12 2400-baud channels and 24 100-baud channels to be relayed simultaneously. Three prototype ground stations are already under development for future deployment in Africa.

Once the viability of the MDD mission has been proven, it may be continued beyond Sirio's lifetime through the Meteosat 'operational' programme.

The LASSO mission

Accurate synchronisation of high-precision clocks at geographically widely separated locations is important for those sciences that require close correlation between observations made at a variety of sites, such as:

- geodesy
- geodynamics
- terrestrial navigation
- telecommunications (for precise time multiplexing)
- astronomy
- deep-space tracking.

The problem is that most existing methods of synchronising clocks are either very

Table 1 – Requirements and methods of time synchronisation

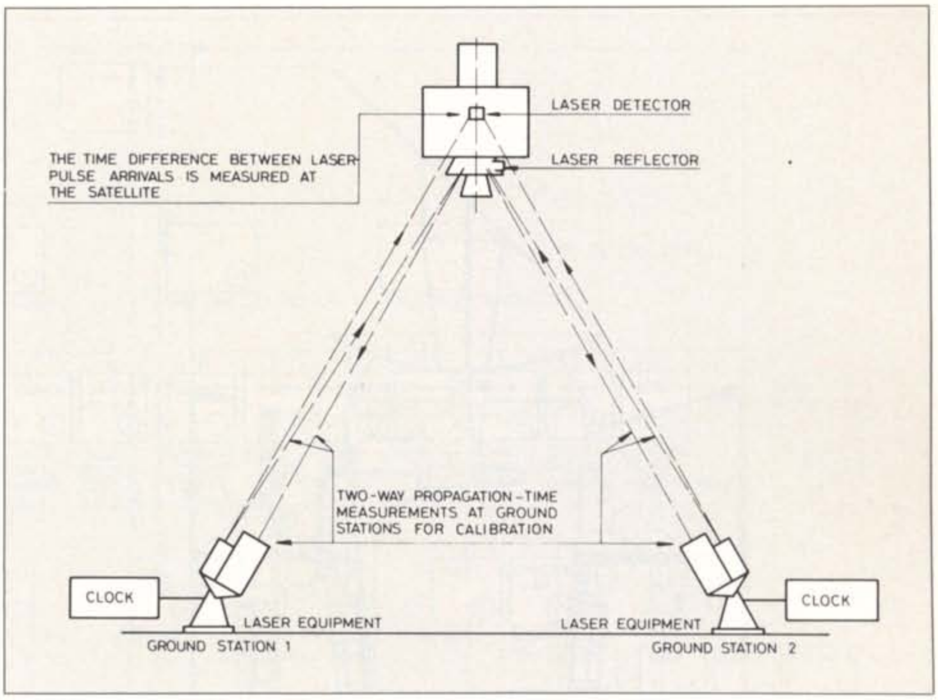
Requirements	
International telephone communication	1 μs
Digital communication	10 μs
Earth-based navigation	1 μs
Deep-space navigation	20 ns
Astronomy } Geodesy }	as accurate as possible

Methods currently used		
Method	Accuracy	Remarks
Very Long Baseline Interferometry (VLBI) using pulsars	1 ns	Slow, expensive ground stations
TV-type transmission via satellite	10 ns	Requires a wideband spacecraft transponder
Portable clocks	30 ns	Slow
Timation-3	100 ns	Military
Loran-C	300 ns	Accuracy limited by propagation phenomena

Table 2 – Laser stations that could use LASSO

Existing European stations:	
Cagliari (I)	
Dyonysos (G)	
Grasse (F)	
Kootwijk (NL)	
San Fernando (E)	
Zimmerwald (CH)	
Wettzell (D)	
Planned European stations:	
Graz (A)	
Herstmonceux (UK)	
North American stations:	
Halifax (CN)	
Miami (USA)	
Washington (USA)	
South American stations:	
Arequipa (Peru)	
Natal (Brasil)	

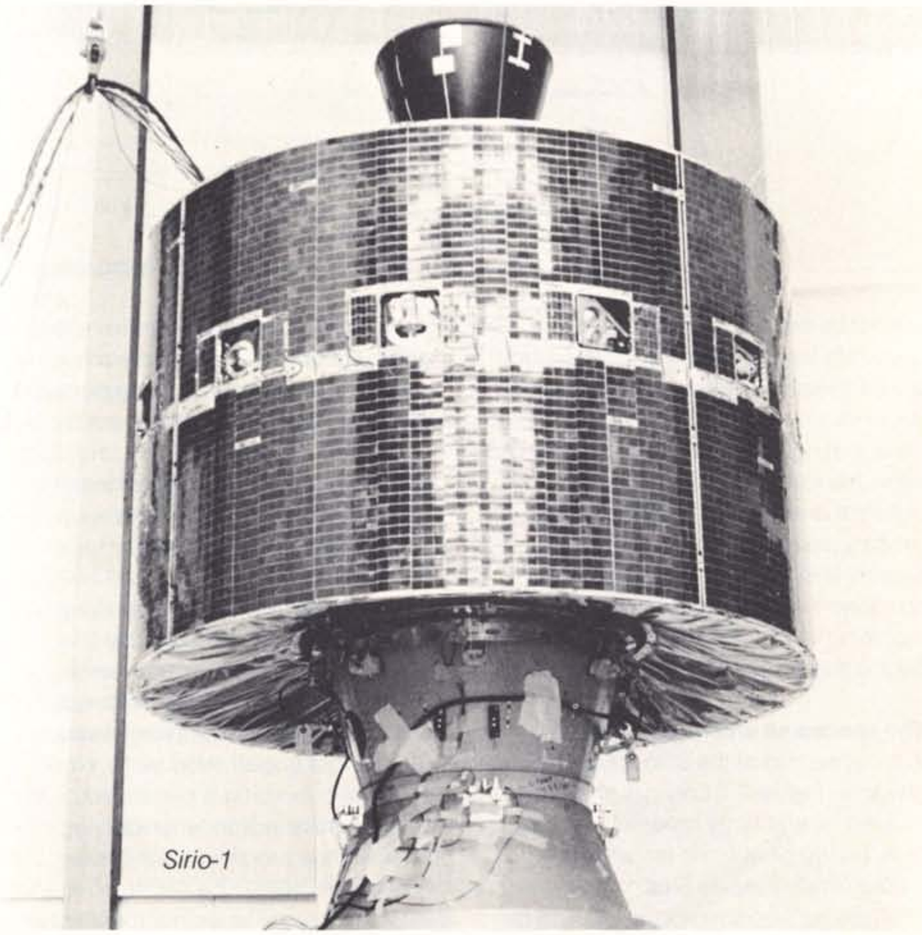
Figure 1 – Schematic of the principle of the LASSO experiment



costly, impractical, or inadequate (Table 1). The LASSO mission promises to make time synchronisation between distant atomic clocks possible with 1 ns accuracy, while at the same time offering high availability and low cost to users.

LASSO works as follows. Suppose it is desirable to synchronise two atomic clocks – one in, say, the United States, the other in Europe (Table 2) – to within about 1 ns of each other. If each clock triggers a laser pulse from a nearby laser station towards the satellite at precisely the same presumed time, the satellite sensor and oscillator assembly can time-tag the arrival of the two pulses. Any measured difference in arrival times will be directly proportional to the synchronisation offset between the atomic clocks. This measured time difference can be transmitted along with the satellite's housekeeping telemetry to the ground for evaluation and subsequent clock synchronisation. This procedure can be repeated for any number of atomic clocks until all are synchronised.

In practice, the measured time differences



Sirio-1

Figure 2 – Cross-section through the Sirio-2 spacecraft

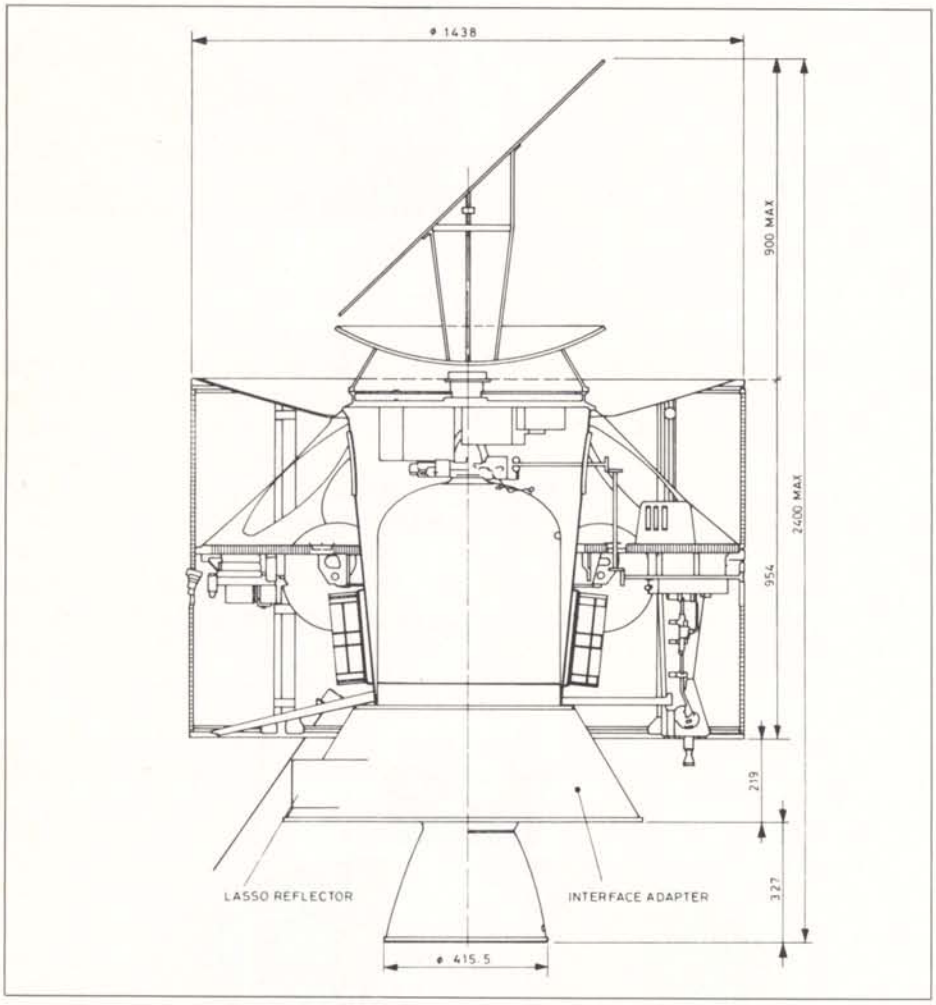
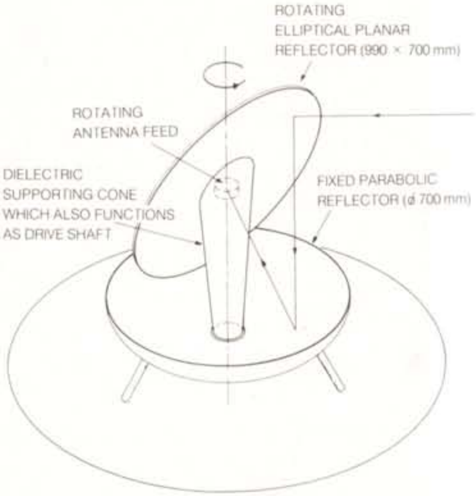


Figure 3 – Operating principle of Sirio-2's mechanically despun antenna. The incoming radio signal is deflected downwards by the 45° planar reflector towards the parabolic reflector, from which it is reflected again onto the parabola's focal point, which contains the antenna feed



will not be perfect reflections of the asynchronism between the clocks, since the earth-satellite laser propagation time depends on the distance between the participating station and the satellite. To allow the stations to calculate that distance and make the necessary propagation-delay corrections, the satellite is to be equipped with mirrors – so called 'retroreflectors' – to reflect each incoming laser pulse back to its originating station (Fig. 1).

The spacecraft and its payloads

A cross-section of the Sirio-2 satellite is shown in Figure 2. It consists of a drum-shaped central body covered with solar cells, on top of which is mounted the mechanically despun S-band antenna. The apogee boost motor, which is to be retained after burn, protrudes from the bottom of the spacecraft. While the directional S-band antenna supports the MDD relay function and transmits the housekeeping telemetry, the omnidirectional turnstile antenna serves telecommand, ranging, and back-up telemetry functions in the VHF.

As the satellite is to be spin-stabilised at 90 rpm and will act as an inertial gyroscope, attitude re-orientation is achieved by torque-induced precession of the spin axis using axial micro-propulsion thrusters in a pulsed firing mode. North-south stationkeeping is performed by the same thrusters in a continuous firing mode, while a pair of radial thrusters allows the satellite to be displaced in an east-west sense. The monopropellant hydrazine fuel is contained in four symmetrically located spherical tanks. The telemetered readings from on-board infrared earth and V-slit sun sensors are used to determine the satellite's attitude in space. The satellite is powered by the solar cells and by a battery sustaining a minimum-load configuration during eclipse transits.

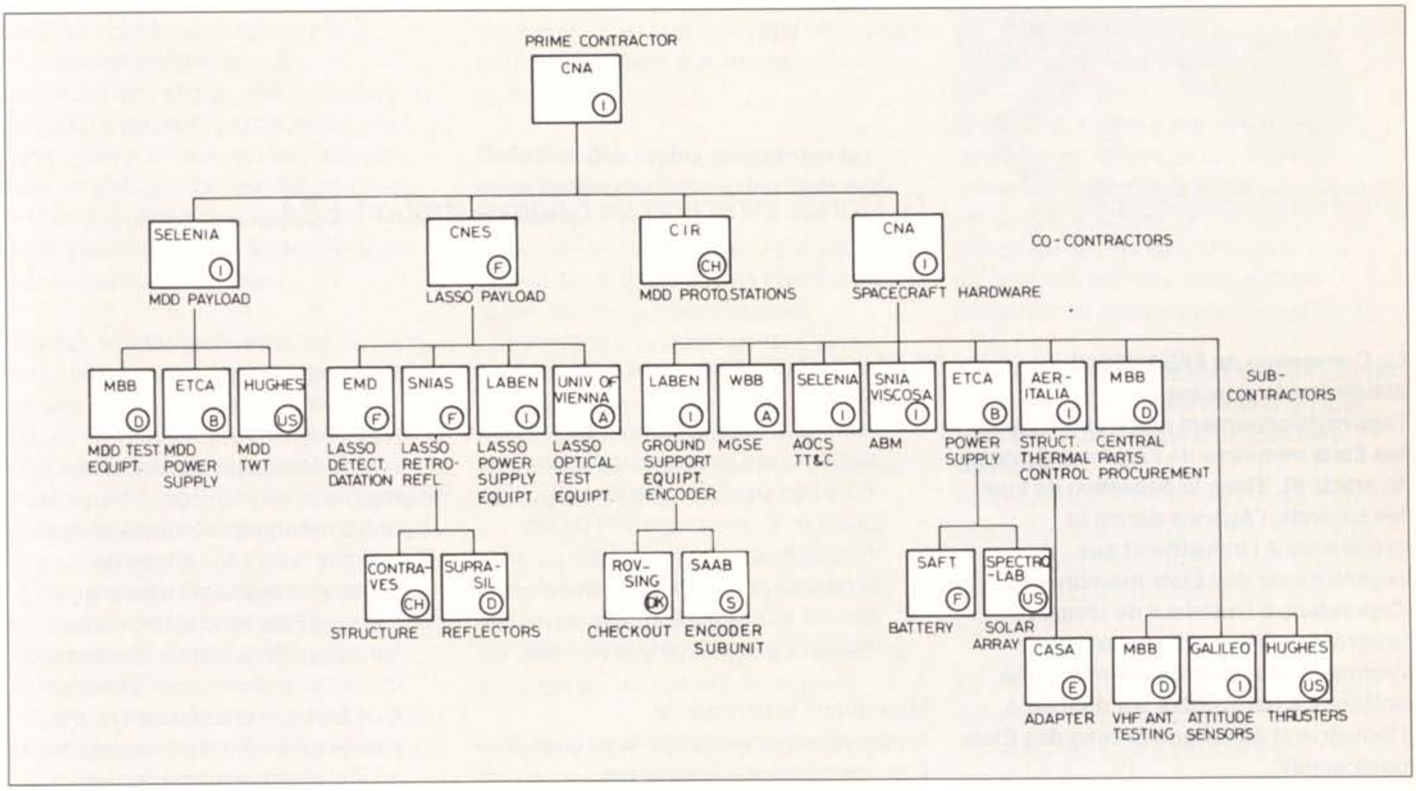
The MDD relay mission uses a linear, transparent S-band transponder with a travelling wave tube as transmitting power amplifier. Contrasting with the otherwise conventional layout of the satellite, the MDD mechanically despun antenna is of an unusual 'pagoda' design, the principle of operation of which is illustrated in Figure 3. The MDD payload includes 12 channels for data relay at 2400 bps and an additional 24 channels at 100 bps.

The LASSO payload is comprised of photodetectors for sensing ruby and neodyme laser pulses, and an ultrastable oscillator/counter to time-tag the arrival of the pulses. These time-tags – or 'datations' – are to be encoded in time-division multiplex with spacecraft housekeeping information before transmission to the ground.

The industrial consortium

The industrial effort for the Sirio-2 project is led by the Compagnia Nazionale Aerospaziale (CNA) in Rome. CNA not only performs the traditional prime

Figure 4 – Organigram of the industrial firms collaborating in Sirio-2



contractor functions such as coordination, management, assembly, integration and test, but is also providing most of the Sirio-1-inherited hardware. France's Centre National d'Etudes Spatiales (CNES) is acting as co-contractor to CNA for LASSO, and Selenia in Rome is in charge of the MDD payload. Another co-contractor, CIR of Switzerland, has been entrusted with building the three prototype MDD ground stations for deployment in Africa during the MDD demonstration campaign. The co-contractors are in turn relying on a variety of European and American subcontractors (Fig. 4).

Management of the 21 MAU (24 M $) Sirio-2 programme is a particular challenge because of the predominance of a single Member State, the very short production time available (two years), the problems of combining existing, refurbished and new hardware in a single satellite, and the comparatively small project team. The overall project management of Sirio-2 is in fact the responsibility of a team with only eight permanent staff, working within the Agency's Earth-Observation Programme Department based in Toulouse.

Present programme status and future plans

At the time of writing (June), the programme is half way into the detailed design phase with a Preliminary Design Review foreseen for mid-June. Three basic satellite models will be built:

- a mechanical model with dummy equipment attached in order to qualify the structural design for the Ariane launch environment
- an integration model, mainly for functional tests with electrically representative subsystems
- a protoflight model, which will be subjected to the acceptance tests prior to launch.

A two-year post-launch exploitation programme is currently being defined and a decision on this programme is expected by mid-1980.

Le problème de l'approvisionnement préférentiel dans les Etats membres de l'Agence

G. Dondi, Direction de l'Administration, ESA

La Convention de l'ESA définit clairement le principe de l'approvisionnement préférentiel dans les Etats membres de l'Agence (Annexe V, article II): 'Dans la passation de tous les contrats, l'Agence donne la préférence à l'industrie et aux organisations des Etats membres. Cependant, à l'intérieur de chaque programme facultatif couvert par l'Article V, 1(b) de la Convention, une préférence particulière est donnée à l'industrie et aux organisations des Etats participants'.

Il est évident que ce principe est dicté par le désir de:

- stimuler le développement de technologies avancées dans les industries des Etats membres,
- protéger le développement de ces industries afin de les rendre compétitives sur le plan mondial,
- assurer aux Etats membres un retour industriel aussi élevé que possible.

Mais autant le principe de l'approvisionnement préférentiel dans les Etats membres de l'Agence est compréhensible en ce qui concerne ses finalités, autant sa traduction en actions spécifiques, quand on passe à l'exécution des programmes de l'Agence, peut donner lieu à des problèmes assez délicats et difficiles à résoudre.

Nous voulons en particulier exposer ici trois de ces problèmes:

- Comment déterminer si une firme appartient ou non à un Etat membre?
- Quelles sont les règles à suivre en ce qui concerne la consultation des firmes des Etats non-membres?
- Quelles sont les règles de choix à suivre lorsqu'une firme d'un Etat membre et une firme d'un Etat non-membre sont en compétition?

Nous allons successivement analyser brièvement chacun de ces problèmes.

Appartenance ou non appartenance d'une firme à un Etat membre

La définition d'une firme comme appartenant à un Etat membre demande d'habitude une analyse délicate et complexe, pour laquelle souvent les données font défaut.

Les cas extrêmes sont relativement simples:

- une firme enregistrée dans un Etat membre, ayant son centre de décision et exécutant les travaux dans cet Etat, est clairement une firme appartenant à un Etat membre;
- de même, le distributeur d'une firme d'un Etat non-membre ayant une activité purement commerciale dans un Etat membre est clairement considéré comme une firme d'un Etat non-membre, même si, légalement, le distributeur, étant enregistré dans un Etat membre, peut soutenir être une firme appartenant à l'Etat membre en question.

Les cas intermédiaires peuvent, par contre, être beaucoup plus nuancés.

Trois cas-types, qui peuvent donner une idée de ces 'nuances', sont les suivants:

- firme multinationale, ayant son centre de décision dans un Etat non-membre, et ayant un grand nombre d'activités (y compris les activités de R et D) exécutées dans un Etat membre;
- firme avec centre de décision dans un Etat membre, mais utilisant amplement des technologies, du matériel et du support en provenance d'un Etat non-membre dans sa production ou ses services;
- firme multinationale, avec centre de décision dans un Etat membre assurant un support technique dans un Etat membre différent.

Il est par conséquent clair qu'il faut analyser les problèmes plus profondément, afin de définir une *liste de critères* qui puissent permettre de juger dans quelle mesure une firme installée dans un Etat membre est intégrée dans cet Etat membre et contribue au développement de son économie et de son niveau technologique.

Une liste non exhaustive de ces éléments, mais qui couvre les aspects essentiels du problème est la suivante:
– Qui a le *contrôle financier* de l'affaire?
– Où sont prises les *décisions stratégiques* concernant les activités de la filiale en question, en particulier son plan d'investissement?
– Comment sont organisées les *activités de recherche* de la multinationale, et dans quelle mesure la filiale en question y participe-t-elle?
– Quel est *l'impact de la filiale en question sur l'ambiance locale?* En particulier, il est important de distinguer:
- l'impact *économique* sur l'expansion de l'économie du pays hôte en général et de la région d'implantation en particulier,
- l'impact *industriel* sur le développement technologique du pays hôte,
- l'impact *social* sur les structures du pays hôte.

– Où sont *exécutés* les travaux confiés à la filiale en question? En particulier, où sont exécutés les travaux de développement pour l'espace confiés à la filiale en question?

Les réponses à ces questions ne sont pas toujours faciles à obtenir; mais il est évident que ce n'est qu'après une analyse de ce type qu'on peut espérer arriver à définir rationnellement la 'nationalité' d'une firme.

D'autre part, il faut bien admettre que l'aspect politique du problème prend souvent une part prépondérante; en d'autres termes, si la Délégation nationale du pays où se trouve la firme considère cette dernière comme une firme 'nationale', il est clair que cette affirmation peut très rarement être remise en question . . .

Définition des règles concernant la consultation des firmes des Etats non-membres

En vue de raisons techniques et de calendrier, et des nuances possibles dans la définition d'une firme comme appartenant à un Etat membre, on ne peut pas exclure automatiquement et systématiquement toute firme d'un Etat non-membre ou ayant des liens importants avec des Etats non-membres des appels d'offres de l'Agence.

Mais, dans ce cas, il est clair que certaines règles doivent être respectées afin, d'une part, d'assurer une consultation équitable et, d'autre part, de sauvegarder les intérêts de l'Agence.

Par exemple, l'ESA applique de façon informelle les règles suivantes:
– Les firmes des Etats non-membres sont en principe consultées seulement s'il y a pour elles une chance non négligeable d'être choisies. Si leurs chances sont marginales, les firmes des Etats non-membres sont mises au courant des règles qui seront suivies pour l'évaluation des offres.
– La consultation des firmes non européennes est en principe exclue pour tous les travaux de R et D. La seule exception est constituée par le cas où une acquisition de technologie est envisageable parce que le coût de développement en Europe pourrait s'avérer trop élevé ou le délai de mise au point trop long. Dans ce cas, les alternatives de politique industrielle envisagées sont en principe indiquées dans l'invitation à soumissionner.
– La procédure de 'demande d'offres' à des fournisseurs d'Etats non-membres est parfois utilisée à la suite d'appels d'offres de l'Agence dans les cas où:
- les prix des offres provenant d'un Etat membre sont jugés trop élevés sans justification,
- les délais de livraison des firmes d'un Etat membre sont incompatibles avec le calendrier adopté.

En résumé, on peut dire que la règle générale est de ne pas consulter les firmes des Etats non-membres; mais, si on est obligé de le faire, la préoccupation principale devient celle d'assurer une compétition honnête, en spécifiant clairement et à l'avance les règles du jeu.

Définition des règles du choix en cas de compétition entre une firme d'un Etat membre et une firme d'un Etat non-membre

Plusieurs questions doivent être éclaircies en ce qui concerne le *choix d'une firme* quand une firme d'un Etat membre et une firme d'un Etat non-membre sont en compétition.

Il y a ici deux aspects de la question qui doivent être bien distingués:
– D'une part, il y a les considérations *stratégiques* ou à long terme qui peuvent être liées à un approvisionnement. En d'autres termes, les questions qualité, prix et délais doivent parfois être mises en perspective afin de bien tenir compte de questions de politique industrielle comme par exemple:
- l'approvisionnement en question sera-t-il suivi par d'autres contrats?
- le choix d'une technologie ne conduit-il pas à une source obligée d'approvisionnement?
- quels sont les domaines où le développement d'une technologie européenne est souhaitable? Et à quel prix?
- le contrat en discussion peut-il être considéré comme vital pour le développement d'une des technologies 'souhaitables', etc.?

– D'autre part, il y a les considérations *quantitatives* concernant l'origine (conception, fabrication et mise en oeuvre) d'un matériel ou d'un service, qui sont essentielles pour arriver à une évaluation correcte de la *répartition géographique des travaux*, élément toujours important et parfois critique dans l'assignation d'un contrat.

Tableau 1 – Règles d'attribution pour quelques cas typiques.

Cas pratique	Règle d'attribution
1. Des composants provenant d'un pays A (membre ou non-membre) font partie d'un équipement intégré dans le pays B. Par exemple: – assemblage brut de matériel importé; – assemblage d'une production locale sur conception provenant de A; – conception locale avec production locale complétée par l'utilisation de certains composants provenant de A.	– La partie attribuable à B doit correspondre à la valeur ajoutée locale y compris la part correspondante des frais généraux, à l'exception des 'royalties' payées à A.
2. Etudes exécutées en B avec l'aide d'experts du pays A.	– Les experts sont à la charge de A, le reste à la charge de B.
3. Assistance technique d'une firme opérant dans le pays B avec du personnel de différentes nationalités.	– Les frais généraux sont attribuables à B, les frais de personnel sont répartis selon la nationalité des personnes.
4. Contrat d'entretien d'un matériel d'un pays A, localisé dans un pays B avec personnel de différentes nationalités.	– Les frais généraux sont attribuables à B, les pièces de rechange à A; les frais de personnel sont répartis selon la nationalité des personnes.
5. Royalties à une firme d'un pays A pour la simple reproduction d'un équipement produit par une firme d'un pays B.	– Le coût des royalties est attribué à A, les coûts restants à B.
6. Royalties à une firme d'un pays A pour un transfert de technologie à une firme d'un pays B.	– Le coût des royalties est attribué pour 50% à A, et pour 50% à B.

Il est évident que les considérations quantitatives concernant l'origine d'un matériel ou d'un service peuvent être très importantes pour arriver à définir le 'degré d'appartenance à un Etat membre' d'une offre particulière; le Tableau 1 donne quelques exemples des cas à traiter et des règles d'attribution correspondantes. En pratique, cette évaluation est très souvent laissée au contractant principal, avec contrôle final par l'Exécutif de l'Agence.

Revenons maintenant à la question des règles de choix quand une firme appartenant à un Etat non-membre est en compétition avec des firmes appartenant à un Etat membre (nous laissons de côté pour l'instant les cas plus nuancés où l'on a affaire à des 'offres provenant *en majorité* d'Etats non-membres' vis-à-vis 'd'offres provenant *en majorité* d'Etats membres').

Nous allons considérer trois cas assez typiques.

1. Cas d'une firme faisant partie a 100% d'un Etat non-membre

– *Toutes autres choses étant égales*, la firme d'un Etat membre a la préférence même si son coût *Y* est supérieur de *X*% à celui d'une firme d'un Etat non-membre (*Y* et *X* à fixer selon les cas*).
– Les aspects 'qualité' et 'calendrier' ne doivent jouer que si les offres de firmes d'Etats membres en compétition ne sont pas acceptables. Une offre marginalement acceptable en provenance d'un Etat membre doit être acceptée.

2. Cas d'une firme avec un sous-traitant d'un Etat non-membre

– On doit distinguer entre une sous-traitance pour laquelle la contribution d'un Etat non-membre est *indispensable* et une semblable sous-traitance qui simplement *améliore l'offre* (prix, délais, avantages techniques non déterminants ...).
– Dans le premier cas, la sous-traitance dans un Etat non-membre est inévitable; mais l'initiateur technique doit démontrer l'impossibilité d'assurer un approvisionnement ou un service comparable dans un Etat membre.
– Dans le second cas, l'offre d'une firme d'un Etat membre doit être écartée seulement si l'avantage offert par la firme d'un Etat non-membre est *très* important (prix *Y* inférieur de *X*%, avec *Y* et *X* à fixer selon les cas*; risques de calendrier diminués d'une façon substantielle; etc.).

3. Questions de la sous-traitance dans un Etat non-membre après l'adjudication d'un contrat

– La sous-traitance doit être révélée et discutée lors de l'adjudication du contrat principal.
– En principe, la sous-traitance passée 'en cours de route' pour diminuer le prix (en particulier un prix forfaitaire) doit être interdite. Cette condition devrait faire partie du contrat principal, et le contractant principal devrait s'engager à la faire respecter.
– Une sous-traitance 'en cours de route' à une firme d'un Etat non-membre peut être considérée seulement:

* Les valeurs de *X* et *Y* sont évidemment liées: *X* = 50% peut être acceptable pour des développements de 50 KUC mais, au contraire, *X* = 10% peut déjà être à la limite de l'acceptable pour un développement de plusieurs MUC. En moyenne, une valeur de *X* = 20% est habituellement retenue; mais dans des cas particuliers où des questions de politique industrielle ayant trait au développement et à l'application de nouvelles technologies entrent en jeu, la valeur de *X* peut devenir très élevée.

- si on est en présence d'impératifs techniques ou de calendrier bien documenté;
- si le pays auquel la sous-traitance échappe est d'accord avec la mesure en question et prêt à accepter la réduction de retour industriel correspondante.

Evidemment, des cas plus nuancés peuvent se produire; en tout état de cause, il est clair que le principe suivi est celui qui consiste à accorder la préférence aux offres en provenance des Etats membres, pourvu que les avantages techniques de délais et de coût auxquels on renonce ne deviennent pas énormes.

Conclusions
Le principe d'approvisionnement préférentiel dans les Etats membres de l'Agence peut présenter, au moment de son application pratique, des problèmes délicats et difficiles à résoudre.

Quelques-uns de ces problèmes ont été exposés, et on a donné une indication des solutions pratiques couramment acceptées et de quelques développements en la matière qui pourraient être envisagés.

Il est évident que seuls les efforts conjoints de l'Exécutif de l'Agence, des Délégations nationales et de l'Industrie pourront permettre l'élaboration et l'application de régles plus précises que celles qui sont couramment appliquées, afin de mettre encore mieux en pratique les principes d'équité et de compétitivité qui ont toujours guidé les actions d'approvisionnement de l'Agence.

Colloquium on the Economic Effects of Space and Other Advanced Technologies

Investment in high technologies raises issues of increasing importance for the industrial nations, and is also becoming a matter of active concern in the developing world.

Government 'think tanks', planning and finance ministries, private and public institutions, and technological agencies, both national and international, spend a great deal of time and money in trying to to determine the best route to take in the high technologies to attain the highest economic and social return, and they have developed a wide variety of techniques and methods to provide answers to the questions.

Now, for the first time in Europe, those who develop and use these techniques will meet to discuss, review and compare their problems, methods and results. The International Colloquium on the 'Economic Benefits of Space and Other Advanced Technologies', organised by ESA and the Université Louis Pasteur, Strasbourg, and co-sponsored by the Parliamentary Assembly of the Council of Europe, will be held in Strasbourg from 28 to 30 April 1980.

The Colloquium will bring together economists, forecasters and technologists in government, research establishments, universities, the sciences and industry, from Europe, the USA and elsewhere in order to present analyses of research policy, surveys of the methods employed to evaluate progress and benefits, as well as descriptions of applied studies in the field.

The occasion will be of particular interest to all those engaged in formulating national and international strategies and policies in science and technology and the evaluation of the economic return of these policies.

Further information can be obtained by contacting the Chairman of the Organising Committee:

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8-10 rue Mario Nikis
75015 Paris
France
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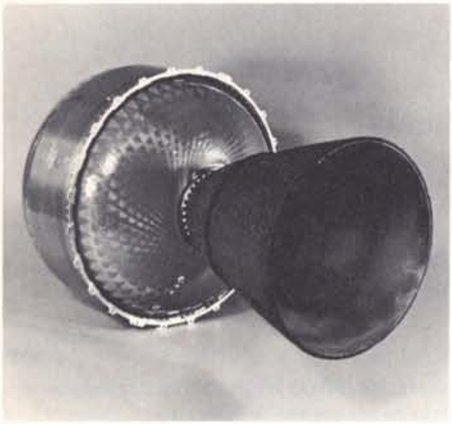

Progress in Solid-Propellant Rocket Motors for Space Application

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When ESA decided in 1973 to foster the development in Europe of state-of-the-art technology in solid-propellant rocket motors for space applications, the programme objectives were specified, but the technological goals were still in the process of being identified. A few years were still needed to acquire the necessary expertise in the advanced technology and to adapt industrial resources and facilities to the requirements of technological progress.

The initial challenge to European industry was to develop and qualify the SM27 motor that was subsequently used successfully as apogee boost motor for the Agency's two scientific geostationary satellites Geos-1 and 2.

Almost in parallel with SM27 development the MAGE* project was started with the dual objectives of improving the performance characteristics of the basic motor design and providing apogee motors for ESA's applications satellites.

* MAGE: Moteur d'Apogee Geostationaire Européen

Performance specifications for the MAGE motor were initially centred around the needs of Delta-2914 launched geostationary satellites. The development of the Agency's own Ariane launcher on the one hand and the evolution of ESA's programmes in the applications satellites field on the other thereafter guided a reorientation of the project and a widening of its scope to meet the new objectives, leading eventually to the definition of a 'family' of MAGE motors rather than a single unit. When the original MAGE programme started in 1973, the development contract was awarded to an industrial consortium in which SEP (France) was the prime contractor, and SNIA-Viscosa (Italy) and MAN (Germany) were co-contractors. As already mentioned, the prime objective was to develop, qualify and deliver an Apogee Boost Motor (ABM) that could be used by the Meteosat, OTS and Marots spacecraft, which were to be placed into initial transfer orbits by Delta-2914 launch vehicles.

In the event, Meteosat was indeed launched by a Delta-2914, but OTS and Marots were later switched to Delta-3914 launchers, thereby achieving a considerable increase in allowable payload mass. Consequently, the initial MAGE motor design was no longer

Table 1 – ABM sizings for missions compatible with US launches and Ariane

	Mass in transfer orbit, kg US systems				Mass in transfer orbit, kg Ariane			
Payload class	Spacecraft	ABM	Total	ΔV, m/s	Spacecraft	ABM	Total	ΔV, m/s
Delta-2914	340	363	703	1845	340	290	630	1532
Delta-3914	456	474	930	1845	456	374	830	1532
Delta-3910 + Payload-Assist Module (PAM-D)	520	532	1052	1845	520	423	943	1532
Shuttle (STS) + Payload-Assist Module (PAM-D)	529	523	1052	1801	529	429	958	1532
Atlas-Centaur	873 (934)*	981 (925)*	1859	1845	878	690	1568	1532
Shuttle (STS) + (PAM-A)	965 (1020)*	1031 (976)*	1996	1801	965	750	1715	1532

* Achievable if MAGE-type motors were to be designed for these particular applications

suitable for the OTS and Marots missions. At the same time, the mission requirements associated with the development of the Agency's own Ariane launcher had to be taken into account.

All in all, the MAGE motor design had to be adapted by means of propellant off-loading techniques to meet the varying performance requirements of a range of applications rather than those of just a single type of launcher– spacecraft combination.

In mid-1977 a new contract was awarded to the MAGE consortium for the development and the qualification of a new generation of motors belonging to the same 'technological family' as MAGE-I, but delivering the higher performance needed for boosting larger payloads into high orbits.

The evolution in Ariane's performance characteristics, and the introduction of dual-launch missions with the development of Sylda (Système de Lancement Double Ariane) also called for

Table 2 – MAGE motor utilisation

Spacecraft				Apogee Boost Motor		
	Mass, kg	Launch system	Launch date		Propellant mass, kg	Velocity incr., m/s
Meteosat-2	532	APEX (Ariane L03)	20 06 80	MAGE-I	250	1532
Marecs-A	532	APEX (Ariane L04)	30 10 80	MAGE-IS	395	1532
Marecs-B	380	Ariane	30 04 81	MAGE-IS	395	1532
ECS-1	559	Ariane	31 11 81	MAGE-IS	408	1532
ECS-2	559	Ariane	June 1982	MAGE-IS	408	1532

further adaptations to ensure that the MAGE programme would be able to provide suitable apogee boost motors for the several geostationary missions foreseen within the Agency's scientific and applications programmes.

In addition, compatibility with possible future launches with US launch systems has also been taken into account as far as possible, following a criterion of maximum commonality in design and technology for reasons of future cost-effectiveness.

Payload classes compatible with US and Ariane launches

In Table 1, six 'classes' of geostationary payload are identified and the mass and performance characteristics of the ABMs

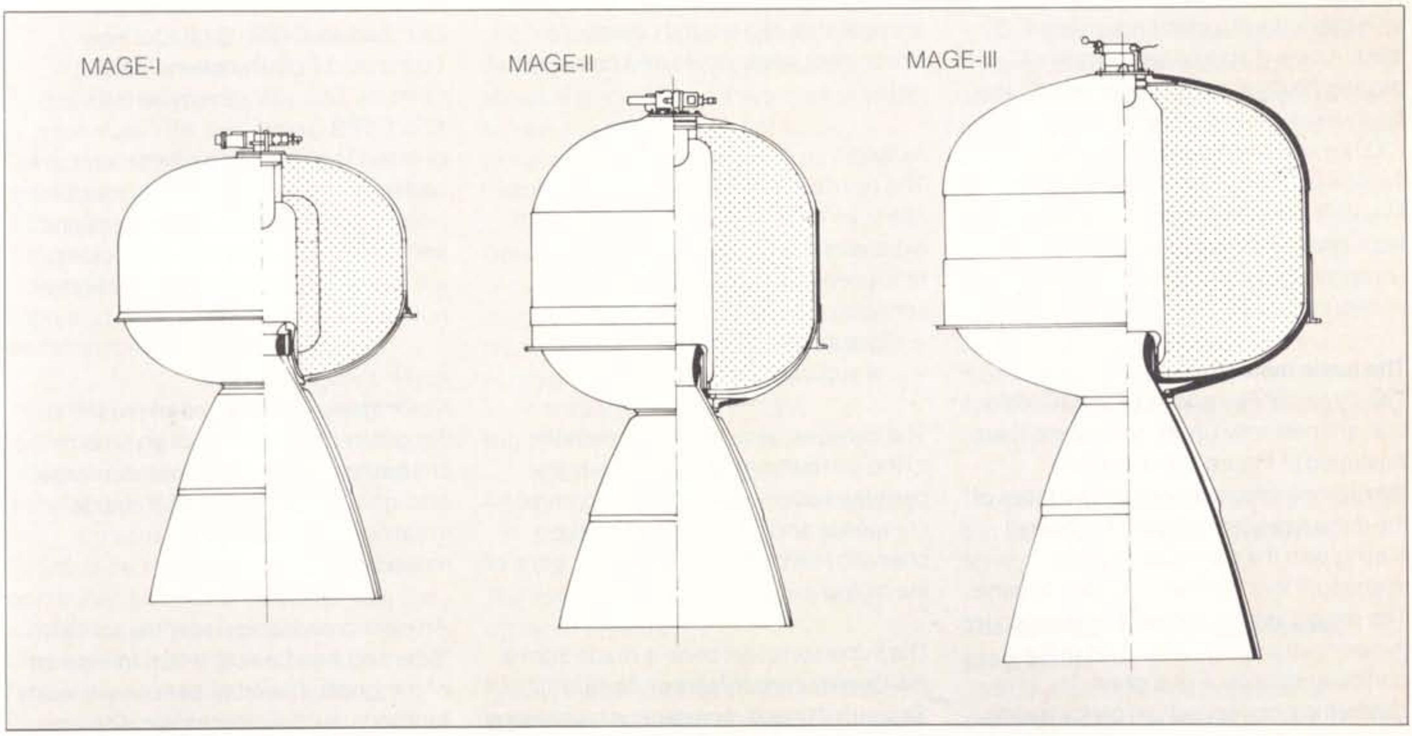


Figure 1 – The basic MAGE motor configurations

needed when using American and European launch systems are computed.

Four basic motor configurations have been identified, namely:

MAGE I	mass range 280–370 kg
MAGE IS	mass range 340–440 kg
MAGE II	mass range 410–540 kg
MAGE III	mass range 670–880 kg

Of these four configurations, only the three that correspond to the needs of already identified missions (indicated in Table 2) are presently under development.

The MAGE-II configuration would only be required in the event that certain ESA payloads were to be launched with US systems or if the mass of those payloads were to be further increased. It is therefore not planned to develop a motor of this particular class at this time.

The MAGE-III motor, on the other hand, is designed for a geostationary payload compatible with Ariane's maximum performance on operational flights. This performance limit has been raised considerably above what was originally specified at the outset of the European launcher's development programme. By 1981, Ariane-2 should be capable of placing 2000 kg in transfer orbit, and this figure will further increase to some 2300 kg with the availability of Ariane-3. Table 3 provides a review of possible MAGE-III design targets: the development work presently being carried out is concentrated on the MAGE-III/2000 configuration.

Table 3 – MAGE-III design requirements

	Transfer-orbit mass, kg		Propellant mass, kg		Satellite mass (excl ABM), kg	
Configuration	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
MAGE-III/1750	1383	1840	570	760	758	1025
MAGE-III/2000	1580	2100	652	867	873	1178
MAGE-III/2400	1896	2520	783	1040	1058	1425

The basic motor design

The three configurations of MAGE motor that are presently under development are illustrated in Figure 1. The overall dimensions and mechanical interfaces of the three types are selected for correct mating with the particular Agency spacecraft that they are intended to serve. The propellant loadings are also tuned to the performance requirements of the particular mission. For a given geometrical configuration, performance adjustments of 25% of the nominal level are possible by off-loading part of the propellant after the grain has been cast and cured.

The motor case

With solid-propellant motors, the motor case serves as both the propellant tank and the combustion chamber. To achieve good performance characteristics, the MAGE case is constructed from an advanced composite material. It consists basically of a pressure vessel and an attachment skirt that allows the motor to be mated with the spacecraft.

The pressure vessel is filament-wound from 'kevlar' fibres in epoxy matrix. The skirt consists of a wound composite structure of kevlar fibres and carbon-fibre cloth.

Nozzle

The nozzle, the subsystem that enables optimum thrust to be achieved through expansion and acceleration of the gas produced by propellant combustion, consists of two main elements:

- a subsonic section, and
- a supersonic exit cone.

The subsonic section, which feeds the gas to the sonic throat, is made of a high-density, erosion-resistant carbon/carbon composite and insulated with carbon phenolic to limit heat flow to other parts of the motor.

The supersonic exit cone is made from a low-density carbon/carbon composite 'Sepcarb 21', and represents a technology that holds considerable promise for the high-performance motors of the future – namely that of being able to manufacture lightweight, high-expansion exit cones.

Liner

The propellant liner, which performs the dual function of flame inhibitor and thermal insulator, consists of asbestos-filled ethylene-propylene-terpolymer rubber. It also has a very important structural task in that it provides the necessary support to the propellant grain.

Propellant grain

The solid-propellant composite that powers the MAGE motors consists of a mixture of fuel and oxidiser and is identified as 'CTPB-1612' (Carboxy Terminated Poly-Butadiene 1612). It contains 72% ammonium perchlorate, 12% CTPB binder, and 16% aluminium powder. The remaining constituents are additives fundamental both to the casting and curing of the propellant grain, and to the motor's final performance, but they are of negligible mass and are therefore not accounted for here.

Igniter subsystem

Motor ignition is achieved by means of hot gas produced by a 'sililane' main charge housed in a stainless-steel case and ignited by a pyrotechnic charge. Initiation is electrical, by means of redundant cartridges.

An electromechanical unit, the so-called 'Safe and Arm Device', which forms part of the igniter assembly, performs auxiliary functions, such as electrical safing and

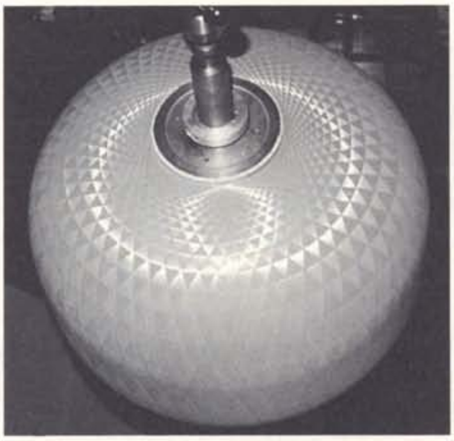


Figure 2 – The MAGE-I motor case

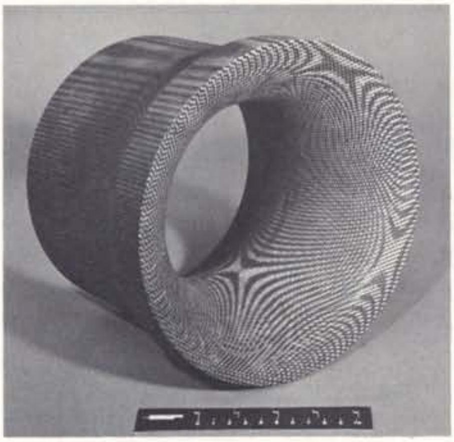


Figure 3 – The MAGE-I nozzle throat, manufactured from high-density Sepcarb 400

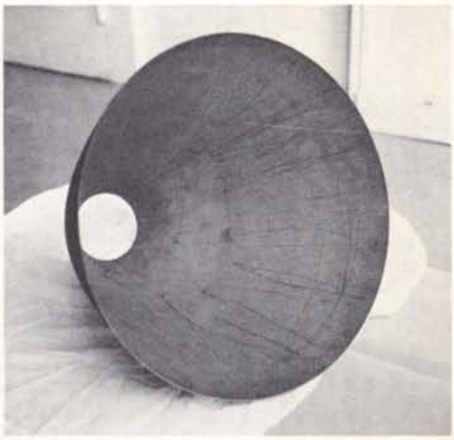


Figure 4 – The MAGE-I exit cone, manufactured from low-density Sepcarb 21

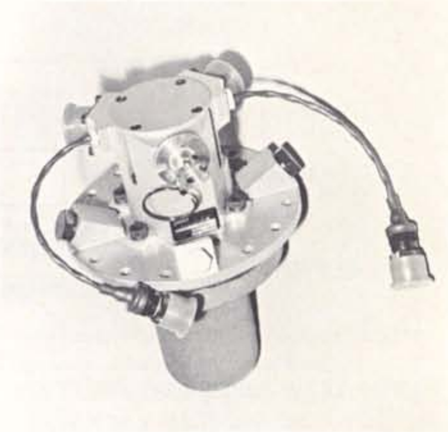


Figure 5 – The MAGE motor's igniter and safe-arm device

arming, and mechanical safing.

Technological goals

The path for the advancement of solid-propellant technology in Europe was already marked out to a large degree when, at the beginning of the MAGE programme, the performance requirements of the users set levels that basically corresponded to the state-of-the-art of American technology. European industry was well aware that a big step forward would have to be made in a relatively short time to match US competition. Although this step was made even harder by the minimal previous experience in apogee-motor development in Europe compared with that in the USA, the challenge was accepted and the MAGE programme was begun.

Two clear criteria guided the MAGE development work:

(i) The maximum possible specific impulse was to be achieved by increasing the percentage of solids in the propellant grain.
(ii) The inert masses were to be reduced:
   - by design optimisation
   - by selection of only high-performance materials, and
   - by improvements in manufacture.

The first criterion led to the present propellant formulation, which, at this time, is the best compatible with the MAGE's design and operational requirements. The inert-mass-reduction objectives have been, and still are being, pursued by updating the inherent technologies.

The MAGE-I kevlar-composite vessel today has a performance factor (K-factor) that puts it among the most advanced technologies in this field (Fig. 2).

The high-density material used for the nozzle inlet and throat (Sepcarb 400) has outstanding erosion-resistance characteristics at high temperature and represents a valuable contribution to motor performance (Fig. 3).

The low-density carbon material used in the supersonic exit cone (Sepcarb 21) allows high nozzle expansion ratios to be achieved without significant mass penalties. The typical 'rosette' structure is just visible in Figure 4.

Optimisation of the ignition system's design, carried out in parallel with the main development activities, had three main objectives which were successfully achieved. These were:

- to reduce its mass by 25%
- to improve intrinsic reliability, by reducing overall complexity
- to minimise imbalance, by employing a quasi-axisymmetric configuration.

The igniter and safe-arm device are shown in Figure 5.

Finally, the off-loading characteristics of the motor, although not specifically linked to the mass/performance optimisation criteria, constitute a technological achievement of great importance to the mission planner because of the flexibility offered.

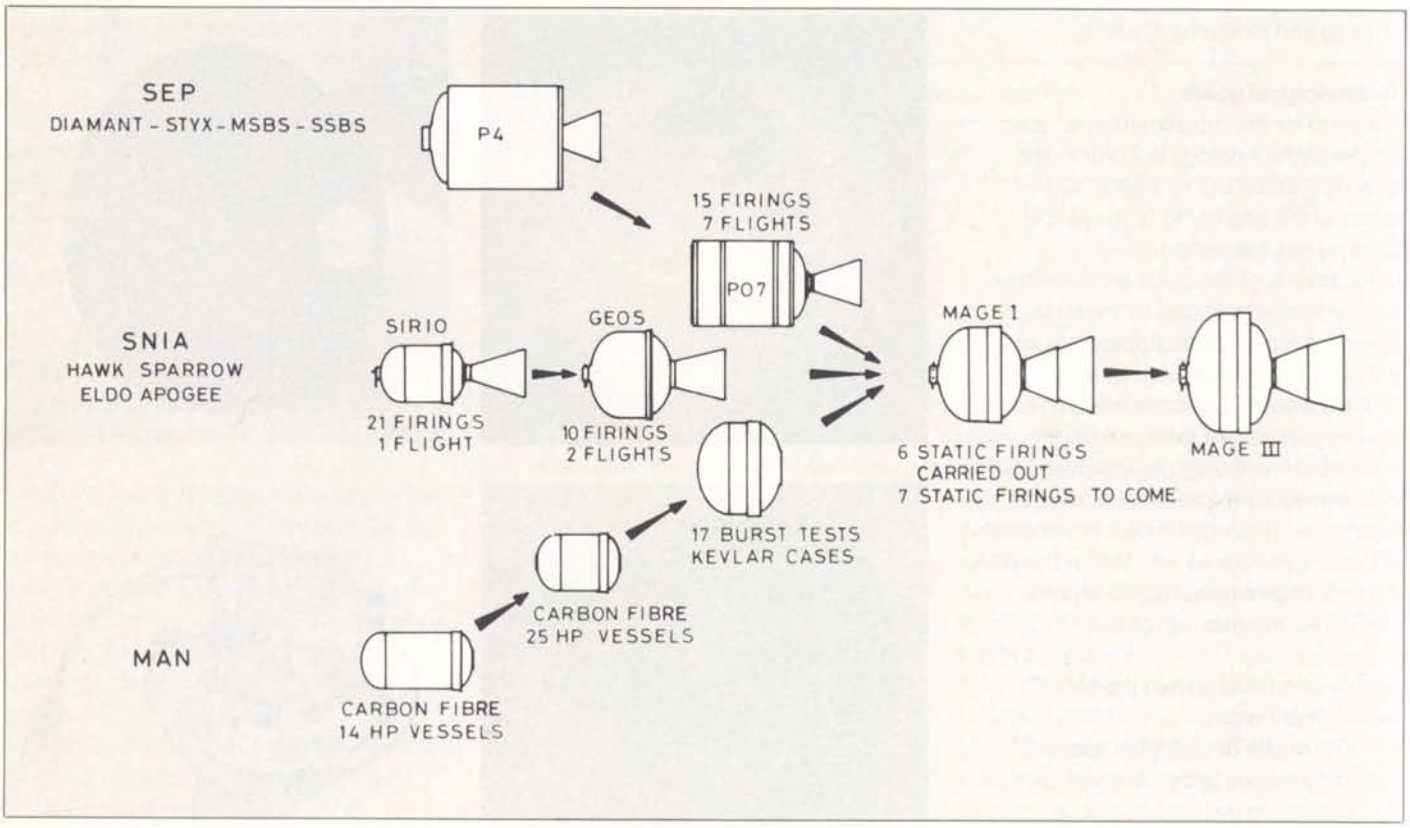
As already mentioned, up to 25% of the MAGE motor's maximum propellant charge can be off-loaded by machining the propellant grain into pre-set configurations that do not alter the motor's ballistic behaviour. The ignition system is easily adapted to the final grain configuration.

The photograph at the start of this article shows the MAGE-I motor's external configuration.

The development and qualification programme

The development and qualification programme for the MAGE motors can be

Figure 6 – Backgrounds of the industrial prime and co-contractors for the MAGE project



divided into five main phases which have often combined system tasks with basic technological activities:

- Phase-I corresponds to the initial development, directed towards a single motor design, based on existing technology.
- Phase-II, a transition or bridging phase, allowed validation through test activities of the basic design and the acquisition of new technologies to meet more demanding requirements.
- Phase-III has consisted of three main lines of activity:
  (a) The development proper of the MAGE-I and IS motors
  (b) Validation by testing of the new technologies introduced during Phase-II
  (c) The definition phase for the MAGE-III motor.
- Phase-IV. The completion of this phase will lead to qualification of the MAGE-I/IS configurations and to delivery of the apogee boost motor unit for Meteosat-2, to be launched in 1980. Completion of this phase is also tied to the motor procurements for the Marecs and ECS satellite missions.
- Phase-V. The majority of this phase relates to the complete development and qualification of the MAGE-III motor, together with off-line technological tasks, such as motor shelf-life definition, materials characterisation, etc.

Project management

The Agency (ESTEC) is responsible for overall project management and interface coordination for the MAGE programme. SEP (Société Européenne de Propulsion) is both the prime contractor for the industrial consortium and has particular responsibility for nozzle and igniter development and qualification. SNIA-Viscosa is charged with the motor's assembly and integration, environmental tests on motor units, static firings of motor units and liner and propellant manufacture, while MAN (Maschinefabrick Augsburg Nürnburg) is working on motor-case development and qualification.

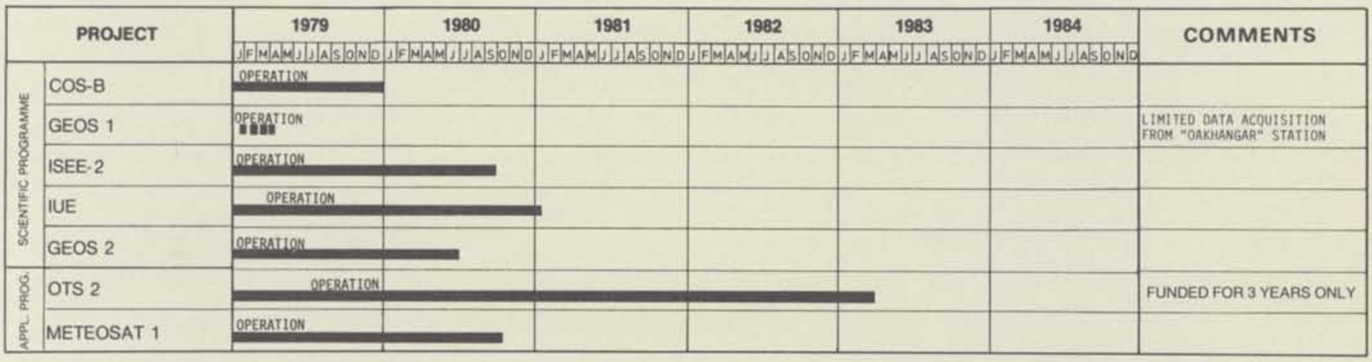
The backgrounds of the three companies in their respective fields of responsibility are illustrated schematically in Figure 6.

Conclusion

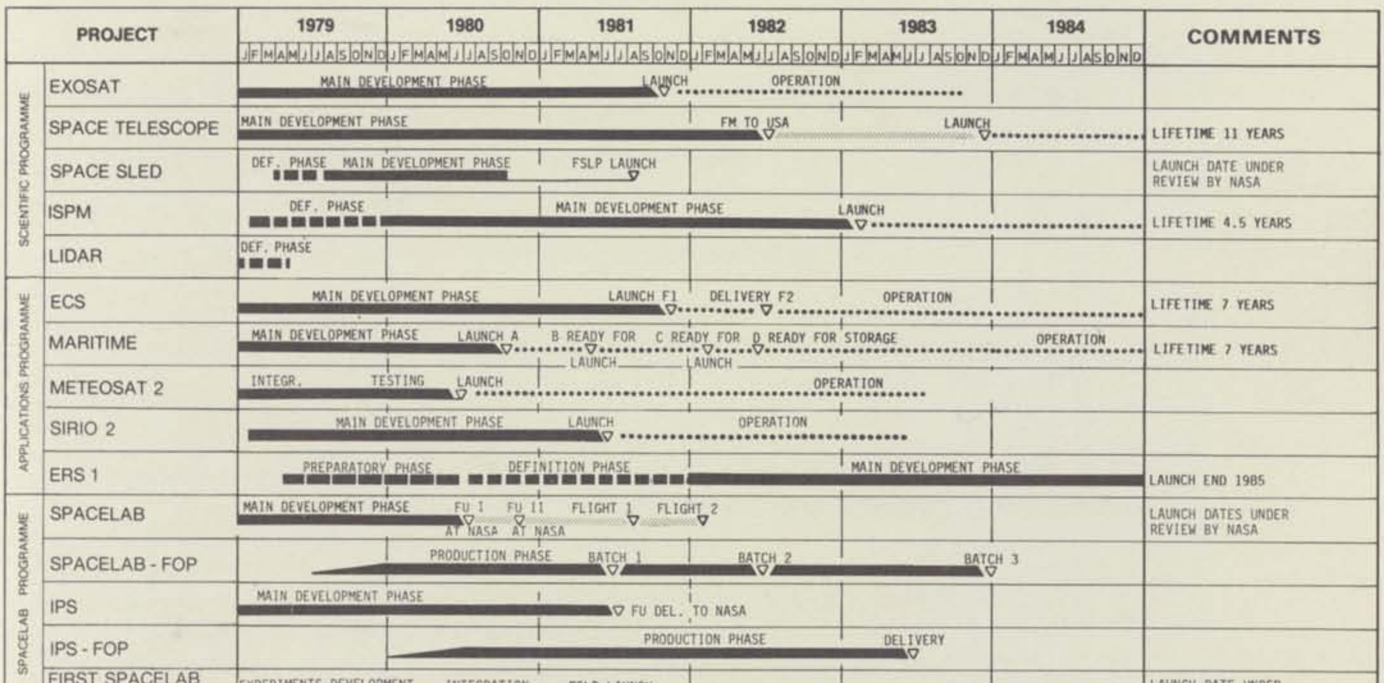
Development and qualification of solid-propellant rocket motors for European space programmes has been identified as a necessity and competition with US manufacturers will undoubtedly dictate that the propulsion schemes that are developed and qualified remain technologically advanced and cost-effective. Moreover, European industry's awareness of the potential expansion in the geostationary-satellite markets is serving as an additional stimulus to the pursuit of technological advancement.

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

In Orbit / *En orbite*



Under Development / *En cours de réalisation*



* Reporting status as per end May 1979/Bar valid per end June 1979

Bien que le planning ci-dessus soit valide jusqu à fin juin 1979, la situation des projets décrits dans les pages qui suivent s' arrête à la fin de mai 1979.

Cos-B

Le fonctionnement du satellite et des expériences reste nominal et on estime, d'après les ressources en matières consommables restant disponibles à bord, que l'exploitation du satellite pourrait être poursuivie au moins pendant la majeure partie de 1980. Considérant le nombre de questions non résolues dans le domaine de l'astronomie du rayonnement gamma qui ne pourront faire l'objet d'une investigation complète d'ici la fin de l'année 1979, les expérimentateurs de la Collaboration Caravane ont demandé à l'ESA de prolonger la mission au-delà de cette date.

La Collaboration Caravane s'engage actuellement dans une coopération avec la Division de Radiophysique de l'Australian Commonwealth Scientific and Industrial Research Organisation dans le cadre d'un accord culturel passé entre l'Italie et l'Australie. Les objectifs de cette coopération sont l'étude simultanée de pulsars aux longueurs d'onde radio et gamma et la recherche de correspondants éventuels des sources de rayons gamma détectées par Cos-B.

La première étape de cette nouvelle collaboration consiste en une deuxième observation du pulsar PSR0740-28 qui a débuté le 2 avril. Les pulsars PSR1055-52 et PSR0833-45 figurent également parmi les objectifs pour 1979. Il est également prévu d'étudier de nouveaux objets extra-galactiques, y compris le quasar de rayons X QS0 2S2251-178 et la galaxie de Seyfert 3C120. D'autres observations auront pour objet l'étude de certaines caractéristiques du rayonnement gamma galactique comme le rayonnement provenant des nuages interstellaires locaux de la ceinture de Gould.

Geos

Geos-1

Au 25 avril Geos-1 avait réalisé, depuis le début de l'année, 50 périodes d'acquisition de données de 3 h chacune y compris deux campagnes coordonnées comportant l'utilisation simultanée de spectromètres de masse sur quatre satellites d'étude de la magnétosphère: Geos-1, Geos-2, Scatha et S-3-3. Geos-1 a également été utilisé pour le soutien d'une campagne d'émission de lithium par fusée effectuée de l'Alaska par des expérimentateurs américains. Pour cette campagne, le satellite a été télécommandé en mode de fonctionnement approprié par des stations de la NASA conformément aux instructions de l'ESOC. L'acquisition des données a été assurée par une station d'Hawaii. On a pu constater que des données de bonne qualité avaient été reçues du satellite pendant 6 h environ après l'émission du lithium au-dessus de l'Alaska. La participation de Geos-1 à cette expérience avait pour objet de permettre d'étudier les mécanismes de déplacement dans la magnétosphère en utilisant le lithium comme traceur. Il y a eu deux ans le 20 avril que le satellite a été placé sur orbite.

Geos-2

Geos-2 vient de sortir, sans difficulté, de sa deuxième période d'éclipse. Le satellite a été utilisé en soutien d'un certain nombre de campagnes importantes de fusées-sondes effectuées de l'Esrange (Suède) et d'Andoya (Norvège). Au cours de la récente campagne Porcupine notamment, Geos-2 a joué un rôle prépondérant, ses données étant transmises de l'ESOC à l'Esrange en temps réel afin d'aider le responsable scientifique du projet à Kiruna à déterminer le moment optimal pour le lancement des fusées.

Le 13 mars, l'axe de rotation du satellite a été réorienté de 180° afin d'éviter les ombres portées par les mâts sur les réseaux solaires.

Les responsables des expériences sont toujours très occupés par le traitement et l'analyse de leurs données et l'esprit de coopération étroite qui règne entre les différents groupes est très encourageant. Les études sur les particules et les ondes, auxquelles tous les expérimentateurs peuvent participer, sont à cet égard particulièrement intéressantes.

Parmi les autres secteurs de coopération, on peut citer l'étude des traversées de lignes de délimitation et les comparaisons entre les mesures de dérive du plasma et les mesures de champs électriques.

ISEE

Les trois satellites ISEE continuent de fonctionner de façon satisfaisante. ISEE-1 et 2 commencent à entrer pour la première fois dans de longues périodes d'ombre, ce qui va mettre à l'épreuve l'efficacité de leur régulation thermique. L'écart entre les satellites est actuellement de 5000 s (ce qui correspond à environ 2600 km à l'apogée) pour permettre l'observation de structures à grande échelle dans la queue de la magnétosphère. Ce sera vraisemblablement l'écart le plus important dans le cadre de cette mission car les phénomènes observés selon de faibles espacements pendant la première année présentant un haut intérêt scientifique, il est probable qu'à sa prochaine réunion, le 2 juin, le groupe de travail scientifique demandera une répétition de ces observations.

Aux dernières nouvelles, 54 documents avaient été publiés sur la base des résultats obtenus par ISEE et leur nombre augmente rapidement. Les chercheurs sont satisfaits de la haute qualité du retour scientifique de cette mission.

IUE

Parmi les questions examinées à la réunion de coordination tenue par les trois Agences (NASA, SRC et ESA) en mars, les points suivants semblent être particulièrement intéressants:

(a) la NASA et le Science Research Council du Royaume-Uni établissent l'une et l'autre des prévisions budgétaires pour une période d'exploitation de l'IUE de cinq ans;

(b) la reproductibilité de la détermination du flux dans des étoiles témoins a montré que l'IUE peut assurer une reproductibilité à 2% rms près dans les bandes 50 Å

(c) les trois Agences poursuivront l'effort commun qu'elles mènent actuellement afin d'améliorer et d'optimiser le logiciel de traitement d'images.

Au terme de la première année d'opérations réservée aux observateurs invités, la Vilspa avait acquis 2032 images spectrales pour 92 groupes différents d'observateurs de 12 pays. Ce chiffre correspond à 32,2% du total et est basé sur le tiers du temps d'observation réservé à cette station. La possibilité d'une prolongation de la vie opérationnelle d'IUE au-delà du 1er janvier 1981 a déjà été avancée et est actuellement à l'étude.

De nouveaux événements scientifiques

Cos-B

Both the satellite and the experiment continue to perform nominally and it is estimated from the remaining supplies of on-board consumables that operation could be maintained at least through the major part of 1980. In view of the number of outstanding questions in gamma-ray astronomy that cannot be fully investigated in what remains in 1979, the Caravane Collaboration of experimenters has requested ESA to extend the mission beyond the end of this year.

The Caravane Collaboration is currently entering into a collaboration with the Australian Commonwealth Scientific and Industrial Research Organisation's Division of Radiophysics under the terms of a cultural agreement between Italy and Australia. The aims of this collaboration are the contemporary study of pulsars at radio and gamma-ray wavelengths and the search for possible radio counterparts of the Cos-B gamma-ray sources.

The first step in this new collaboration is a second observation of the pulsar PSR0740-28, started on 2 April. In addition, PSR1055-52 and PSR0833-45 are foreseen as targets during 1979. It is also planned to investigate more extragalactic objects, including the X-ray QSO 2S2251-178 and the Seyfert galaxy 3C120. Other observations will be aimed at studying certain features of the galactic gamma radiation, such as that from the local interstellar clouds of Gould's belt.

Geos

Geos-1

On 25 April, Geos-1 completed 50 data acquisition periods each of 3h duration in 1979. These periods included two coordinated composition campaigns during which mass spectrometers on four different magnetospheric spacecraft were operated simultaneously. The four spacecraft were Geos-1, Geos-2, Scatha and S-3-3. Geos-1 has also been used to support a lithium-release rocket campaign carried out from Alaska by US experimenters. For this campaign, the spacecraft was commanded into the appropriate mode by NASA stations on the basis of ESOC specifications. Data acquisition was undertaken by a station in Hawaii. Confirmation has been received that good-quality data were acquired for about 6h after the lithium release over Alaska. The purpose of involving Geos-1 in this experiment was to study magnetospheric transport mechanisms by using lithium as a tracer. On 20 April, Geos-1 had been in orbit for two years.

Geos-2

Geos-2 has just completed its second eclipse period without difficulty. This spacecraft has been supporting a number of important sounding-rocket campaigns conducted from both Esrange (Sweden) and Andoya (Norway). During the recent Porcupine campaign in particular, Geos-2 played a prominent role, its data being transmitted from ESOC to Esrange in real time to help the project scientist at Kiruna determine the optimum moment for rocket launch.

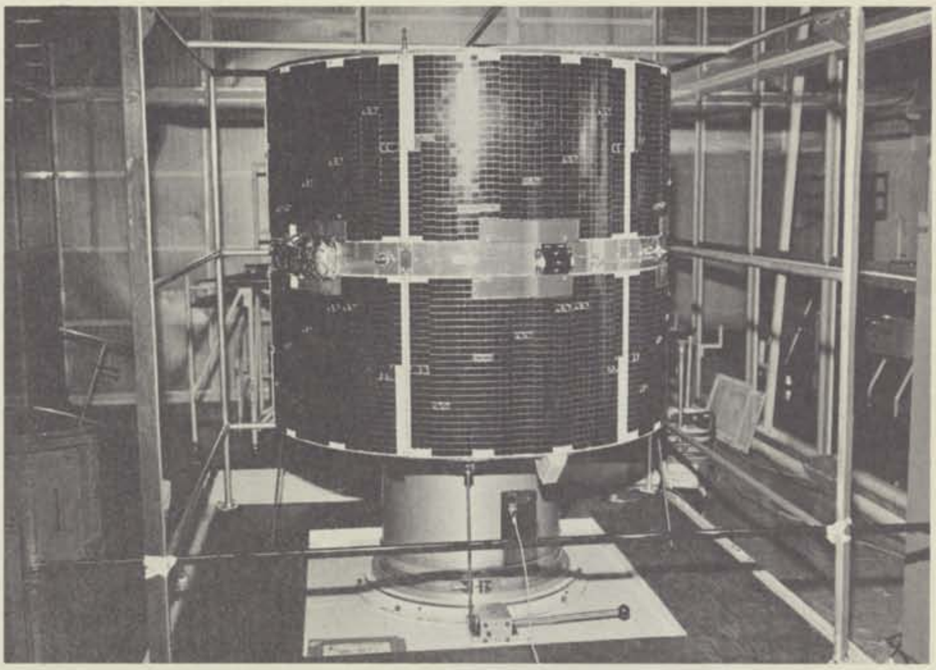
On 13 March, Geos-2's spin axis was turned through 180° to avoid the booms shadowing the solar arrays.

Geos experimenters are still heavily involved in processing and analysing their data and the very cooperative spirit between the various groups is proving very encouraging. The wave-particle studies, to which all experimenters can contribute, are of particular interest. Other areas of cooperation include the study of boundary crossings and comparisons between plasma drift and electric-field measurements.

ISEE

All three ISEE spacecraft continued to operate well, with ISEE-1 and ISEE-2 beginning to enter long shadow periods for the first time and this will test the effectiveness of their thermal control. ISEE-1 and 2 are currently separated by 5000 s (about 2600 km at apogee) for the examination of large-scale features in the magnetotail. This is likely to be the largest separation during the mission, as there is high scientific interest in the phenomena observed with small separations during the first year and the scientific team is likely to ask for a repeat of these.

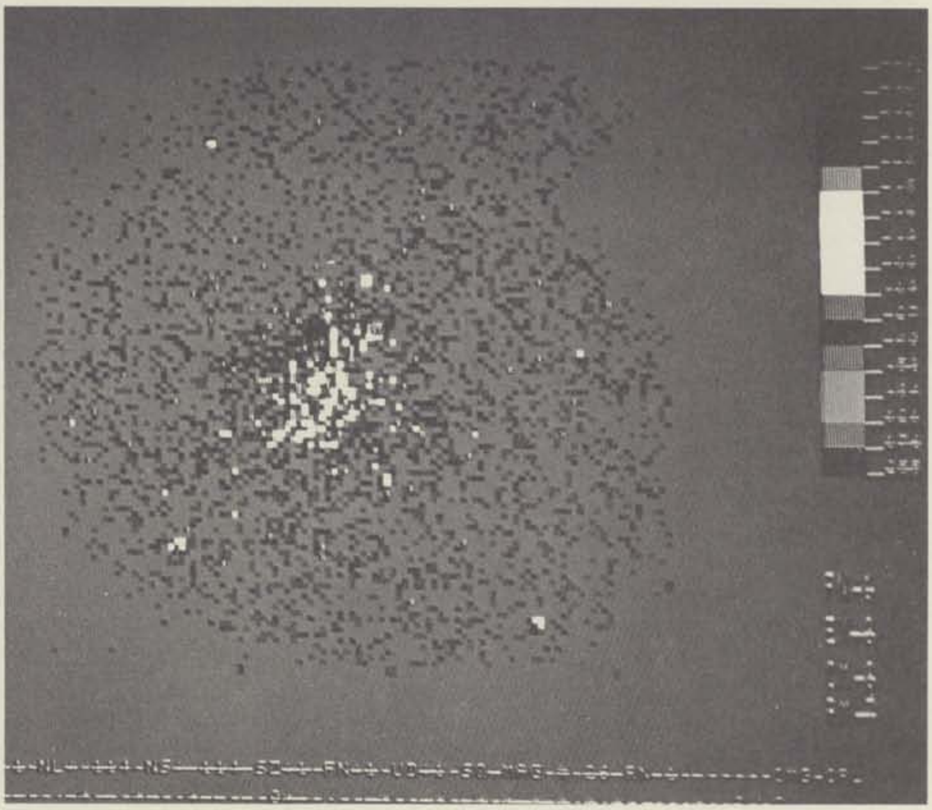
At the latest count, 54 papers had been published on the basis of ISEE results and the number is rising fast. There is



The Cos-B spacecraft, the experiments of which have been operating so successfully since they were first switched on on 11 August 1975.

Le véhicule spatial Cos-B, dont les expériences fonctionnent toujours parfaitement depuis leur mise sous tension le 11 août 1975.

importants ont été annoncés par les utilisateurs de la station de Vilspa lors d'une Conférence Internationale intitulée 'La première année d'IUE' qui s'est tenue à Londres. Des raies interstellaires d'une intensité inattendue ont été découvertes en provenance de composants fortement ionnisés dans une nébuleuse entourant une étoile de Wolf-Rayet. La raie d'émission Lyman alpha dans une galaxie de type n fait apparaître deux composantes (l'une, étroite, qui, selon les observations optiques, aurait l'intensité de la raie bêta de l'hydrogène, l'autre, large, présentant un déficit d'un facteur 16). Les résultats recueillis sur le quasar 3C273 grâce à une large collaboration des groupes européens ont révélé la production de raies d'absorption dans les régions extérieures de notre galaxie et un excès de l'émission ultraviolette qui pourrait correspondre à une accrétion de matière sous l'effet de la source d'énergie nucléaire du quasar. Une étude des taux de perte de masse à partir de types spectraux qui n'avaient pas été étudiés par le satellite Copernicus a montré que la présence de vents stellaires est principalement fonction de la luminosité, donc de la masse, des étoiles.



Cette supernova, située dans la galaxie Messier à environ 100 millions d'années-lumière de la Terre, a été observée par le satellite scientifique IUE et enregistrée à la station terrienne de l'Agence à Villafranca.

Supernova in the Messier galaxy, about 100 million light years from earth, observed by the IUE scientific satellite and recorded at ESA's Villafranca (Spain) ground station

Météosat

Secteur spatial

Météosat-1 continue de bien fonctionner en orbite. Le refroidisseur du radiomètre a été décontaminé en avril; on n'envisage pas de nouvelle opération de décontamination avant la fin de l'année. Le nombre des commutations inopinées (une par semaine) a diminué de moitié par rapport à ce qu'il était à la même époque l'an dernier, malgré une activité géomagnétique de niveau similaire. Il semble que le satellite acquière une sorte de 'résistance' sur orbite.

En ce qui concerne la préparation du lancement Météosat/L03 en juin 1980, le modèle de qualification (P2) subit actuellement des modifications préalables à l'essai de vibrations dont l'exécution est prévue pour la 'qualification' Ariane en août/septembre de cette année.

Exploitation

Le système de calcul Météosat fonctionne désormais de façon satisfaisante, avec un temps moyen entre pannes d'environ 20 h. La troisième campagne d'extraction des vents a été menée à bien, les données obtenues étant de qualité comparable à celles fournies par les satellites américains et japonais. Les travaux se poursuivent sur les températures de surface de la mer et la néphanalyse.

Démonstration/Expérimentation

Une nouvelle tournée de démonstration de la SDUS est en cours: Erice (Italie), Oberpfaffenhofen (Allemagne) et Le Bourget (France). La PDUS est actuellement installée au CNES, à Toulouse, pour une évaluation conjointe du système par l'ESA et par le CNES.

Une plate-forme de collecte de données (DCP) a été embarquée à bord du RSS Bransfield – unité britannique d'hydrographie opérant dans l'Antarctique – pour des essais 'système' avec Météosat dans des conditions de couverture et d'environnement défavorables. Ces essais ont été jusqu'ici couronnés du plus grand succès.

Projet GOES-1

Cela fait maintenant environ six mois que l'ESA assure l'exploitation du satellite GOES situé au-dessus de l'Océan indien (GOES-1), de la station au sol de Villafranca. L'opération s'est déroulée sans problèmes mais des interruptions intermittentes ont été récemment enregistrées dans le signal IR du satellite. La cause exacte de ces interruptions n'apparaît pas clairement, mais on pense qu'elles seraient dues à un problème de composants qui avait été identifié lors des essais au sol mais que l'on pensait avoir résolu avant le lancement.

Sirio-2

La mise en route des activités industrielles a progressé de façon normale dans la plupart des secteurs. En particulier, les activités concernant les sous-systèmes de la plate-forme du satellite et l'approvisionnement centralisé des pièces pour lesquelles le facteur temps est critique semblent bien engagées tandis que des difficultés mineures touchant les interfaces structurelles avec le lanceur et la disponibilité du transpondeur MDD provenant de Météosat sont en voie d'être résolues.

Télédétection

En ce qui concerne le programme de satellites de télédétection (ERS) de l'ESA, satisfaction among investigators with the high value of the scientific return from this mission.

IUE

At a three-agency (NASA, SRC & ESA) coordination meeting in March, several items of particular interest were recorded:

(a) NASA and the UK Science Research Council are both making budgetary provisions for five years' operation of IUE;
(b) the reproducibility of the flux determinations in standard stars has shown that IUE can achieve a repeatability in 50 Å bands of 2% rms;
(c) the three Agencies will continue their on-going joint effort to improve and optimise the image-processing software.

After the first year of guest-observer operations, Vilspa had acquired 2032 spectral images for 92 different groups of observers from 12 different countries. This represents 32.2% of the total observations, and is based on Vilspa's one third share of the available observing time. The possibility of extending the operational lifetime of IUE beyond the present January 1981 limit has already been advanced and is currently under discussion.

New scientific highlights were announced in May by Vilspa users at an International Conference in London: 'The First Year of IUE'. Unexpectedly strong interstellar lines have been detected from highly ionised species in a nebula surrounding a Wolf-Rayet star. The Lyman alpha line in an n-type galaxy shows two components (one narrow with the strength expected from optical observation of the hydrogen beta line, one broad showing a deficit of a factor of 16). Studies of the quasar 3C273 by a wide collaboration of European groups have detected absorption lines in the outer parts of our galaxy and an excess of UV emission possibly representing material being accreted onto the nuclear power source of the quasar. A survey of mass loss rates from spectral types not studied by the Copernicus satellite has shown that the presence of stellar winds is primarily a function of stellar luminosity and hence mass.

Meteosat

Space segment
Meteosat-1 continues to perform well in orbit. The radiometer cooler was decontaminated in April; a further decontamination is not envisaged before the end of the year. The level of spurious switching (once per week) is only half that at the time last year, although the level of geomagnetic activity is similar. Some sort of in-orbit 'hardening' seems to be occurring.

In preparation for the Meteosat/L03 launch in June 1980, the qualification model (P2) is presently being modified ready for the Ariane 'qualification' vibration test planned for August/September.

Exploitation
The Meteosat computer system is now working satisfactorily with a mean time between failures of about 20 h. The third wind campaign has been successfully completed and has yielded data similar in quality to those produced by the American and Japanese spacecraft systems. Work is continuing on sea-surface temperatures and cloud analysis.

Demonstration/experimental activities
A new SDUS (Secondary Data User Station) demonstration tour is under way to Erice (Italy), Oberpfaffenhofen (Germany) and Le Bourget (France). The PDUS (Primary Data User Station) is at present installed at CNES, Toulouse, for a joint ESA/CNES system evaluation.
A DCP (Data Collection Platform) has been put on the British Antarctic Survey Vessel RSS Bransfield for system tests with Meteosat in adverse coverage/environmental conditions. These tests have been proving very successful.

GOES-1 project
The Indian Ocean GOES (GOES-1) has now been operated by ESA through the Villafranca ground station for about six months. The operation has gone very smoothly, except that the spacecraft has recently shown intermittent loss of IR signal. The exact cause is not clear, but it is thought to be due to a component problem previously identified in ground testing, but supposedly solved before launch.

Sirio-2

The starting up of industrial activity has progressed normally in most areas. In particular, the spacecraft platform subsystems and time-critical centralised parts procurement appear to be in good hands. Minor difficulties with launcher structural interfaces and MDD transponder availability from Meteosat are in the process of being resolved.

King Hussein of Jordan viewing the Meteosat exhibition on the ESA stand at Le Bourget.

Le Roi Hussein de Jordanie visitant l'exposition Météosat au stand ESA au Bourget.

les deux études de phase A sur les systèmes destinés respectivement aux applications terrestres et à la surveillance des océans dans les zones côtières ont été achevées. Les résultats en ont été évalués par l'Exécutif et par les groupes d'experts en télédétection de l'Agence, pour aboutir en mai à un réexamen des spécifications de performances 'mission/système' et à l'identification d'études supplémentaires.

En dehors de ces études de systèmes, un programme préparatoire de télédétection a été lancé le 13 mars. Ce programme (9 MUC pour deux ans) couvre l'étude et le prédéveloppement d'éléments technologiques critiques en préparation d'une phase B pour le premier satellite de télédétection de l'ESA (ERS-1) dont le lancement devrait avoir lieu à la mi-1980. Tous les Etats membres plus le Canada se sont déclarés intéressés par ce programme préparatoire ou y participent activement.

Traîneau spatial

La communauté des utilisateurs du Traîneau spatial ayant confirmé que la nouvelle conception proposée par l'Agence représente un strict minimum pour que le projet soit scientifiquement valable, le Comité du programme scientifique a décidé à sa réunion du 22 mars d'approuver le nouveau programme et notamment les crédits supplémentaires nécessaires. L'un des éléments essentiels de la proposition était que l'Agence procèderait à tous les travaux d'ingénierie au niveau système pour respecter les délais désormais très réduits avant la première mission du Spacelab.

La nouvelle version du Traîneau consiste en une structure de type monorail boulonnée sur le plancher de l'élément central du module. Sur le chariot mobile sont montés le siège du sujet de l'expérience et le matériel fourni par l'expérimentateur. Le siège peut être orienté dans l'une quelconque des trois directions orthogonales par rapport à la direction du mouvement linéaire. Le Traîneau est mû dans les deux sens sur toute la longueur du Spacelab au moyen d'un moteur à courant continu, son dispositif de commande électronique étant installé dans l'un des châssis normalisés du Spacelab, à l'arrière du module.

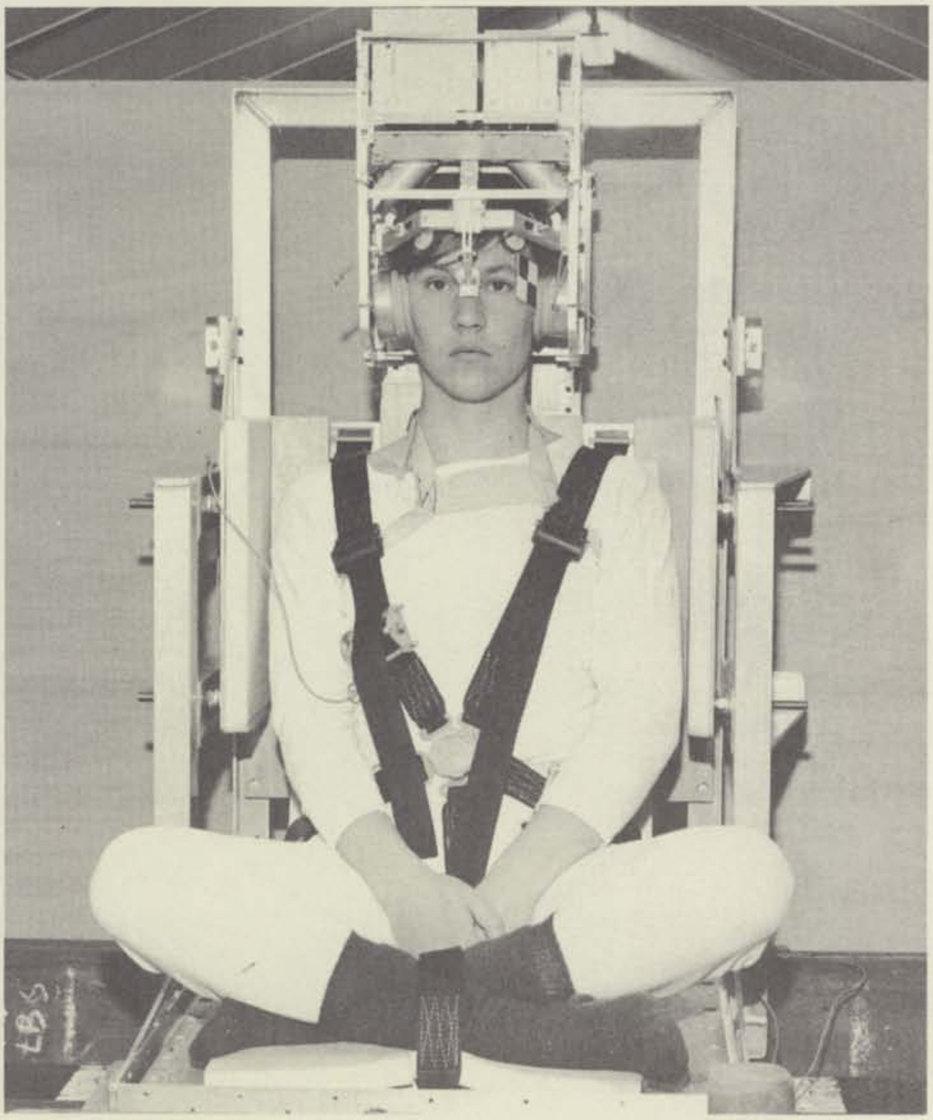
Toutes les expériences menées sur le sujet assis dans le siège sont commandées par le conducteur des essais à l'arrière du Spacelab. Des ordres ne peuvent être envoyés du sol ou de la cabine arrière de l'Orbiteur que par liaison phonie avec le conducteur des essais. Le sujet de l'expérience et le conducteur des essais peuvent l'un et l'autre arrêter le Traîneau à tout moment. Des butoirs déformables assurent la douceur et la sécurité de l'arrêt du chariot aux extrémités du rail en cas de malfonctionnement.

Il s'agit d'un programme de développement à un seul modèle dans lequel les deux unités sont fabriquées en parallèle. La durée totale prévue du programme est de l'ordre de dix-huit mois, y compris une phase de définition de quatre mois. Les deux unités doivent être livrées au SPICE aux dates suivantes:

- *Modèle d'entraînement: mi-août 1980*
- *Prototype de vol: mi-octobre 1980.*

Le retard accompagnant le démarrage du programme provoque une incompatibilité de calendrier compte tenu des dates impératives du SPICE; il sera possible d'y remédier en modifiant la séquence d'intégration de la charge utile du Spacelab de telle sorte que le modèle d'entraînement soit intégré en premier et remplacé ultérieurement par le modèle prototype de vol, dès que celui-ci sera disponible.

Le nouveau programme de Traîneau spatial a démarré officiellement le 2 avril. Les travaux d'ingénierie au niveau système ont alors été mis en route à l'ESTEC. La société Bell Telephone Manufacturing Company (B), qui avait été retenue précédemment pour la fourniture du sous-système électrique, a reçu le feu



Maquette du Traîneau spatial équipé du casque de l'expérimentateur au cours d'essais à l'Institut royal de Médecine spatiale de Farnborough (R-U).

Sled seat mock-up and instrumented experimenter helmet under test at the Royal Institute of Aviation Medicine, Farnborough (UK).

Remote Sensing

In the ESA Remote-Sensing Satellite Programme, the two Phase-A studies for Land Applications and Coastal Ocean Monitoring systems have been completed. The results of these studies have been evaluated by the Executive and the ESA Remote Sensing Experts' Groups, leading in May to a review of the mission/system performance specifications and the identification of supplementary studies.

Apart from these system studies, a remote-sensing preparatory programme was initiated on 13 March. This programme (9 MAU for two years) covers the study and pre-development of critical technology elements in preparation for a Phase-B for the first ESA remote-sensing satellite (ERS-1) which is expected to be launched in the mid-1980s. All Member States and Canada are either actively participating in this preparatory programme or have already expressed interest.

SLED

Following confirmation by the Sled user community that the new Sled concept proposed by the Agency is an absolute minimum to be scientifically worthwhile, the Science Programme Committee decided at its meeting on 22 March, to approve the new programme, including the necessary additional funds. An essential element of the proposal was that the Agency would perform all system-level engineering work to meet the now very much reduced time schedule available before the first Spacelab mission.

The newly designed Sled consists of an integral rail structure to be bolted to the centre aisle floor of Spacelab. The Sled carriage has mounted on it a seat for the human test subject, and experimenter-supplied hardware. The seat can be orientated in any one of three mutually orthogonal directions with respect to its direction of linear motion. The Sled's movements back and forth along the length of Spacelab are controlled by a DC electric motor, which is driven by an electronics control unit situated in a standard equipment rack at the aft end of Spacelab.

All Sled experiments with the test subject in the seat will be controlled by the test operator in the aft end of Spacelab. Control from the ground or from the Orbiter aft flight deck can only be effected by voice communication with the test operator. The test operator and test subject can stop the Sled independently at any time. There is a crushable end stop to ensure a smooth and safe arrest at the end of the runway in the event of a malfunction.

The Sled programme is a single-model development programme in which two models are to be built in parallel. The programme is expected to last approximately 18 months, including a four-month design phase. The predicted delivery dates for the two models to SPICE:
Crew training model – mid-August 1980
Protoflight model – mid-October 1980.

A schedule incompatibility with respect to SPICE need dates introduced by the delay in the start of the programme can be solved by modifying the Spacelab payload integration flow such that the training model is integrated first and replaced later by the protoflight model when it becomes available.

The new Sled programme formally started on 2 April. System engineering work then started in ESTEC. Bell Telephone Manufacturing Company (B), selected previously for procurement of the electrical subsystem, was given preliminary authorisation to proceed. A parallel action instituted immediately after programme approval by the Science Programme Committee (SPC) led to the selection of Marshall of Cambridge (Engineering) Limited (UK) for procurement of the mechanical subsystem. Authority was given by the Industrial Policy Committee at the end of April to place both proposed contracts with industry. Work on the mechanical subsystem started in industry on 2 May.

System design work is well under way, with several verification tests for critical design items either completed or in preparation. An important series of tests is planned at the Royal Air Force Institute of Aviation Medicine, Farnborough, in June to establish ergonomic interface requirements and to verify the safety of the seat's design. Long-lead procurement items are being identified and some have already been ordered to meet the tight schedule demands of the programme. It is planned to complete the system design phase by August.

Spacelab

Development
The second Spacelab pallet and all essential associated Mechanical Ground Support Equipment (MGSE) items were delivered to NASA/Kennedy Space Center in April as scheduled. The pallet is part of the so-called Spacelab engineering model and is intended for use by NASA during the Orbiter test-flight phase. The first Spacelab pallet was delivered to NASA last December.

Integration and testing of the engineering model is continuing at the prime contractor's site, with detailed interface tests. A significant achievement has been the finalisation and implementation of an increased recording capability to support qualification testing and to allow quicker evaluation of the test results. Flight unit integration and test planning is now in an advanced stage, with flight hardware arriving at ERNO.

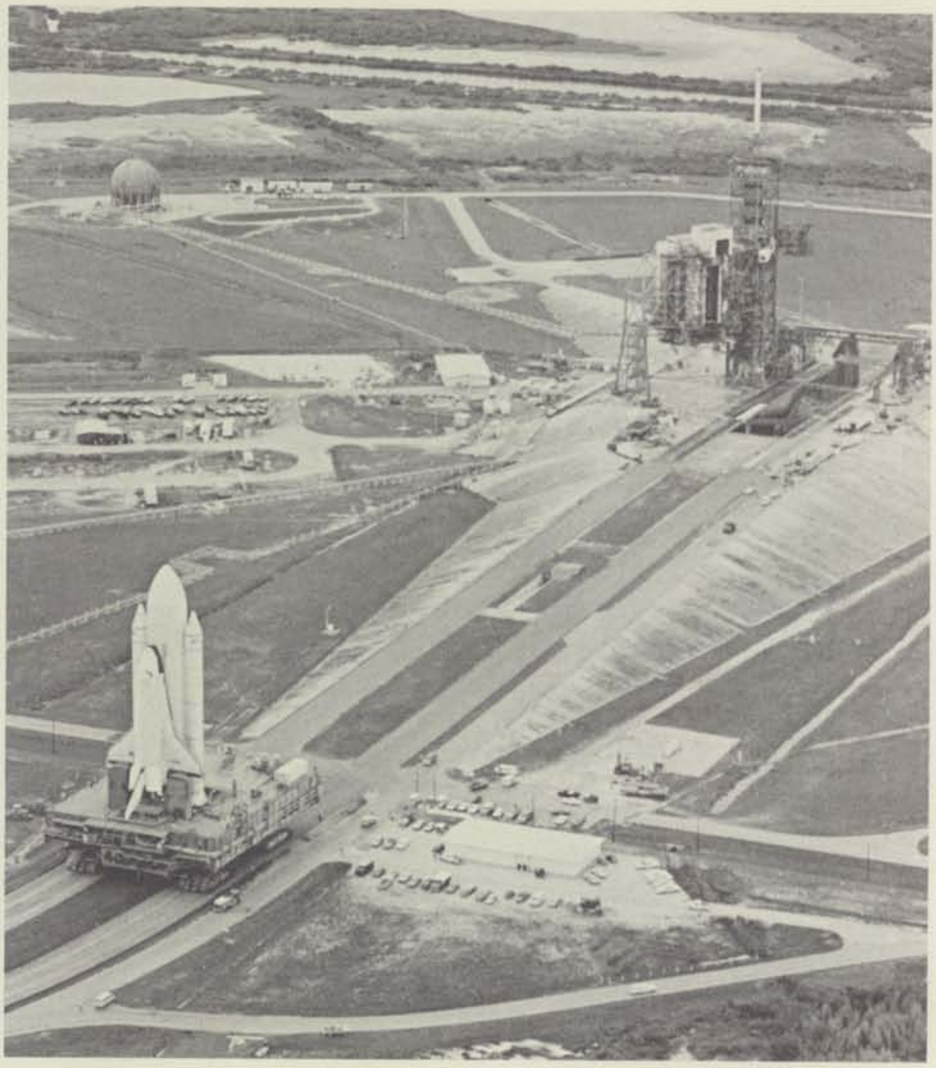
There is still uncertainty as to the impact of increased Orbiter dynamic loads on the load-carrying capability of Spacelab. The problem is being studied by means of a so-called 'coupled load analysis', which will be completed in September.

Cost
The Spacelab Programme Board has discussed overall cost-to-completion estimates on several occasions and, in particular, the arrangements for continued execution of the Programme over and above 120% of the original financial envelope. In a unanimously approved resolution, the Board has invited the Director General to take the steps necessary to bring the Spacelab Programme to a successful conclusion within the limits of the present cost-to-completion estimates.

Spacelab utilisation
At its May meeting the ESA Council discussed possible approaches for Spacelab utilisation in Europe during the 1982-1984 time frame, after the First Spacelab Payload (a joint ESA/NASA project). Council considers that several payload packages should be defined in the various disciplines based on the experiments actually supported by Member States and, if agreed by NASA, flown on suitable NASA missions, fully European missions being deferred to a later stage. Council is of the opinion that such frequent 'partial missions' will make

vert préliminaire. Une mise en concurrence lancée immédiatement après l'approbation du programme par le SPC a conduit à la sélection de Marshall of Cambridge (Engineering) Limited (UK) pour la fourniture du sous-système mécanique. Le Comité de la politique industrielle a autorisé à la fin du mois d'avril la passation aux industriels des deux contrats proposés. Le travail sur le sous-système mécanique a démarré dans l'industrie le 2 mai.

Les activités de définition du système se poursuivent normalement, plusieurs essais de vérification portant sur des éléments critiques de la conception étant achevés ou en préparation. Il est prévu de procéder en juin à une importante série d'essais à l'Institut de Médecine aéronautique de la Royal Air Force, Farnborough, pour établir les impératifs d'interface ergonomique et pour vérifier la sécurité de la conception du siège. Les articles à long délai de livraison ont été recensés et certains ont déjà été commandés, compte tenu des impératifs stricts de calendrier. La phase de définition du système devrait être achevée pour le mois d'août.



L'Orbiteur 'Enterprise' de la Navette spatiale au cours des vérifications de montage et de fonctionnement sur le pas le tir du Centre spatial Kennedy. Spacelab effectuera son premier vol à bord d'un Orbiteur similaire à l'automne 1981.

Space Shuttle Orbiter 'Enterprise' undergoing fit and function checks on the launch pad at Kennedy Space Center. Spacelab will make its maiden flight on such an Orbiter in Autumn 1981.

Spacelab

Développement du Spacelab

Le deuxième porte-instruments du Spacelab a été livré comme prévu au Kenedy Space Center (KSC) de la NASA en avril 1979, avec tous les éléments essentiels de l'équipement mécanique de soutien au sol associé. Le porte-instruments fait partie du modèle désigné sous le nom de 'modèle d'identification' du Spacelab et sera utilisé par la NASA au cours de la phase des vols d'essais de l'Orbiteur. Il faut rappeler que le premier porte-instruments a été livré à la NASA en décembre 1978.

Les essais et l'intégration du modèle d'identification se poursuivent dans les locaux du contractant principal où l'on procède également à des essais détaillés d'interface. Une étape importante a été atteinte avec la mise au point définitive et la mise en oeuvre d'une capacité accrue d'enregistrement qui permettra le soutien des essais de qualification ainsi que l'évaluation plus rapide des résultats des essais. Le planning des essais et de l'intégration de l'unité de vol est actuellement bien avancé, le matériel de vol étant en cours de livraison à ERNO.

L'accroissement des charges dynamiques de l'Orbiteur aura des incidences sur la capacité d'emport du Spacelab qui ne sont pas encore définies précisément. Ce problème est actuellement étudié dans le cadre d'une 'analyse couplée des charges' qui s'achèvera en septembre 1979.

Coûts du Spacelab

Le Conseil directeur du Programme Spacelab a examiné à plusieurs reprises les estimations du coût à achèvement global du programme et, en particulier, les modalités de poursuite de l'exécution de ce programme au-delà des 120% du montant de son enveloppe financière initiale. Dans une Résolution, approuvée à l'unanimité, le Conseil directeur a invité le Directeur général à prendre certaines mesures afin de mener le programme à bonne fin dans les limites du coût à achèvement estimatif cité.

Utilisation du Spacelab

Le Conseil de l'Agence a examiné, lors de sa session du mois de mai, les voies possibles de l'utilisation du Spacelab en Europe pour la période 1982-1984, après la première charge utile du Spacelab qui constitue un projet commun ESA/NASA. Le Conseil a estimé qu'il conviendrait de définir plusieurs ensembles de charge utile dans les différentes disciplines, en partant des expériences ayant l'appui des Etats membres, ces ensembles de charge utile étant embarqués sur des missions appropriées de la NASA, si cette dernière y consent. Les missions entièrement européennes seraient reportées à un stade ultérieur. Le Conseil a jugé que des missions partielles fréquentes feraient plus pour le progrès scientifique que des missions entièrement européennes mais très espacées dans le temps.

for quicker scientific progress than that would be provided by wholly European but much less frequent Spacelab missions.

A Russian cosmonaut being shown the Spacelab mock-up at Le Bourget in the company of the ESA Spacelab astronauts, by Michel Bignier, Director of the Spacelab programme (right).

Un cosmonaute soviétique examinant la maquette du Spacelab au Bourget, en compagnie des astronautes européens du Spacelab et de M. Michel Bignier, Directeur ESA du programme Spacelab (à droite).

Ariane

The propellant-mock-up operations were concluded towards the end of May with a simulation of the complete countdown as far as Ho-4 seconds, covering all the operations involving filling with propellants or other fluids. In all, the first two stages were each filled twice and the third stage four times during the whole campaign. The conclusion of this operation represents a major milestone, and the following main conclusions could be drawn:

- The launch-site facilities worked very satisfactorily, and the modifications to be carried out – generally minor – will not jeopardise the L01 launch date.
- The automatic programmes for filling and preparing the launcher were validated following the first automatic fill. This is a remarkable achievement, bearing in mind the complexity of the operations, particularly for the third stage.
- The launch teams were able to demonstrate their competence to deal with any problems that arose.

In Europe, integration of the L01 vehicle is being completed on schedule. Here again, operations proceeded very smoothly and the very few problems that were encountered may all be considered minor.

Following the delays in the acceptance of the flight model of the inertial platform, all launcher integration was carried out with the qualification model. The flight model will be integrated into the equipment bay during July and additional tests will then be carried out to ensure that the system's performances are up to standard.

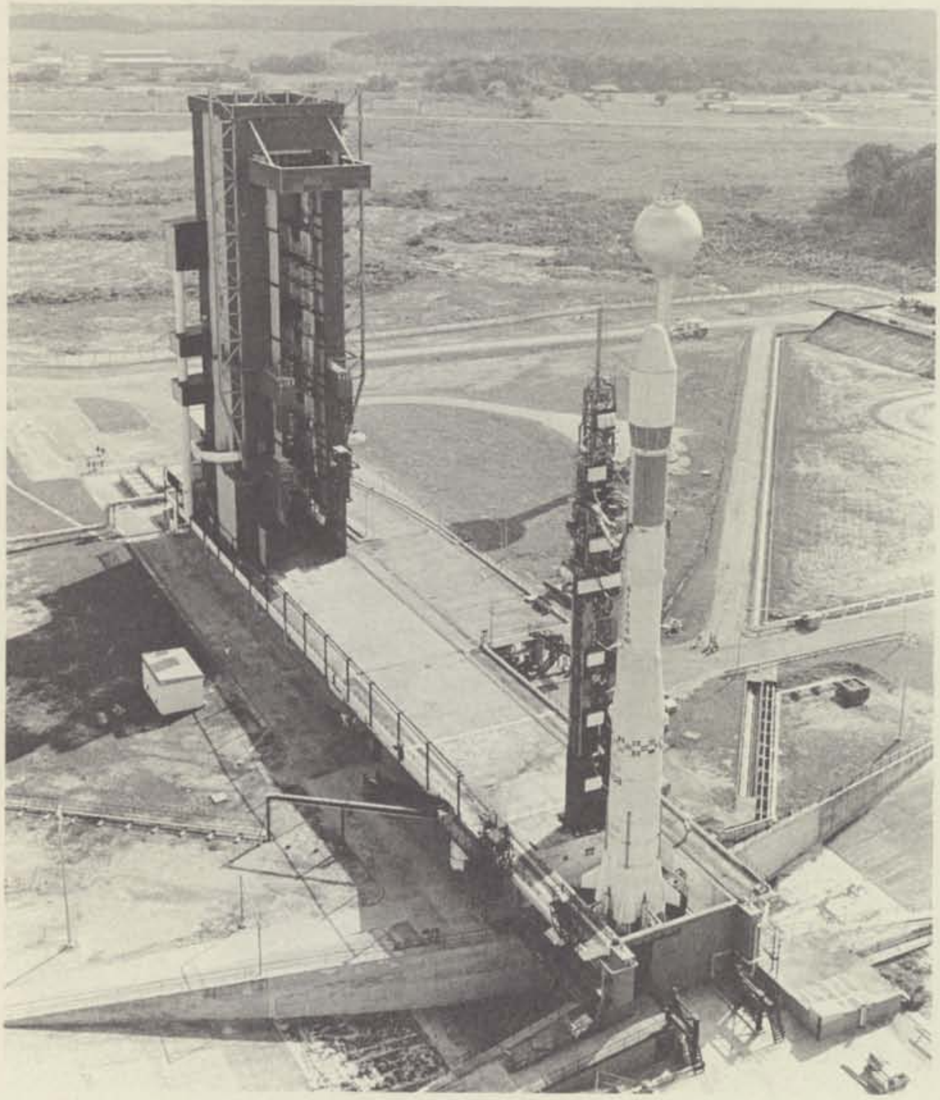
The first qualification firing of the first stage's propulsion system was carried out successfully on 17 May. The second and last test is scheduled for early September.

The second qualification test of the Viking engine was nominal in both duration and performance, but subsequent examination of the hardware showed premature wear in a turbopump bearing. Investigations revealed some anomalies in the procedure for assembling the bearings and, although the risk of problems occurring during flight was considered very slight, it was decided to change the bearings on the flight-model engines of the first and second stages and on the two engines remaining to be qualified. This operation, for which no detailed timetable has yet been drawn up, will be carried out on the stages after integration at the Launch Integration Site in Les Mureaux (SIL).

The first qualification test on the new nozzle for the second stage was carried out using extreme conditions, with completely nominal results.

The test campaign for the B2 propulsion bay of the third stage was terminated after a very good series of six tests, beginning in November 1978, all successful and totalling nearly 3000 s of operation. All the lessons learnt in this campaign have been incorporated into the EP4 propulsion system and will be introduced into the flight stage before shipment to Guiana.

The first test of the EP4 propulsion system took place on 6 June. This test was stopped after 7 min when a small hydrogen leak was observed. At that time, all parameters were completely nominal. The hardware tested is in good condition and the problem observed would not have had any effect during the flight of the (empty) third stage. There would appear to be a ground problem associated with the test configuration (stage plus test stand) which does not allow the bay to be correctly ventilated. Remedial action will be taken before the next test.



Ensemble de Lancement Ariane (ELA) avec la tour de montage et le mât ombilical.

The Ariane Launch Site (ELA) with mobile mounting tower and umbilical mast.

Ariane

Les opérations maquette ergols se sont achevées fin mai par la simulation d'une chronologie complète jusqu'à Ho–4 s, pour toutes les opérations relatives aux remplissages en ergols et fluides divers. Globalement, les deux premiers étages auront été remplis deux fois chacun et le 3ème étage quatre fois durant l'ensemble de cette campagne. La fin de cette opération constitue une étape extrêmement importante dont on peut tirer les principales conclusions suivantes:

- *Les installations de l'ensemble de lancement ont présenté un comportement très satisfaisant et les modifications généralement mineures à effectuer ne mettront pas en péril le calendrier L01.*
- *Les programmes automatiques de remplissage et préparation du lanceur ont pu être considérés comme validés dès le premier remplissage en automatique. Il s'agit là d'un résultat remarquable compte tenu de la complexité des opérations à réaliser, et notamment sur le 3ème étage.*
- *Les équipes de lancement ont pu acquérir et démontrer une bonne maîtrise des problèmes impliqués.*

En Europe, l'intégration du lanceur L01 s'achève conformément au calendrier prévu. Là encore, les opérations se sont enchaînées de façon très satisfaisante, et les quelques problèmes rencontrés peuvent être considérés comme mineurs. Par suite de retards intervenus dans la recette de la centrale inertielle de vol, toute l'intégration lanceur a été réalisée avec la centrale de qualification. La centrale de vol sera intégrée dans la baie d'équipements courant juillet et des essais complémentaires seront effectués à cette époque pour s'assurer de la conformité des performances au niveau système.

Le premier tir de qualification de l'ensemble propulsif du 1er étage a été réalisé le 17 mai dans des conditions parfaitement nominales. Le prochain et dernier essai est prévu début septembre. Pour ce qui concerne le moteur Viking, le deuxième essai de qualification, nominal quant à sa durée et aux performances, a fait apparaître lors de l'expertise du matériel, une usure prématurée d'un roulement de turbo-pompe. Après enquête ayant montré quelques anomalies dans la procédure de montage des roulements, il a été décidé, bien que le risque soit extrêmement faible, d'échanger les roulements sur les moteurs de vol des 1er et 2ème étages et sur les deux moteurs restant à qualifier. Cette opération, pour laquelle le calendrier n'a pas encore été établi de façon détaillée, sera effectuée sur les étages après l'intégration au Site Intégration Lanceur.

Au niveau du 2ème étage, le premier essai de qualification du nouveau divergent a été effectué dans des conditions extrêmes, de façon parfaitement nominale.

En ce qui concerne le 3ème étage, la campagne d'essai de la baie de propulsion B2 a été arrêtée après une très bonne série de six essais, tentés et réussis depuis novembre 1978, totalisant près de 3000 s de fonctionnement. Tous les enseignements issus de cette campagne ont été incorporés dans l'ensemble propulsif EP4 et seront introduits sur l'étage de vol, avant son expédition en Guyane.

Le premier essai de l'ensemble propulsif EP4 a eu lieu le 6 juin. Cet essai a été arrêté après sept minutes sur constat de l'inflammation d'une petite fuite d'hydrogène. Tous les paramètres étaient à cet instant parfaitement nominaux. Le matériel essayé est en bon état et le problème constaté n'aurait eu aucune influence durant le vol du 3ème étage (vide). Il semble en fait que l'on soit en présence d'un problème sol lié à la configuration d'essai (étage plus banc d'essai) qui ne permet pas d'effectuer une ventilation correcte de la baie. Des remèdes seront apportés pour le prochain essai.

Spacelab and Its Services to Users

K. Clausen & H. Martinides,
Spacelab Project Office, ESTEC, Noordwijk, The Netherlands

Spacelab is an earth-orbiting laboratory that from 1981 onwards will provide its user community with a scientific research and applications facility having the sorts of features that have so far only been available to them in traditional ground-based laboratories. In addition to providing experimenters with faster access to space, it will bring to space research and exploitation the substantial benefits associated with manned experiment attendance, reusability of hardware, standardised interfaces, and less stringent experiment acceptance criteria.

Background to Spacelab's development

A key consideration in NASA's planning for the post- Apollo era of space exploration and exploitation has been the realisation that the implementation of large and important space projects, such as the construction of a space station, would not be feasible with expendable launchers because of the excessive cost. As a result, NASA has pressed ahead with the development of its re-usable Space Transportation System (STS), commonly referred to as the Space Shuttle. It is to make the capabilities of this System immediately available to the user community when it becomes operational that Europe has agreed to develop Spacelab in parallel with the Shuttle. Spacelab's capabilities and services to users have to be seen against this background.

The Space Shuttle and its major elements are shown in launch configuration in Figure 1. The Orbiter is the element of the system that carries the payload into orbit and returns it to ground. The solid-rocket boosters are also recovered, and only the external tank is expended. Spacelab, one of the major Shuttle payloads, is carried in the Orbiter's cargo bay, where it remains throughout the flight (Fig. 2).

The Spacelab programme, started in 1974, represents ESA's first venture into manned space flight. The first flight-hardware deliveries are planned for 1980 and Spacelab's first flight, with a mixed European and American payload, will take place in 1981.

The Spacelab concept

Spacelab has been designed to provide a versatile space laboratory and observation facility that forms an integrated system with the Orbiter and converts the latter's basic resources into experiment support with a laboratory character.

The services available to the user can be divided into two categories:

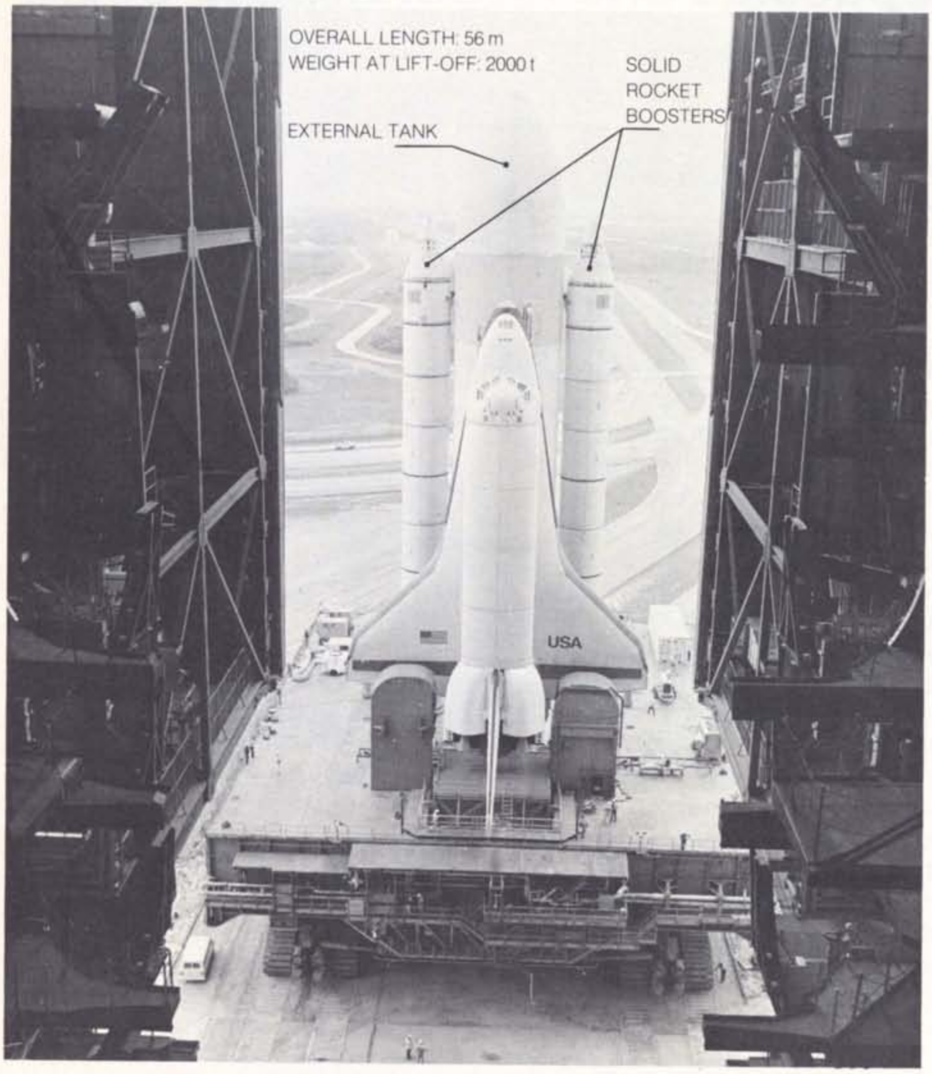
(a) those provided by Spacelab, which include crew support for payload operation and physical and functional interfaces to payloads, and

(b) those provided directly by the Orbiter, some of which will only become available after the Shuttle's initial operational phase has been completed. These latter include the capability to perform extravehicular activity and the use of a manipulator arm for moving objects out of or into the cargo bay.

Spacelab receives important resources from the Orbiter and in consequence the services that it can provide are dependent on the Orbiter's capabilities and performance. An important example in this respect is the flight duration, which is presently constrained by the amount of fuel that the Orbiter can carry on board for power generation. Improvements in such areas are under study at NASA, including the design of a separate Power Module that generates electrical power from solar energy. These improvements will have a direct beneficial effect on the services that Spacelab can provide to the users. ESA has been examining similar

Figure 1 – The Space Shuttle and its major elements in launch configuration. The solid-rocket boosters are recovered after launch, and only the external propellant tank is expended

Figure 2 – Spacelab, carried in space in the Orbiter's cargo bay



types of improvements for Spacelab itself in the context of a Spacelab follow-on development study.

Spacelab's design features

The functional relationship between the experiments, Spacelab, the Orbiter and the ground system is shown in Figure 3. The basic Orbiter resources, namely power, heat rejection, and telecommunications facilities, are converted into payload support by five subsystems

- Structural
- Electrical Power Distribution (EPDS)
- Command and Data Management (CDMS)
- Software, and
- Environmental Control (ECS)

supplemented by Common Payload Support Equipment (CPSE) consisting of a high-quality window and a scientific airlock. In addition, an Instrument Pointing System (IPS) provides for precision pointing of large observational payloads.

One of the most important design features of Spacelab is its modularity (Fig. 4a), which has come about for two main reasons:

(a) Spacelab has to satisfy a wide range of user requirements, involving both small payloads relying on manned

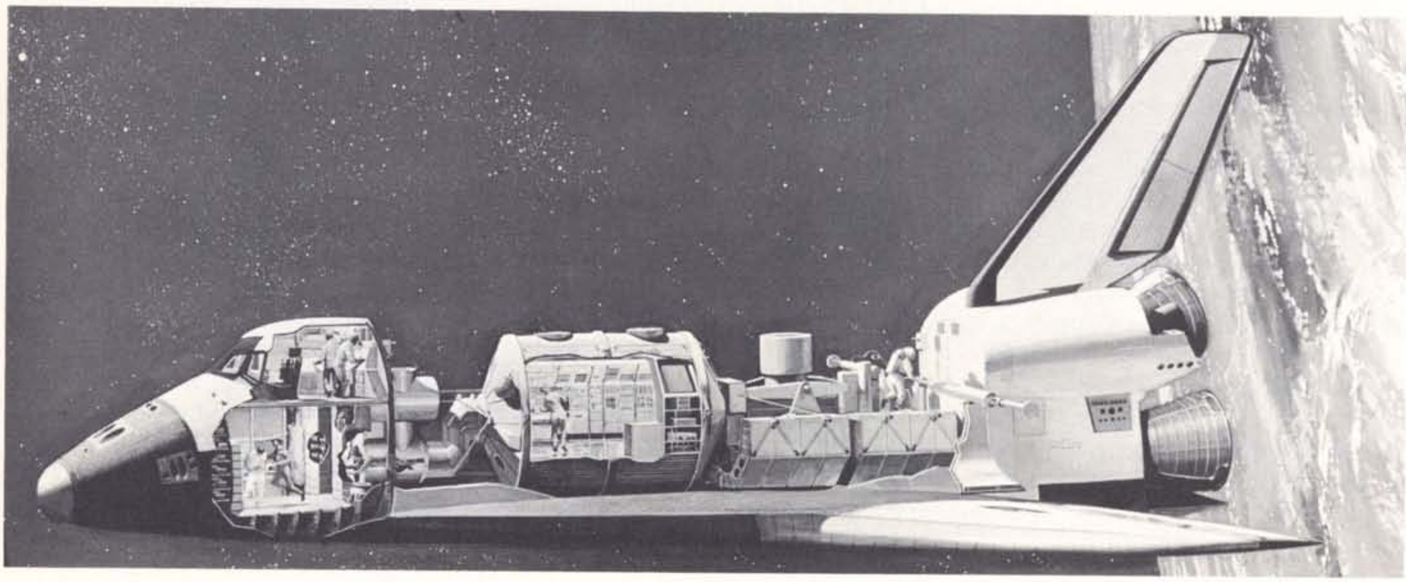


Figure 3 – Functional relationship between the payload, Spacelab, the Orbiter and the ground system

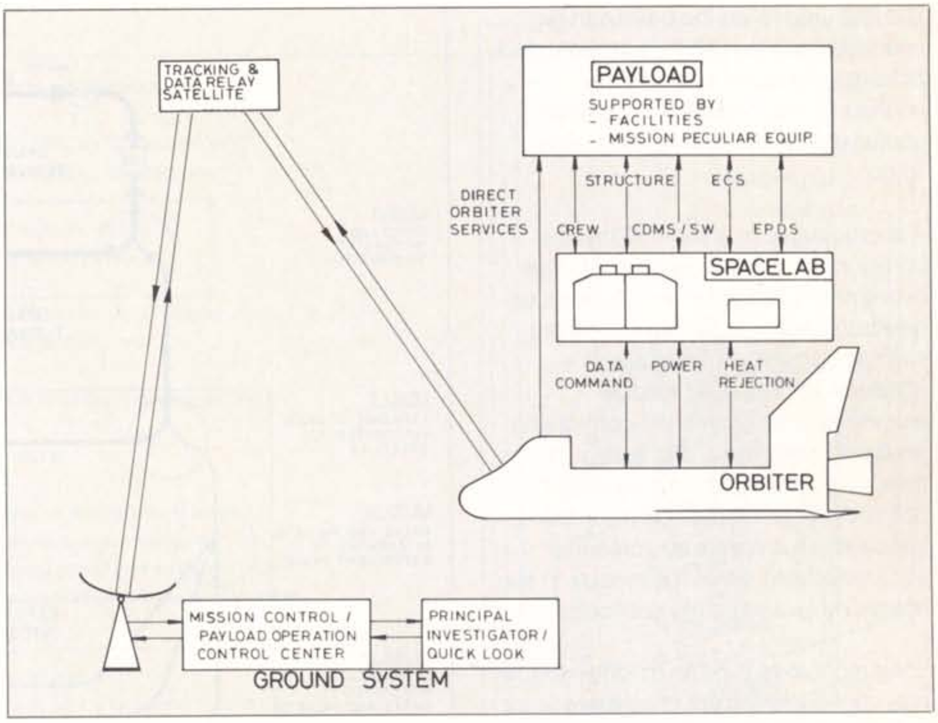
Figure 4a – The modular elements that can be used in the make-up of a particular Spacelab configuration

Figure 4b – Typical Spacelab configurations for experiments in specific scientific disciplines

attendance in the laboratory's one-atmosphere environment, and large celestial-observation payloads calling for undisturbed access to free space.

(b) Time-consuming payload integration and check-out activities need to be separated from the stringent between-flight Shuttle and Spacelab turnaround flows. The modular approach to Spacelab's design allows offline integration of payloads onto pallets or into experiment racks if they are to be accommodated in the module.

Modularity to satisfy user requirements
A variety of Spacelab configurations can be composed at system level, as shown in Figure 4b. Pallet-only configurations are most appropriate for astronomy and solar-physics disciplines, which mainly employ large telescope-type instruments, requiring an unobstructed view to space.



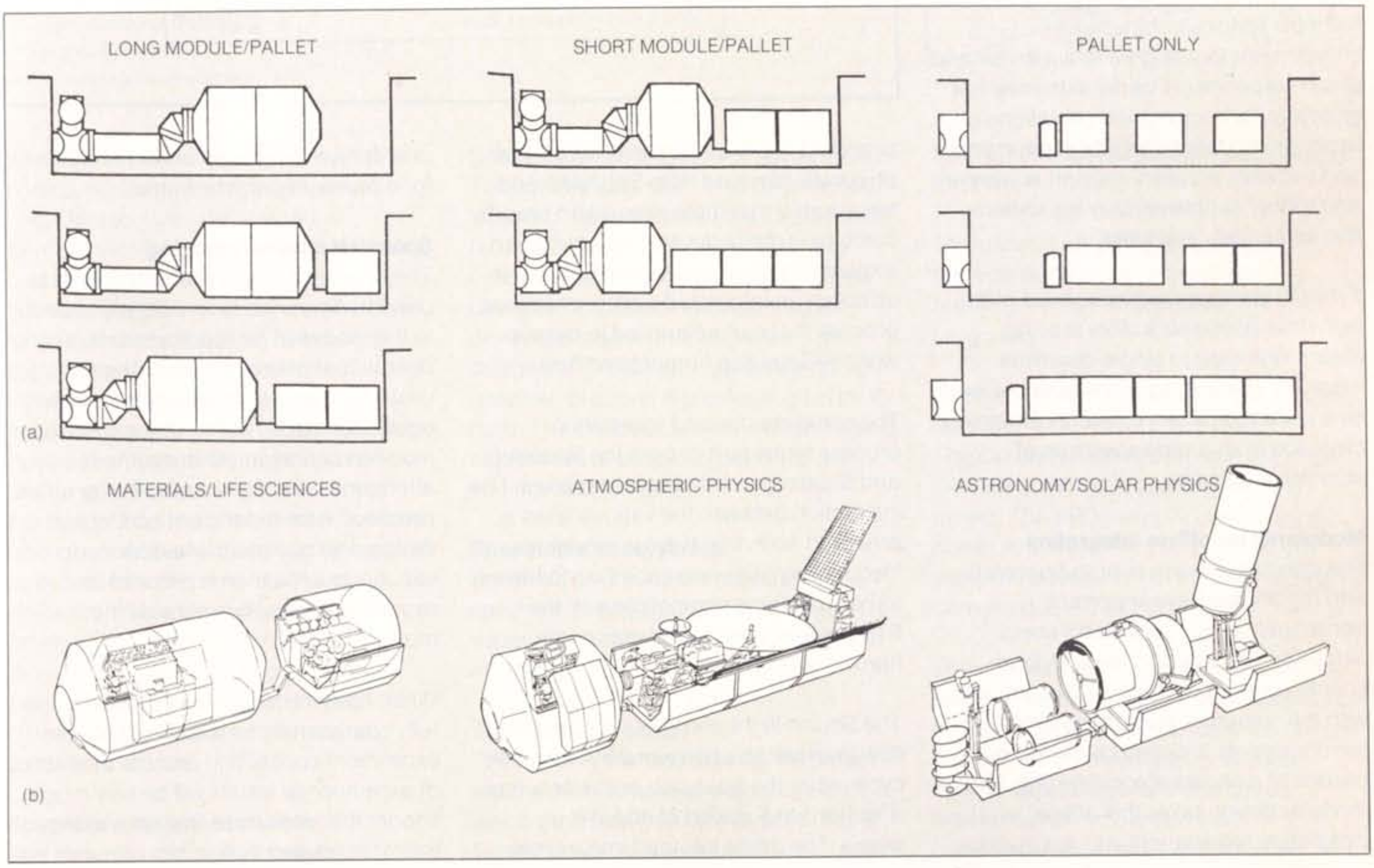
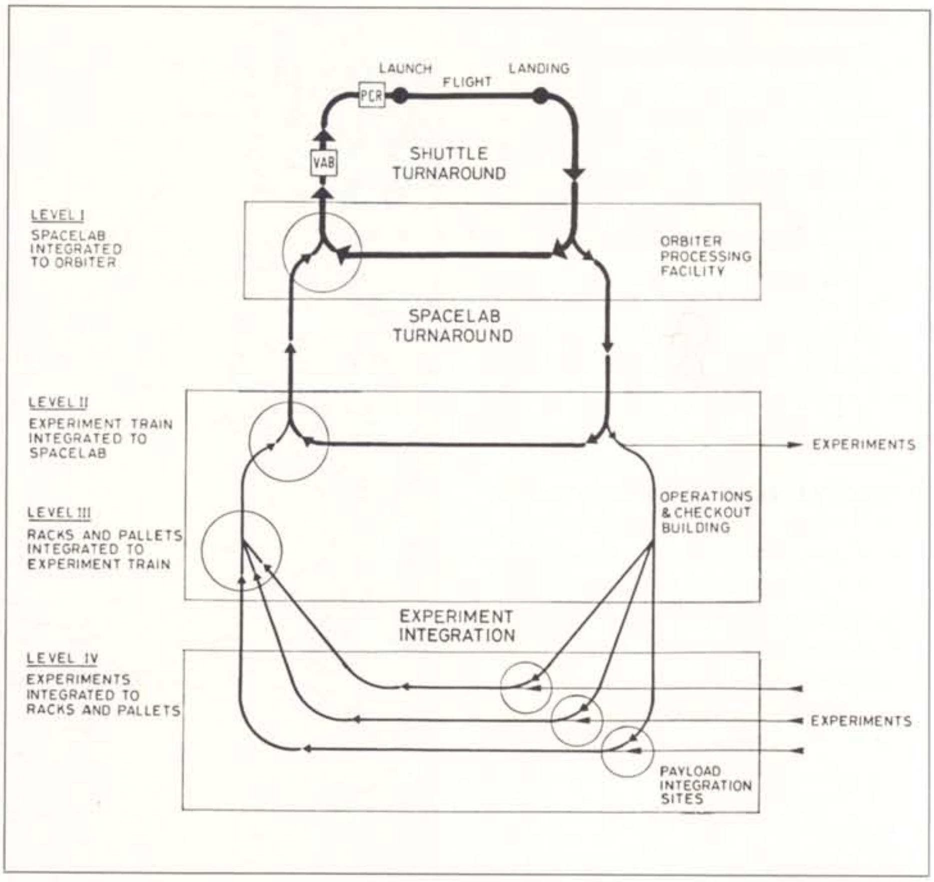


Figure 5 – The four levels of integration that will be employed in preparing for Spacelab missions



The instruments on the pallet can be operated from the Orbiter's aft flight deck or from the ground in pallet-only configurations. Spacelab's subsystem equipment is housed in a pressurised 'igloo'.

A short module plus pallet is a typical configuration for atmospheric-physics experiments. The pallet accommodates detectors and 'stimulating' equipment such as transmitters and particle accelerators. The short module accommodates experiment control and analysing equipment, and is also the crew's work station during experiment operation. In all-module configurations, Spacelab's subsystem equipment is accommodated within the module in two double racks and on the subfloor.

Long module-plus-pallet or long-module-only configurations are characteristic for space-processing and life-science applications. The long module provides the most spacious shirt-sleeve environment for the crew to supervise and service experiments under extremely low gravitational acceleration conditions and to accommodate biological experiments and samples. Auxiliary support equipment and further supplementary equipment can be carried on a pallet.

It should perhaps be emphasised at this point that Spacelab's utility is by no means restricted to single-discipline missions. The first flight, for example, will be a multidisciplinary mission, combining payloads from a wide spectrum of scientific disciplines.

Modularity for offline integration
The operating cycles of both Spacelab and the Shuttle have important consequences for Spacelab's users, whose payload-design and payload-checkout concepts have to be compatible with the resources available during and the constraints imposed by the various phases of payload integration (Fig. 5). The modular design takes this offline integration requirement into account by providing racks and pallets that can be physically removed from Spacelab and transported to remote integration sites. By combining the racks and pallets into an 'experiment train' it has been possible to establish an integrated system checkout process that can be applied in parallel with the Spacelab 'turnaround flow'.

The complete payload-integration process forms part of both the Spacelab and Shuttle ground-processing flows. The interaction between the various flows is arranged such that there is maximum 'decoupling', allowing each flow to have a turnaround time compatible with the STS's overall objective of maximum hardware re-utilisation.

The Shuttle flight and ground operations flow involves an approximately two-week cycle, while the Spacelab online flow has a 'turnaround' period of about four weeks. The offline payload integration process with Spacelab elements allows for a much longer time frame.

Spacelab mission planning
The novelty of the possibilities offered to users by Spacelab is very closely related to the modes of payload preparation and operation that are provided. The re-usability inherent in the system permits equipment to be reflown in the same or in modified condition, while manned attendance and crew support offer a new perspective for experiment conception, design and operation. In addition, no vacuum qualification is required for experiments to be flown inside the module.

When both the Shuttle and Spacelab are fully operational, the lead time between experiment conception and the availability of experimental results will be very much shorter than in the pre-Shuttle era, and the more relaxed design requirements that

Figure 6 – Cut-away of a Spacelab experiment double rack, showing the physical and functional support services that it provides to payloads via standard interfaces

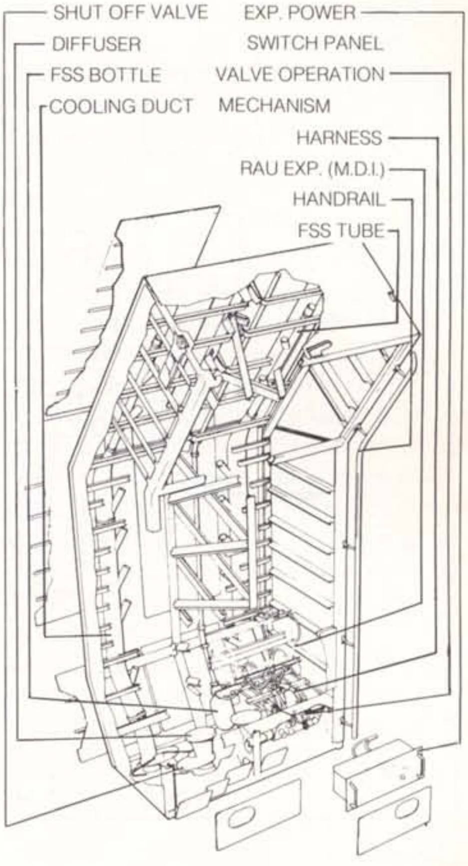


Table 1 – Spacelab's payload resources

Crew size	1-4 payload specialists
Payload mass	3900 - 5500 kg for module/pallet 7650 - 8500 kg for pallet only
Payload volume	8 m^3 in short module 22 m^3 in long module
Electrical power for payloads – average	1.9 - 2.3 kW for module/pallet 4.4 kW for pallet only
– peak (for 15 min/h)	4.3 kW in addition to average power
– auxiliary (essential)	60 - 200 W
Heat rejection	via two air and two liquid loops, capability commensurate with electrical power and metabolic heat generation of crew/biological samples
High data rate – acquisition – temporary storage	 up to 50 Mbit/s up to 32 Mbit/s for 20 min recording
Data-processing assembly – low-rate data acquisition – experiment control – monitoring/housekeeping	dedicated computer with data bus, up to 22 standard interface units

will be possible in the areas of materials control, reliability and procedures will considerably facilitate payload development. Launch and development costs per unit payload mass will be substantially lower than for comparable satellite projects, not least because a support system with standardised interfaces and well-defined features/procedures will be available for Spacelab missions. During mission planning, the physical and functional services of Spacelab, the Orbiter services and crew involvement have to be carefully coordinated to achieve maximum efficiency. This aspect makes mission planning for Spacelab fundamentally different from the planning of satellite projects, where the payload largely determines the satellite's physical and functional services.

Spacelab's system resources

The nominal in-orbit stay time for Spacelab and the Orbiter is seven days. This can be extended to 12 days without affecting the room available for payloads by carrying additional hardware and consumables on board, the major item being the additional fuel required for power generation in the Orbiter. The designs of Orbiter and Spacelab do not, however, preclude flights lasting up to 30 days. The principal system resources and capabilities available to payloads are summarised in Table 1.

Spacelab's subsystems

Spacelab's subsystems provide a wide spectrum of physical and functional support to payloads via sets of standard interfaces.

Structural subsystem

The racks in the module and the pallets are the main structural elements with which payloads interface directly (Fig. 6, Table 2), most of the standard interfaces from other subsystems being available at this level.

The pallet (Table 3) is designed as a general-purpose structure providing maximum volume for payloads in the cargo bay.

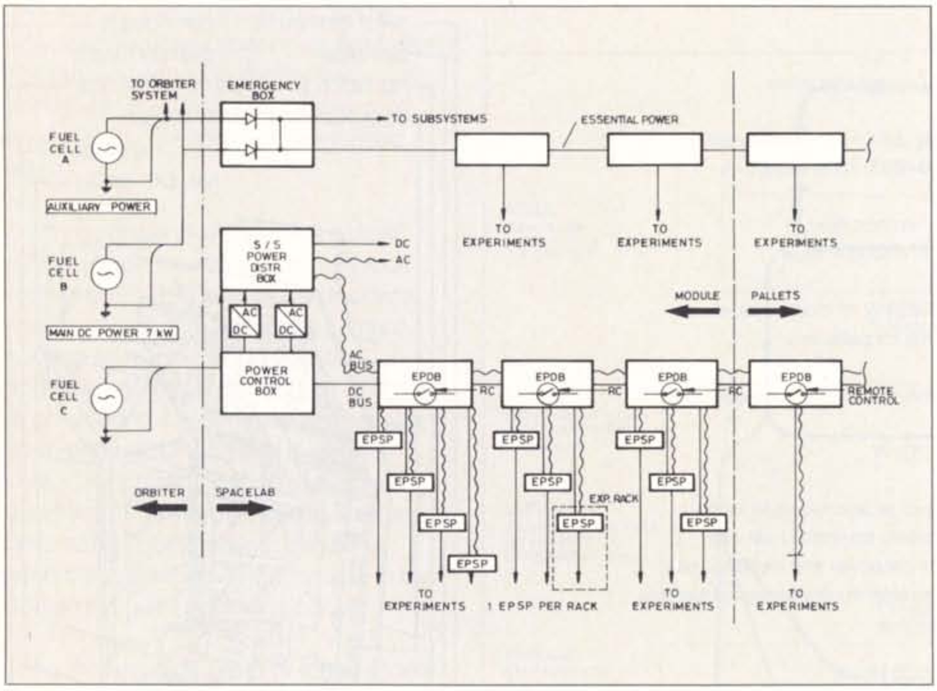
Electrical Power Distribution Subsystem (EPDS)

The Orbiter's fuel cells provide the main DC (28V, 7kW) and auxiliary (400 W) power. The EPDS (Fig. 7) distributes this power to subsystem and payload on separate buses. Part of the main power is converted to AC (400Hz, 115V).

The interface with the experiment AC/DC buses is via Experiment Power Distribution Boxes (EPDBs). Circuit-protection devices prevent failure propagation. Remote-control capabilities for these circuit breakers and remote current measurement capabilities for the DC and

Figure 7 – Spacelab's Electrical Power Distribution Subsystem (EPDS)

Figure 8 – Spacelab's Command and Data Management Subsystem (CDMS)



three AC phases are provided to support payload operations.

To bring the EPDS interface down to rack level, there are Experiment Power Switching Panels (EPSPs) located in the experiment racks. These panels contain manually operated circuit breakers.

In addition to the main DC and AC power buses, there is also a dedicated essential-power bus fed from redundant Orbiter fuel cells to support holding and emergency functions in the event of main power loss.

Command and Data-Management Subsystem (CDMS) and Software

A High-Rate Data-Acquisition Assembly (HRDA) accepts the digital data from multiple sources for transmission to the ground and an experiment Data-

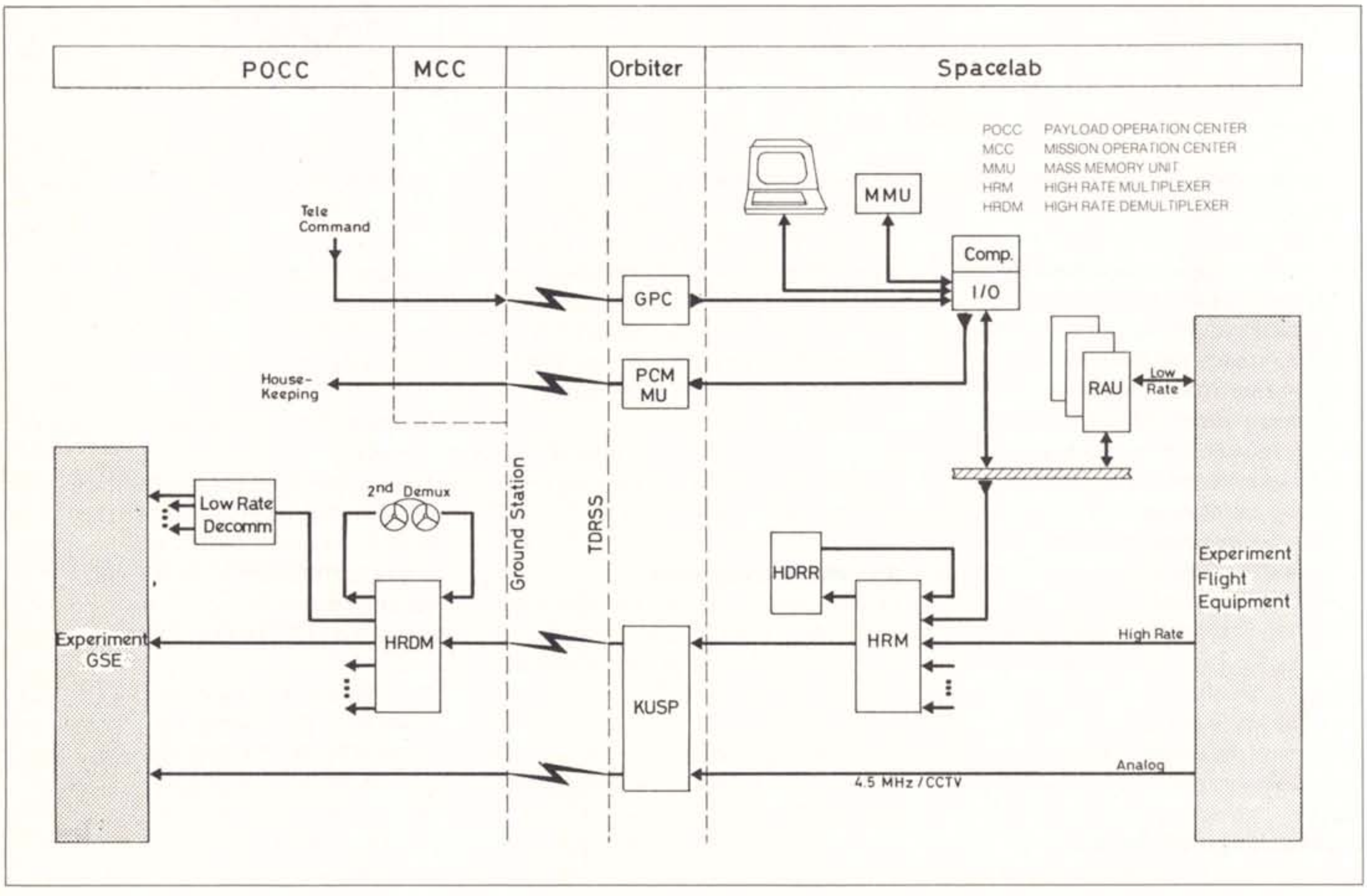


Table 2 – Experiment-rack characteristics

Rack standard	19 inch, MIL-STD-189
Types of rack	single (19 inches wide) double (2 × 19 inches wide)
Number of racks	
– short module	two single, two double
– long module	four single, six double
Payload-carrying capability	290 kg/single rack 580 kg/double rack
Payload volume	0.9 m^3/single rack 1.75 m^3/double rack
Rack equipment (including mission-dependent equipment)	– Experiment power-switching panel for EDPS interface – Airducting and adjustment valves for payload cooling; 1.6 kW for single, 3.13 kW for double racks – Standard interface unit for CDMS/DPA interface – Fire suppression system – Feedthrough and tie-down provisions for payload cables – Strengthening (diagonal) struts
Special equipment	One rack can accommodate a payload-dedicated heat exchanger and a cold plate for payload cooling

Table 3 – Pallet characteristics

Design	Aluminium structure consisting of five frames, four longerons, two sill and one keel covered by honeycomb panels to carry sheer loads
Dimensions	3 m long, 4 m diameter
Modularity	Up to three pallets can be connected to form one structural element
Payload-carrying capability	3000 kg nominal for one pallet 5000 kg nominal for double and triple pallet train (actual load-carrying capability depends on payload geometry)
Payload attachment	24 hard points/pallet attach provisions close to Orbiter attach fittings/6 × 4 hole pattern/panel for utility attachment or small payloads
Pallet equipment	Subsystem package with experiment power distribution box for EPDS interface and standard interface unit for CDMS/DPA interface Cold plates (0.5-0.75 m) for active payload thermal control

Processing Assembly (DPA) supports low-rate data acquisition and experiment operation. There is also a subsystem DPA which is independent of the experiment DPA, both to ease payload integration and to prevent failure propagation from experiments to subsystems.

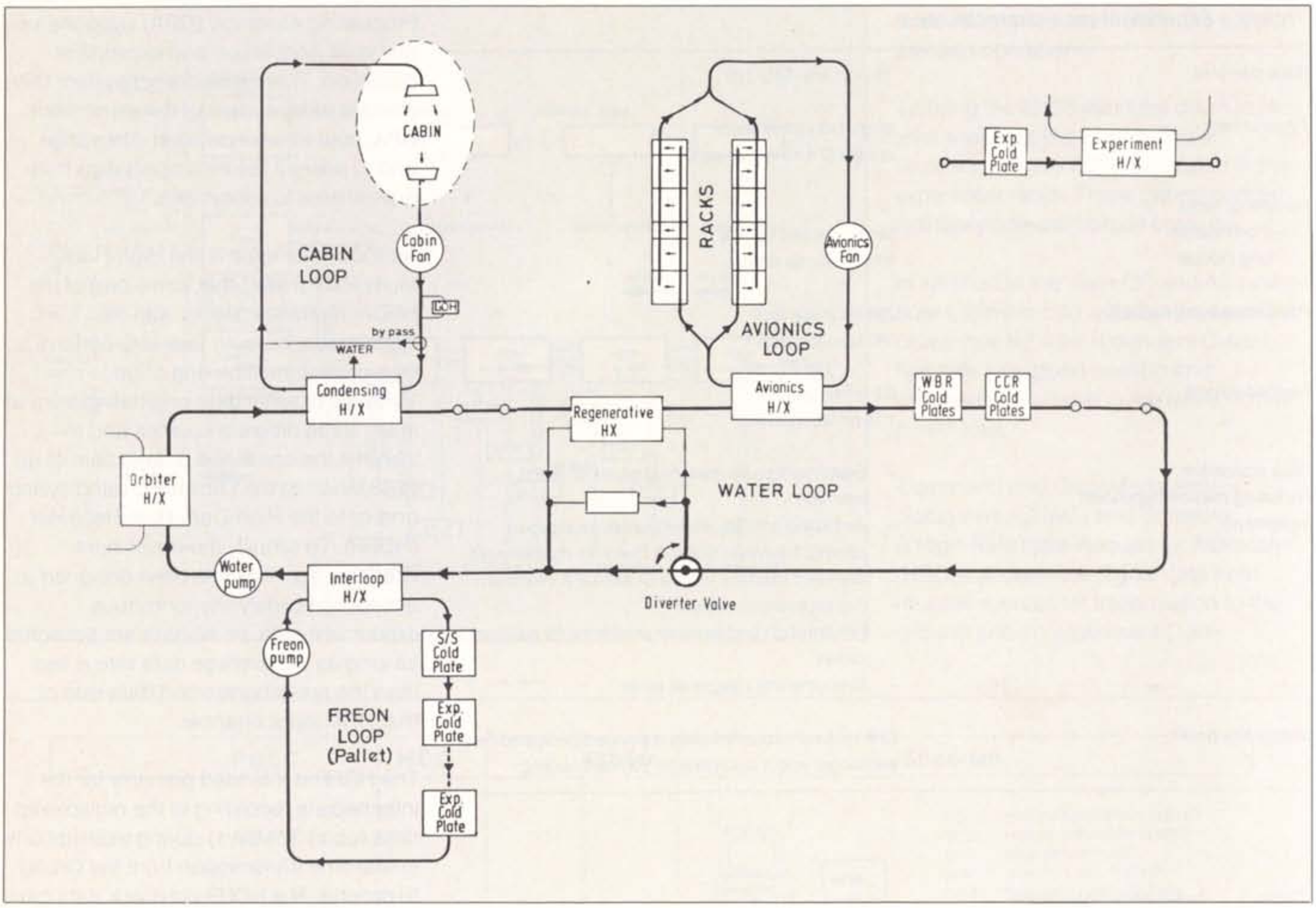
As shown in Figure 8, the High-Rate Multiplexer (HRM) that forms part of the HRDA interfaces directly with the experiments. Its main task is to perform a time-division multiplexing of up to 16 Mbit/s of serial data originating from as many as 16 different sources and to transmit the combined data stream of up to 48 Mbit/s to the Orbiter Ku-band system and/or to the High-Data-Rate Recorder (HDRR). To simplify the experiment interface, the HRM has been designed to accept completely asynchronous experiment data, i.e. all data are accepted as long as the average data rate is less than the pre-programmed data rate of that HRM input channel.

The HDRR is intended primarily for the intermediate recording of the multiplexed data (up to 32 Mbit/s) during interruptions in real-time transmission from the Orbiter to ground. The HDRR playback data can subsequently be interleaved into the real-time data stream, so that an uninterrupted data-acquisition service can be provided to Spacelab experimenters.

The experiment DPA consists of a computer (3.5 × 10^5 ops/s, 64 K memory), an input/output unit, and a data bus routed through Spacelab with standard interface units (RAUs) providing 128 discrete or analogue and four serial digital inputs. The data acquired via the RAUs are available on board for data processing and monitoring by the flight crew. They can also be transmitted to ground via a dedicated HRM channel to be available in the Payload Operation Control Centre (POCC).

The experiment DPA is software controlled and is able to handle applications programs written in Fortran.

Figure 9 – Spacelab's Environmental Control Subsystem (ECS), with its cabin, avionics, water and freon loops



In particular, it provides for the following functions:

- task management;
- input/output management;
- sampling of the RAU inputs and outputs at predetermined frequencies or in an asynchronous manner;
- time management, including GMT and user time-clock services and time-delay requests;
- computer memory management;
- keyboard/display systems, allowing displays in certain formats and keyboard messages;
- command and data services, to handle telecommands and keyboard and applications-program commands;
- monitoring services, to allow periodic checking for out-of-limits data.

Environment control

Spacelab's Environmental Control Subsystem (ECS) (Fig. 9) carries away the heat generated within the laboratory by electrical dissipation in the subsystems and in payload equipment, and that produced by metabolic/chemical processes, to the Orbiter's heat-rejection system. The heat from the cabin and avionics air loops and from the pallet freon loop is collected through heat exchangers and, together with the heat from various cold plates, transferred to the Orbiter via the water loop.

It is the cabin loop, controlling temperature and humidity and removing carbon dioxide, that provides the 'shirt-sleeve environment' in the Spacelab module for the crew. It also provides a 1 kW heat-rejection capability for experiment equipment.

The avionics loop provides cooling (up to a total of 3.7 kW) in the equipment racks by sucking air via ducts and adjustable orifices to the individual experiment boxes accommodated in the rack. This standard cooling system simplifies experiment design and also allows aircraft-type equipment to be used.

An experiment liquid-loop heat exchanger and an experiment-dedicated cold plate, both located in the module, allow experiments to reject heat (up to 4 kW) directly into the water loop. This is particularly useful for, for example, material-science experiments that rely on furnaces generating large amounts of heat.

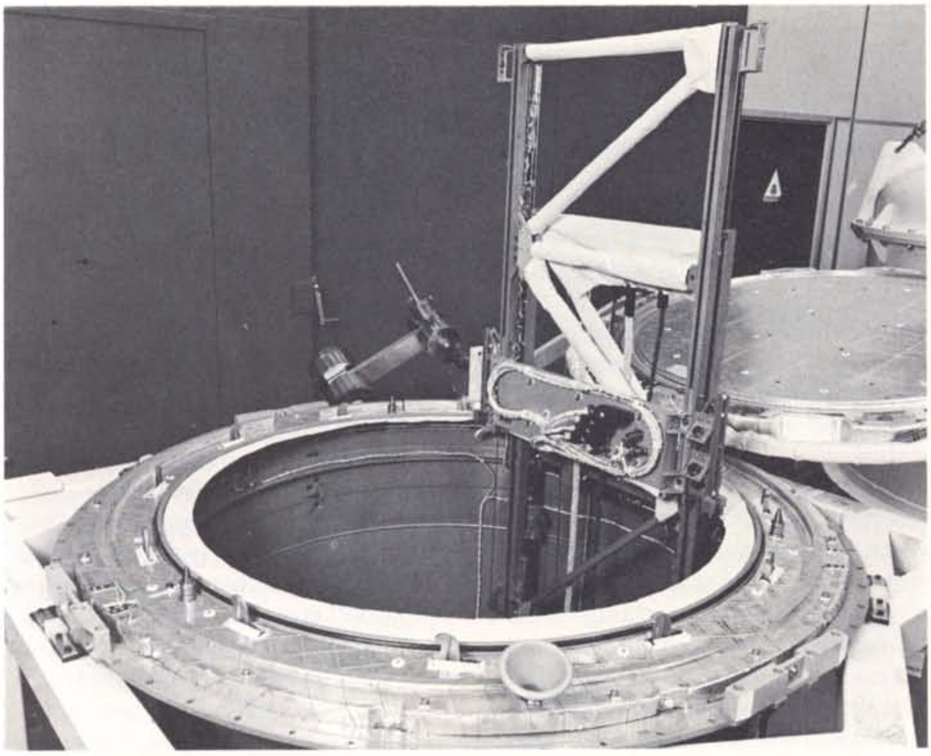
Figure 10 – The air lock that will provide those Spacelab experiments carried within the module with direct access to space

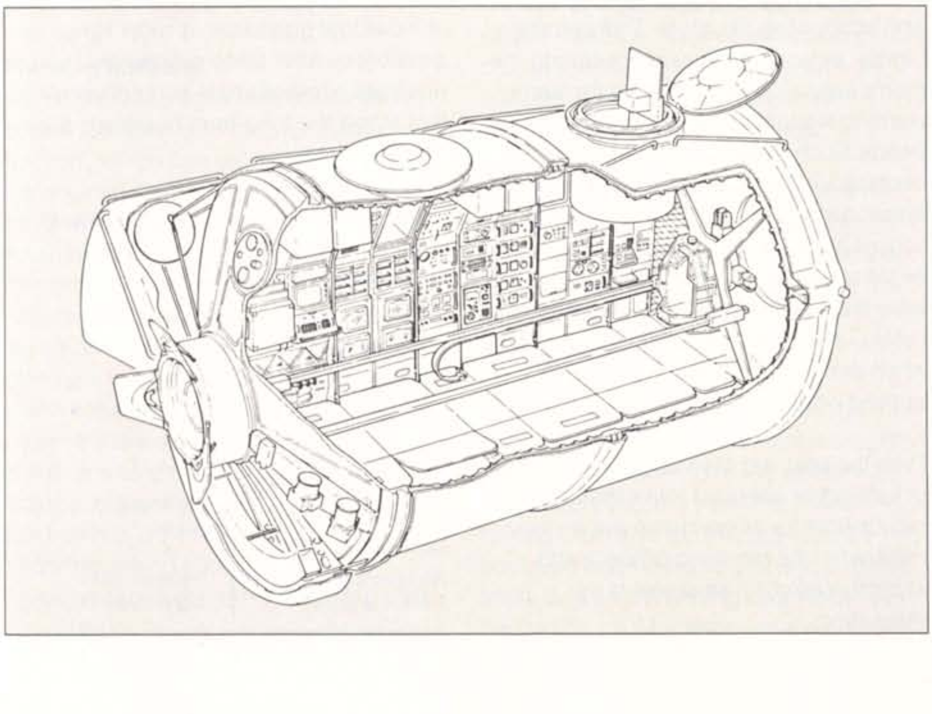
Experiments located on the pallet can reject heat through the cold plates in the freon loop (up to 1 kW per cold plate). The amount of experiment-generated heat that can be removed via the various cooling loops depends on the Spacelab configuration being used; it is limited to a maximum consistent with the total power available to experiments.

Common Payload-Support Equipment

The Common Payload-Support Equipment (CPSE) is provided to support more specific classes of payload and it consists, as has already been mentioned, of two main elements:

- a scientific air lock for experiments requiring exposure to space from the module's interior
- an optical window for instruments viewing from inside the module.



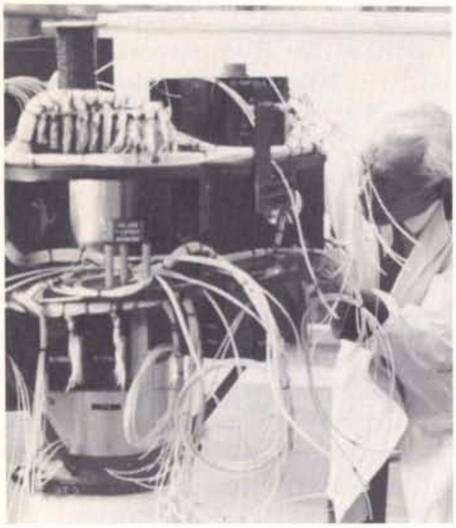


The scientific air lock (Fig. 10) consists of a cylinder 1 m long and 1 m in diameter mounted into the Spacelab module's shell. Experiments can be mounted inside the air lock on a sliding platform that moves parallel to the cylinder's axis. This platform, or experiment table, can be extended out into space by opening the outer hatch, or it can be retracted into the module by removing the inner hatch. The air lock is manually operated and flexible power and signal harnesses routed through its shell follow the experiment table's movements.

The optical window is mounted in an adapter plate which closes off the module's top opening. It consists of a single rectangular (41 cm × 55 cm) pane of glass with a spectral transmissibility in the range 400–1000 nm. An electrical heater minimises thermal gradients across the glass to maintain optical performance. A viewing port mounted next to the optical window serves as a viewfinder for the operators of optical instruments.

The Instrument Pointing System (IPS)

This system which is being developed as part of the Spacelab programme has been described in detail in a previous issue of the Bulletin (No. 6, August 1976). It provides precision pointing in the arc-second range for payloads that require greater pointing accuracy and stability than can be provided by the Orbiter alone. The IPS is designed to accommodate instruments ranging in weight from 200 to 2000 kg.



Making the Plan Work*

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With the ever growing need for effective deployment of resources, 'the plan' – a graphic display of expected future happenings – is gaining in importance not only as a device for initial projection, but also as one of the most powerful management tools. It must be a consensus between those responsible for its development and those to be entrusted later with carrying it out or with providing appropriate expertise. It must be updated regularly to reflect the operational environment at all times, and not degenerate to a mere record of past events. Last but not least, 'the plan' must be imprinted on the minds of all involved to direct them effectively towards the final objective.

'The plan' can range from a mental formulation of a number of steps leading to a future state of affairs, to a comprehensive package of graphic displays prescribing in detail how and when something must be done to achieve a certain objective. A mere forecast of a future condition cannot be considered a 'plan' since it lacks the directives leading to the accomplishment of the objective and the criteria for assessing compliance.

These directives of the plan must already reflect the structure of the mechanism by which it is going to be transformed into reality. Once declared as a binding plan, a so-called 'baseline', no changes should be made in the management system, as this could jeopardise the assessment of actual performance. If changes become inevitable, the baseline must be formally adjusted to reflect the new management and accounting structure. This permits regular detection of deviations during the plan's execution and provides for 'early warning signals' of possible unfavourable trends. Such 'signals' must be correctly assessed in terms of severity and must be systematically reported to the hierarchy, so that appropriate corrective action can be taken in good time. It is therefore essential that the cybernetic management cycle (Table 1) be fully taken into account when making plans, and rigorously applied when putting them to work.

Even the best laid plan only has a chance of fulfilling its intended role if those responsible for its execution are actively involved in the planning process and explicitly commit themselves to its realisation.

Planning subjects

While the concept of planning is applicable in countless spheres, this article concentrates on planning in organisations such as ESA which are involved with modern technological systems, projects, operations and programmes.

Sound planning is to be seen as one of the first and most important activities in an all-embracing management process, and it must commence with the establishment of broad, long-term goals. Before any specific programmes, systems, projects and operations are identified, the institution** in question must establish a conceptual overall programme based on its statutes and policy. At the outset it may be sufficient to identify a number of essential key goals (cf. Table 2). Usually, the approving authority makes a selection of individual goals from a wider range of possibilities after some preliminary analyses of programme alternatives. At that stage, the long-term objectives are

Table 1 – The cybernetic management cycle

Initiation	
Approach selection	
Planning	
Baseline implementation	
Execution	
Collection of actuals	follow-up action
Measurement	
Course determination	
Acceptance *or* corrective action*	feedback into higher-order planning

* In the interests of wider reader appeal, this article draws upon experiences in several organisations, and does not therefore necessarily reflect ESA practice or policy in all its aspects.

**used throughout this article as the collective term for any commercial enterprise, research laboratory, government agency, international organisation or other institutionalised body engaged in programmes involving technological systems.

Figure 1 – Breakdown of an ESA programme goal using the PBS approach

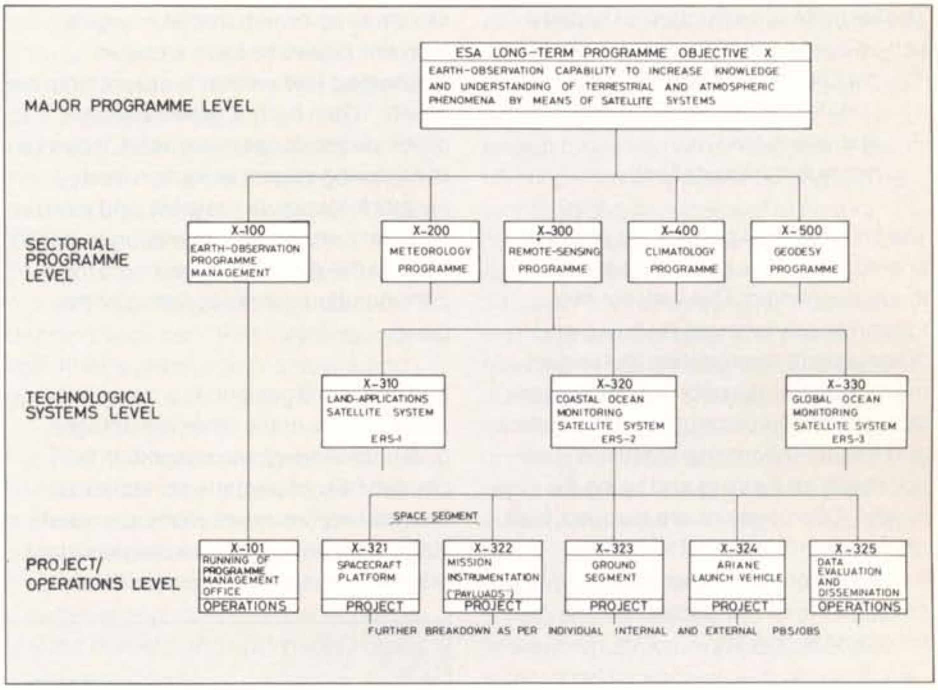


Table 2 – Broad, long-term goals for a conceptual programme for institution X

Goal	Envisaged year* of accomplishment
High-speed automatic translation of conventional typed or printed text, based on optical reading	1985
Portable TV-telephones ready for commercialisation in Europe	1989
Hydrogen-fuelled aircraft	1995
High-powered human-like robots available for handicapped people	1990
Individualisation of rapid-access urban public transport	2010
Large-scale terrestrial utilisation of solar energy	1990

* strictly non-committal

broken down into their major elements, namely the different (hard- and software) systems required to accomplish the chosen objectives. The systems can, in turn, after a certain amount of systems planning, be further broken down into their pertinent projects and operations. Figure 1 is an example of such a breakdown applied to an Agency programme.

Planning horizons

With the initial programme breakdown comes the question of a 'planning horizon', which can be defined as the maximum distance into the future to which we can develop realistic plans with a certain resolution, depth and precision. The establishment of an optimum horizon requires considerable experience in the discipline and environment for which the plans are to be developed. It is usually much easier and more appropriate to determine the depth and precision of plans as a function of a given planning horizon, rather than vice versa, and it is this that has led to the common practice of distinguishing between:

– long-range planning (more than five years)
– medium-range planning (three to ten years)
– short-term or operational planning (up to five years).

For the long-range planning, such as the initial analysis of the broad, long-term goals and the identification of major systems, it may be sufficient to establish a number of objectives with associated global resource requirements, using coarse estimating techniques such as notional estimates, monoparametric estimates or trend extrapolation.

For medium-range planning, where the long-term objectives and major systems are analysed and broken down into their constituent projects and operations, it is necessary to use more accurate techniques.

The short-range planning should be based on further detailed resolution of the constituents identified in the medium-range planning; it is here that more refined tools and techniques must be deployed and where insufficient analysis, short-cuts and 'planning cosmetics' will have to be paid for later – at a high price – during the execution phases.

The importance of systems management in the planning process

The accomplishment of the broad, long-term goals of an institution depends predominantly upon the conception, design, development, construction and operational deployment of a number of specific technological systems. If the planning process and the resulting plans are to be seen as a means of providing and optimising the deployment of resources, the planning must pivot around the systems to be acquired and operated, since they determine the type and level of resources required.

Having determined the systems in an overall programme, it is then possible to identify the individual projects and operations. These form the basis for a down-to-earth planning and validation exercise because they can be broken down into their *constituent resource-consuming elements, activities, processes and objects*. From this it follows that the concept of life-cycle systems management plays an essential role in effective planning.

The life cycle of technological systems can be divided into three major phases:

- conception and acquisition (creation)
- operations (use)
- dissolution (liquidation)

The first and third phases are objective-oriented, while the second phase is function-oriented. This calls for two fundamentally different planning and management approaches: the project management approach for conception, acquisition and dissolution of the system, and the operations management approach for running and using the system. Often systems are planned, built, operated and dissolved within the framework of an autonomous programme, the 'single system programme' (Fig. 2).

In the interests of performance, reliability and economy, systems must be planned, designed and built such that they can be not only acquired, but also operated, with the best return on invested effort, and also such that the three major system phases, taken as a single integrated block, can be realised with the greatest possible efficiency. It is in this context, if project and operations management are adequately merged into a management entity for a synergic effect, that one talks about 'systems management'.

Feeding the techniques and experience gained from modern systems management into the planning process at an early stage not only produces more realistic and reliable plans, it also increases the degree of control considerably beyond that attainable with conventional planning methods.

As an example, if, instead of a conventional bar chart, a very simple and coarse project planning network is established and used during the preliminary project analysis or feasibility study, this provides considerable insight into the problems to be expected, the critical interfaces to be dealt with, and the resources to be required at any given moment. Networks have a built-in forecasting feature that is absent from bar charts. When such a network is later developed to its optimum detail, it can be used during project execution as a yardstick for actual progress and it allows important predictive information to be fed back to the planning department for consideration during updating of the plans.

Systems management as a discipline, apart from its many other advantages, guarantees adequate integration and compatibility of all strategic, technical, financial and resource plans at an early stage. It therefore deserves an important place in the planning function of any cost-conscious institution handling technological systems.

Making plans for systems

Having fixed the long-term goals, the next question to answer is 'What systems are likely to best serve the accomplishment of the objectives?'. In this analysis one must consider not only the hardware systems required to achieve the long-term goal, but also the management mechanism necessary to create and deploy those systems. Almost the same techniques and principles can be used here as for Project Breakdown Structuring – the method of breaking projects down into their smallest manageable tasks and objects, or 'work packages' (Fig. 3).

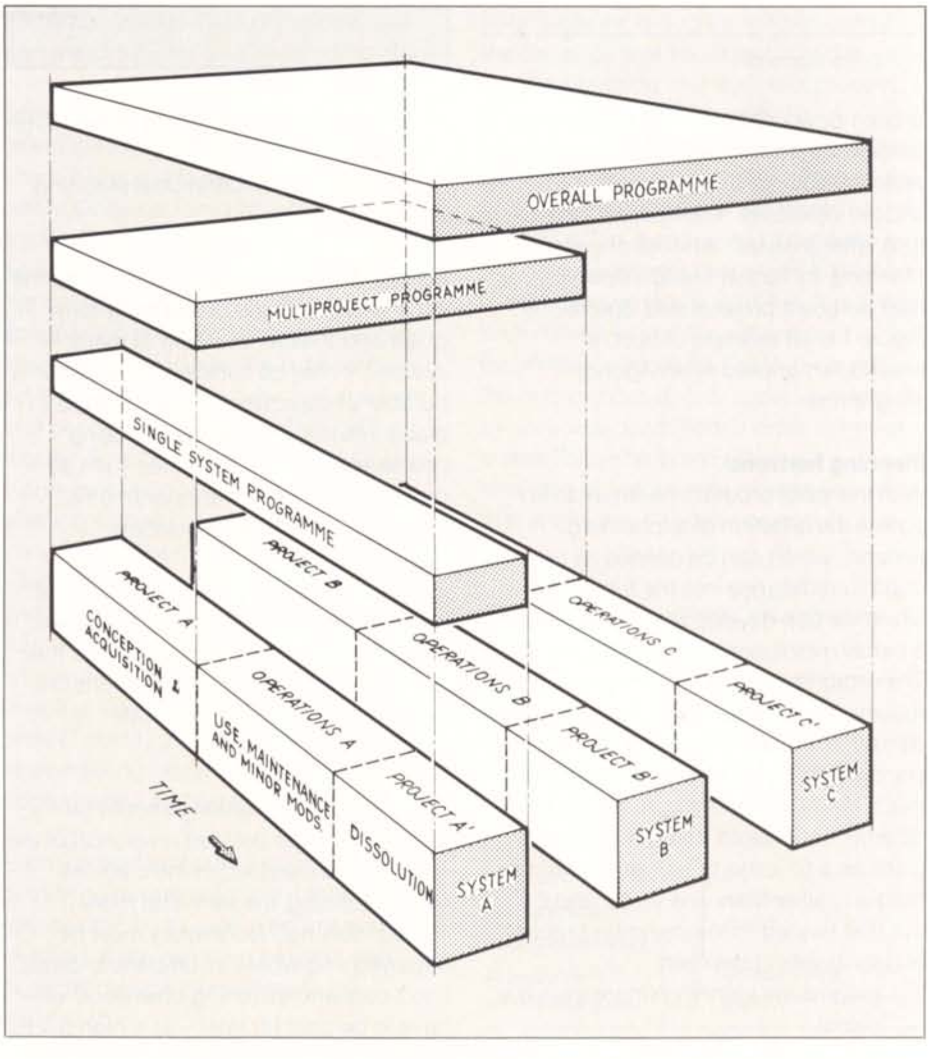
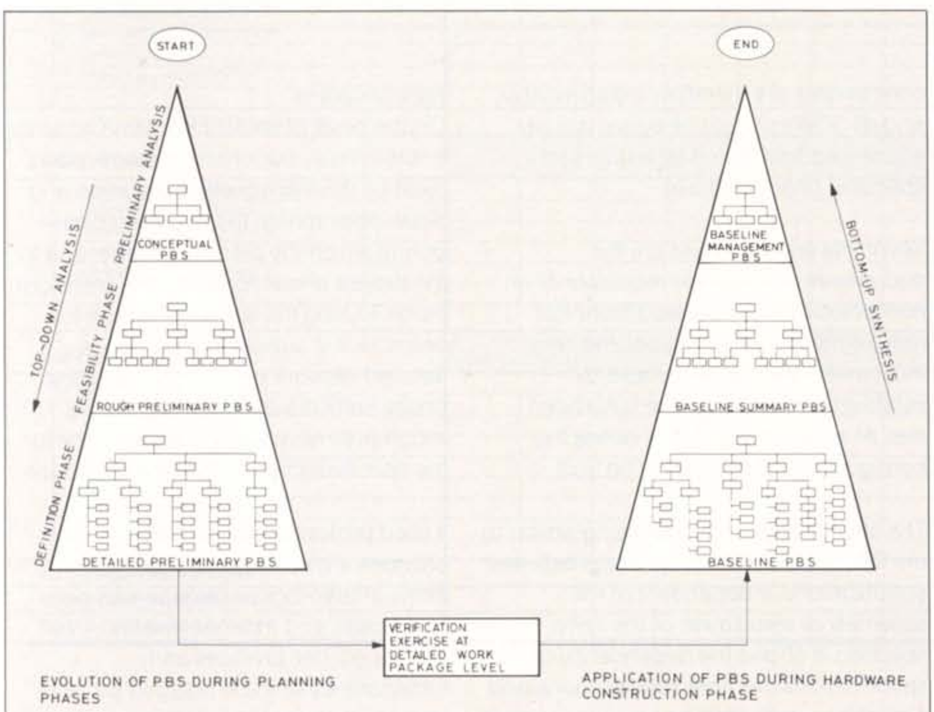


Figure 2 – Concept of projects, operations and programmes for planning and general management purposes

Figure 3 – Top-down/bottom-up approach in PBS



Successful planning (and execution!) much depend on an orderly process of transforming people's amorphous ideas into concrete, detailed plans. For this it is best to use the so-called 'top-down/bottom-up approach', an iterative process in which the project is broken down into its major and then minor constituents, elements, etc., checked at the detailed level for correctness, completeness, compatibility and against other criteria, and then re-summarised on the basis of any adjustments made at the lower levels.

Once the upper-level breakdown into systems, projects and operations has been made, the planner can proceed to the development and integration of the appropriate project and operations plans.

Making plans for projects and operations

The tendency in many institutions is still for the pertinent specialist to develop particular plans and to disseminate these in isolation. This leads to hidden incompatibilities and divergences in both the plans and the work that follows. To avoid such anomalies, one must work actively towards complete integration of the various plans from the very beginning, ideally by appointing a 'planning integrator'. ESA nominates study managers for its projects and operations and prepares Project Development Plans (PDPs) appropriate to the system/project phases, which integrate the various tasks into a comprehensive, self-contained planning document that serves as a basis for further system/project analysis and planning.

The PDP, the first issue of which should be established during the project feasibility study, embraces the phasing plan, the project and operations breakdown structures, the work statements and technical specifications, and the network and cost/budget plans.

The phasing plan

This document establishes the major phases and pertinent objectives of a project or technological system during its evolution from concept to reality (Table 3). Its purpose is to formalise a logical thinking and ranging process and it provides for distinct checkpoints, with the recurring option to proceed to the next phase or to abandon the project without undue commitments. Under this scheme, project funds and other resources have to be committed only phase by phase. The synchronised development of project plans in accordance with a pre-established phasing plan is called 'Phased Project Planning'. It is essential that the project phases and phase objectives should be clearly established during preliminary analysis and transmitted to all concerned, to ensure compliance and to discourage the performance of unauthorised trans-actions under the umbrella of obscurity.

The Project Breakdown Structure (PBS)

A PBS, sometimes referred to as Work Breakdown Structure (WBS), must be established for each project phase. It is a graphic, hierarchical representation of the project and is most important during hardware development and construction. It successively resolves the project, level-by-level, down to the degree of detail required for effective planning and subsequent control. The PBS must include all tasks, processes, objects, efforts, etc., required to reach the objective of the pertinent project phase. The lowest element in a PBS, an optimised manageable entity of tasks and/or products, is called a Work Package (WP). Two kinds of WP exist: the 'task-oriented' for continuous effort, and the 'object-oriented' for hardware/software items such as black boxes. The advantages of the PBS approach over the conventional mix of arbitrary breakdowns are the organisational leverage and the ability to visualise the total project phase and all its major and minor elements rapidly in a logical and orderly manner.

As we have said, 'the plan must be imprinted on the minds of all concerned', and the PBS allows those working on the project to marshall their thoughts and achieve a common basis for communicating, classifying, checking and memorising project matters.

Table 3 – Phasing plan for system life cycle

Life-cycle phases	Elementary system phases	Management required	Task and objective
Creation	Preliminary analysis	Project management	Problem and/or requirement analysis, definition of constituent problem elements, market surveys
Creation	Conceptual development	Project management	Development of vague ideas into clear system concepts and alternative solutions
Creation	Feasibility assessment	Project management	Analysis, examination and assessment of the realism and feasibility of the envisaged system concepts and solutions. Examination of the resources and anticipated system benefits. Elimination of the less promising solutions or concepts
Creation	System definition	Project management	Tender action for, and performance of, the system definition studies. Working out of system specifications, subsystem specifications and interface requirements. Evaluation of the study reports. Decision on the final concept. Tendering and selection of the contractors and main suppliers. Validation of commercial viability
Creation	Design and development	Project management	Validation of the baseline plans. Engineering, design and development of the system, its constituents and elements. Construction, testing and evaluation of development models and prototypes. Preparation of manufacturing drawings, bill of materials and process specifications
Creation	System acquisition and integration	Project management	Manufacturing and testing of the system constituents and elements. Construction, assembly, installation and testing of the final system. Acceptance and commissioning
Use	System operations	Operations management	Operation and use of the system. Maintenance and minor modifications. Evaluation of system effectiveness
Liquidation	System dissolution	Project management	Dissolution, disposal or transformation into another system

The Operations Breakdown Structure (OBS)
The OBS is very similar to the PBS, the only fundamental difference being that it is routine-task or function oriented. It includes all tasks, processes and functions that are, or should be, performed by a given system or institution.

Statements of Work (SOW) and technical specifications
SOWs are written requirements which explicity define what is expected of each project participant, what equipment they must use, how they must work, and how they must ensure that their work is correct. In many cases, the work is contracted out and an insufficient or poorly written SOW may result in serious technical, legal and financial repercussions for the customer institution. Precision, clarity and conciseness are therefore indispensable, and all SOWs should be systematically scrutinised and edited by a qualified specialist prior to release.

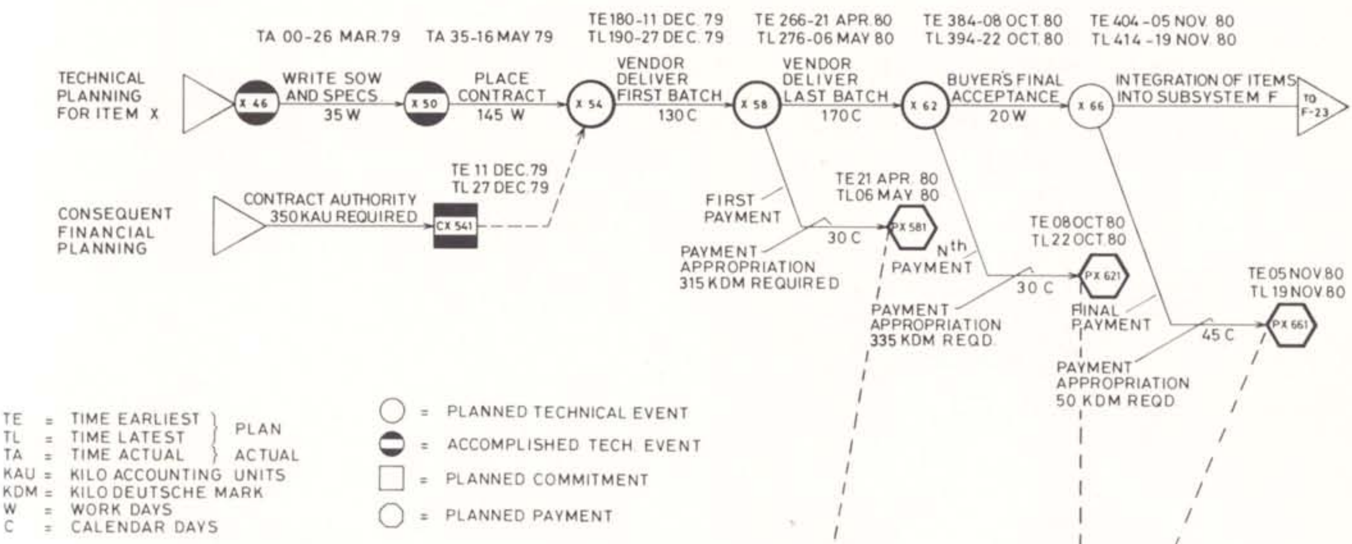
Technical specifications are the documents in which the requestor of an item prescribes the detailed technical requirements and conditions the item must meet, and the procedure for establishing whether these have been met. At a certain point they define the configuration of the item to be built.

The specification tree, a drawing similar to the PBS, shows the relationships between specifications, independent of the assembly or installation of the items specified. It shows the dependence of specifications on other specifications and it must be established as soon as possible.

Network plans
On the basis of earlier conceived notional or preliminary bar charts, network plans must be developed with a precision and depth appropriate to the project phase *during* which the plans are made, and to the project phase *for* which the plans are made. During the feasibility phase, for example, it is sufficient to prepare a detailed network only for the definition phase immediately following, while a rough preliminary network will suffice for the later design and development phase.

If used professionally, the network plan provides a vivid model of a project in terms of task-logic, interdependencies, time scales and manoeuvrability. A well developed 'net' provides early transparency of the envisaged project and encourages the project's members to

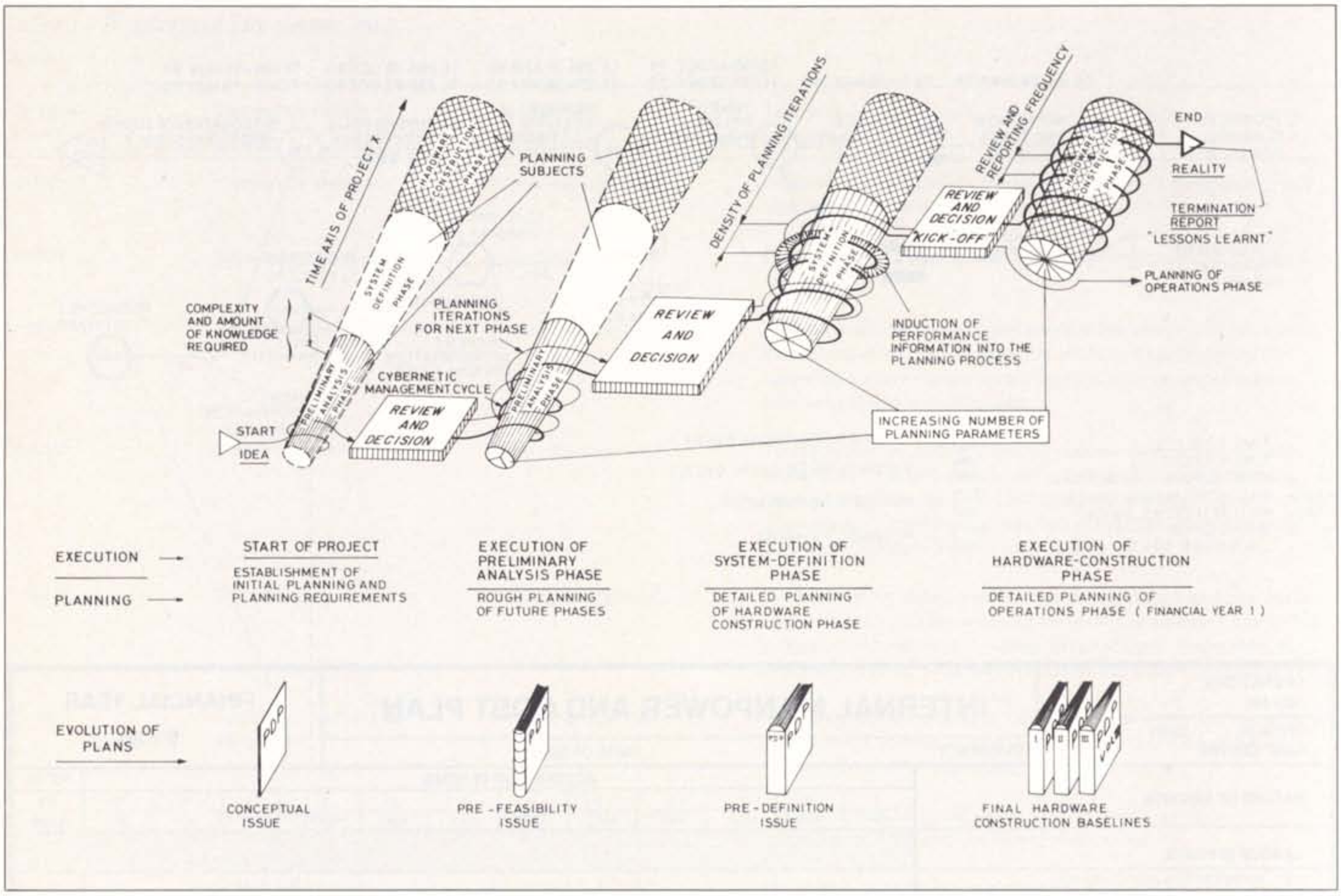
Figure 4 – Linking financial with technical network planning



OPERATIONS OBS NR.	INTERNAL MANPOWER AND COST PLAN		FINANCIAL YEAR FY 80
DIVISION DEPT COST CENTRE	CURRENCY:	DATE OF ISSUE:	

NATURE OF EFFORTS	RATES	1 JAN	2 FEB	3 MAR	4 APR	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	TOTAL FY 1980
LABOUR EFFORTS														
MANAGEMENT & ADMINISTRATION														
ENGINEERING & SCIENTISTS														
DRAFTING & DOCUMENTATION														
MANUFACTURING														
OTHERS (e.g. TECHNICIANS)														
TOTAL LABOUR EFFORTS (MANHOURS)														
LABOUR COST	RATES													
MANAGEMENT & ADMINISTRATION														
ENGINEERING & SCIENTISTS														
DRAFTING & DOCUMENTATION														
MANUFACTURING														
OTHERS (e.g. TECHNICIANS)														
TOTAL LABOUR COST														
NON-LABOUR COST														
MATERIALS														
INTERNAL SPECIAL FACILITIES														
EXTERNAL MAJOR PRODUCTS														
EXTERNAL SPECIAL EQUIPMENT					315						335	50		
EXTERNAL SERVICES														
TRAVEL & SUBSISTENCE														
PACKING & SHIPPING														
OTHERS (SPECIFY)														
TOTAL NON-LABOUR COST														
TOTAL COST INCREMENTAL		0	0	0	315	0	0	0	0	0	335	50	0	
TOTAL COST CUMULATIVE FY					315	315	315	315	315	315	650	700	700	700

Figure 5 – The dynamic planning process



think through their contributions in a realistic and logical manner. The net also stimulates creative project thinking and helps to develop what may initially be a collection of seemingly incompatible ideas and plans into viable, specific work plans. This in turn helps to ensure that resources are ready by the time they are required.

An aspect still little exploited but with considerable potential is the integration of the early network planning with the financial planning and that of other resources. The profile of the requisite financial resources depends on the activity schedule. Contract authority ('commitment money') is required no earlier and no later than when a contract is to be placed, and payment appropriation ('payment money') when the payment is contractually due, usually a number of days after delivery of a specific item or completion of a certain activity.

The simplified example of Figure 4 shows how the financial planning department can profit from the dynamic network information of the technical planning department and optimise the level of resources ahead of time. To bring this benefit to full fruition, however, requires ample flexibility in the financial budgeting and control machinery.

Most modern project-planning software packages provide for automatic linking of the technical and financial planning strategies.

Cost plans and budgets

For each element of the PBS/OBS, a detailed and justified cost plan must be established showing the type of resource, the time during which it is required, and the appropriate level of support expected. After verification, this information can be converted into financial requirements and summarised into an overall financial plan for a project, an operation, a system programme, or for the entire institution. In the early phases of planning it is sufficient to make summary cost plans encompassing several work packages at a higher level of the PBS. Cost plans are, at the outset, only an indicator and must pass through a strict and thorough procedure before becoming 'budgets' – the baseline plans for financial management.

Plan validation and implementation

To make plans work they have to be subjected to a well-organised validation and approval process. Each plan must initially be checked to ensure that it is feasible within the scope of its object and in the particular aspects for which the signatory is responsible.

When all the relevant plans have been collected into a total planning package, they are submitted to a Planning Review Board, which checks for incompatibilities and inconsistencies. Any such discrepancies are to be eliminated via a well-coordinated reconciliation process.

When, as a result of this iterative exercise, the entire package has been found acceptable, the plans are formally identified and distributed to all concerned as *the valid baseline*.

Feedback of actual performance into the plans

In technological ventures hardly anything happens exactly according to plan, particularly as far as system configurations, schedules and budgets are concerned. Once a plan has become a baseline, it is essential that all concerned strive to meet not only the end goals of their respective plans but, equally importantly, all intermediate objectives. This allows corrective steps to be taken early, when there is still a good chance that the project, operation or programme can be successfully redirected. Sometimes, despite all the conscientious planning and control, it proves impossible to correct an unfavourable trend. This is particularly the case in risky ventures such as technological development work with a high degree of innovation, or where the initiator keeps changing his mind about what he wants without fully assessing the implications as to schedule, cost, etc. 'Just change it – we'll sort things (cost and schedule) out afterwards' is a frequently encountered attitude on the part of an initiator acting under pressure for technological performance. The astute initiator/manager knows that he will eventually be pardoned for a bad schedule or cost performance if he meets the technical requirements. What would happen if he met cost and schedule requirements, but not technical performance?

In spite of these unavoidable constraints it is necessary to observe strict discipline when completing the cybernetic management cycle. We must compare actuals with plans, follow-up, decide whether the deviations and trends are acceptable or need intervention, determine the appropriate corrective action and re-assess the baseline for realism. If a bad situation is the result of 'force majeure' and cannot be rectified, the least that must be expected is rapid, honest and unobstructed reporting of the facts to top management.

For the above and other reasons, baselines sometimes do become 'planologically' obsolete from time to time during project execution and have to be revised to reflect the latest planning assumptions. This can only be done if there is strong feedback of 'real-life' information into the planning and replanning process at all levels.

Conclusion

To *make the plan work* requires an all-embracing analytical and consistent planning approach, successively resolving the broad, long-term goals of an institution into systems, projects and operations, and further down the chain into individual activities and objectives. Once plans have been declared within the framework of an integrated dynamic planning process (Fig. 5) as the official and binding baselines, any changes must be the subject of rigorous scrutiny by the institution's high-level planning board, comprising technical, financial, legal and planning experts. Effective performance monitoring, replanning and reporting must be instituted and maintained at all times, and sound interfaces must be established between those executing the plan and the planning office. Honesty and rapidity in reporting must be encouraged, and in multiproject institutions like ESA standardised planning, measurement and reporting formats are an absolute must.

Plans must never be expected to work miracles, for example in reversing inevitable schedule and cost overruns, but if developed and applied conscientiously, as postulated here, they will serve as an effective source of visibility and control in the activities of an institution such as ESA which is heavily engaged in technological programmes.

The International Astronautical Federation

*R. Gibson**

Is the International Astronautical Federation (IAF) just a respectable annual excuse to spend a week with the boys at the firm's expense, or has it a more serious function and utility?

Before replying to this question, a little background is necessary.

The IAF was founded in September 1950 at a meeting of astronautical societies from Argentina, Austria, Denmark, France, Germany, Great Britain, Spain and Sweden. Twenty-nine years later, the Federation has 58 members from 36 countries, and a few more are in the pipeline.

Since 1950, the IAF has organised 29 annual congresses. They attract between 500 and 1000 participants, according to accessibility of the location, and it is not necessary to be affiliated to a member society in order to take part. The Congresses regularly have some 40 sessions (often five running in parallel at any given moment), and about 300 presentations can be expected. Topics cover everything from satellite communications, through bioastronautics to youth rocket experiments. Moreover, the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL) – with both of which the IAF is closely associated – organise symposia in conjunction with the Congress. The week of the congress also has to accommodate the IAF's General Assembly and meetings of its Executive Bureau. Add to these the usual social activities and you have a crowded, not to say chaotic, week.

It is difficult to assess the value of such a week's activity, but certain features can be identified. Firstly, there is an astounding variety in the disciplines of the congress participants: engineers, scientists, lawyers, historians and even the occasional administrator. Secondly, there is a similar diversity in the nationalities: the Soviet Union and the countries of Eastern Europe are just as well represented as the USA, Europe and Japan. There is some hope that in 1979 the People's Republic of China will send a delegation.

These two characteristics are nothing more than the realisation of two of the main objectives of the Federation, set nearly thirty years ago by the Provisional Committee chaired by Dr. Eugen Sänger (D) and which contained such space pioneers as the much-missed Val Cleaver (UK) and, from Argentina, Ing. Tabaneva. They aimed to create an international, multidisciplinary and nongovernmental organisation which would provide a neutral meeting point where the World's space specialists could amicably discuss their work and their problems. Judged against this criterion, the IAF has and is a real success, for it is one of the few events for which travel funds and permission are forthcoming in even the most restrictive countries. Furthermore, many specialists take advantage of the opportunity to visit laboratories or attend other symposia during their trip.

The standard of the papers is admittedly varied. My personal view is that the programme committees have in the past been too lenient in their selection. At the same time, one has to appreciate the desire of the organisers to encourage a wide spectrum of papers, and to avoid the near monopoly which would inevitably follow a rigorous selection procedure. Moreover, the standard of presentation is

** Mr. Gibson Director General of ESA, was elected President of IAF at the 30th IAF Congress in Dubrovnik, September 1978.*

not always high, for some authors lack experience in speaking before such an international audience. The combination of the large numbers of papers which are available and the excellent possibilities that exist for making or renewing contacts, however, makes the IAF Congress very good value – particularly if the congress organisation is up to standard.

It will be no surprise for you to hear that Congress participants include a few for whom the social events are more important than the technical sessions, and others who seem to push their interest in fluid dynamics too far. One thousand representatives of any field of human interest would produce the same result.

The legislation body of the IAF is the General Assembly, held during the congresses, when voting members (not more than one society per country) decide on such things as the admission of new members, the location and theme of the next congress and the election of officers and committee members. The executive arm is provided by the IAF's Bureau, which consists of a President (elected for not more than two successive years), five Vice-Presidents and the past-President. The Presidents of the IAA and IISL, and the IAF's General Counsel are nonvoting members. The Bureau normally meets in April each year to prepare material for submission to the General Assembly, and again during the course of the Congress.

A Congress is organised by a host society, after the General Assembly has accepted its invitation. However, the actual content of the Congress is the responsibility of the International Programme Committee, which is elected annually. It must be remembered that, apart from the two ladies in the secretariat, all the IAF work is done on a voluntary basis, and the post of Chairman of the Programme Committee is a particularly thankless one. The 1979 Congress, which is to be held in Munich from 16 to 22 September, will have 48 technical sessions containing around 400 papers.

Apart from the Programme Committee, the IAF has a number of standing committees which are responsible for pushing work along in their sectors between congresses. As with all voluntary organisations, the level of activity is not uniform, but the most active do an excellent job in arranging specialist meetings and producing reports. Good examples of these technical committees are the Bioastronautics Committee, the Committee on Space Applications and the Space Energy and Power Working Group.

In addition, there are what one might call 'housekeeping' committees, such as the Financing Committee (which grapples with the familiar task of balancing the IAF's minute budget) and the Publications Committee (responsible for arranging preprints and publishing the Proceedings).

Finally, mention should be made of two committees with important and rather special functions:

- the United Nations Liaison Committee, which arranges for the IAF to send observers to the increasingly important meetings of the UN Committee on the Peaceful Uses of Outer Space and its subcommittees, and the provision of the IAF's reports to the UN; and
- the Students Activities Committee, which endeavours to give special attention to students interested in astronautics, for this was one of the most earnest wishes of the founders of the IAF.

The IAF has close relations with a number of governmental and nongovernmental organisations, and perhaps the relationship with COSPAR is of the most practical importance because of the danger of overlap and duplication. My predecessor (M. Marcel Barrère) and I have made a particular effort to achieve a better coordination with COSPAR, and we have had a good response from their past and present Presidents (Prof. C. de Jager and Prof. J. Denisse, respectively). I am personally hopeful that we shall be able in due course to hold COSPAR and IAF Congresses in alternate years, and for the organisation holding the Congress to offer hospitality to the other, for a business meeting or perhaps a small symposium on a subject that deserves not to have to wait for the next Congress. Although the IAF depends on its Congresses for around 50% of its funds, it ought to be possible to find alternative sources for such small amounts. The reduced rhythm of Congresses would in my view be welcomed by serious participants and would help to improve the quality of presentations.

I hope that this short article has explained a little of the IAF's objects and activities. Further information can be obtained from the IAF's Secretariat at 250 rue Saint Jacques, 75005 Paris.

The Systems Engineering Department at ESTEC

H. Stoewer, Head of Systems Engineering Department, ESTEC, Noordwijk, The Netherlands

As space systems become more complex and new advanced technologies emerge, the need to understand the interdependencies and interactions of such new technologies with subsystems and systems and their missions increases. The key to successful application of new technologies and to user-responsive designs for new spacecraft will in the future depend more and more on a proper balancing of performance, cost and schedule parameters with operational needs, and on analyses and trade-offs that transcend interfaces that have been established on the basis of classical subsystem responsibilities. ESTEC's recently created Systems Engineering Department therefore has the task of weighing the relative priorities of all the parameters that contribute to the ultimate success of a mission and pursuing an iterative trade-off process to find the most economic and technically most simple solution to a given operational need.

Origin of the Systems-Engineering Department

The decision to create a Systems Engineering Department (SED) within the Agency's Technical Directorate was stimulated by the recognition that there was an increasing need to complement the Agency's specialised technical resources and assist in their effective application. In terms of organisation, the SED is one of four line departments within the Technical Directorate (Fig. 1), which since 1 August 1978 has combined the former functions of Director ESTEC with the major part of those of the Technical Inspector. The other Departments in this Directorate are:

(i) The Spacecraft Technology Department (with the Attitude and Orbit Control, Spacecraft Power Supplies, and the Structure and Thermal Control Divisions).

(ii) The Payload Technology Department (with the Instrument Technology, Data Handling and Signal Processing, and the Space Communications Divisions).

(iii) The Assurance, Testing and Mathematical Department (with the Product Assurance, Test Services and Mathematical Support Divisions).

The primary function of these three technical departments is one of ensuring that all of the specialised technology and support services needed for the European space programme are developed to sufficient depth and are appropriately applied within the Agency. The role of the Systems Engineering Department can be seen as one of 'horizontal integration' for a variety of clearly defined tasks, working hand in hand with the other three departments.

What is SED supposed to accomplish?

The SED is charged specifically with:

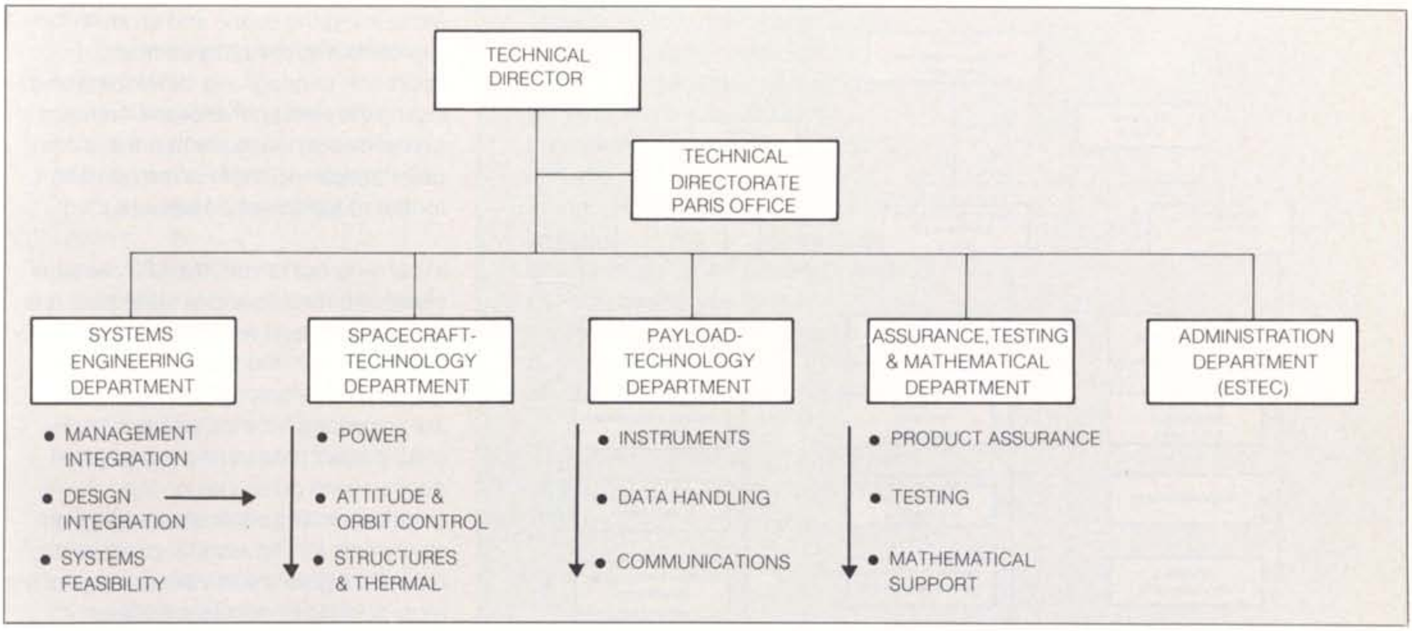
- promoting the standardisation of selected aspects of the technical work of the Agency;
- ensuring additional emphasis on early programme phases in the form of more comprehensive technical support to mission feasibility and definition studies;
- providing occasional support to the execution of the Agency's projects at system level (as opposed to support with subsystems and specialised technologies);
- ensuring long-term, goal-oriented, planning within the Agency's technological research programme, and
- providing an independent source of advice to the Technical Director and the Director General on the technical status of projects.

What tasks will SED undertake?

The Systems Engineering Department will provide support to projects, as and when required, largely in the form of special problem-solving or similar efforts. It is responsible for formulating and planning the Technological Research Programme(s), has the lead responsibility for the standardisation of the Agency's technical processes and methods at system level, and has certain technical overseeing functions in the context of project, procurement and in-orbit performance reviews. SED will also serve

Figure 1 – The structure of the Technical Directorate

Figure 2 – Distribution of tasks within the Technical Directorate



as the focal point for all system studies carried out within the Technical Directorate.

The distribution of tasks within the Technical Directorate is summarised in Figure 2.

How is SED organised?
The SED is organised into three specific offices/divisions (Fig. 3):

- the Management Integration Office (SED/MO), which has four specific tasks assigned to it, each of which has a bearing on most of ESA's projects and technical systems-level work;
- the Design Integration and Interfaces Office (SED/DO), which will be responsible for design integration and interface allocations and related engineering trade-offs in a number of key technical areas, and
- the System Design and Feasibility Office (SED/SO), which will deal with the early phases of new programmes.

The end of 1979 staff complement for the Department is 19, and ideally these staff should represent a cross-section of capabilities from the Agency's programmes and technologies.

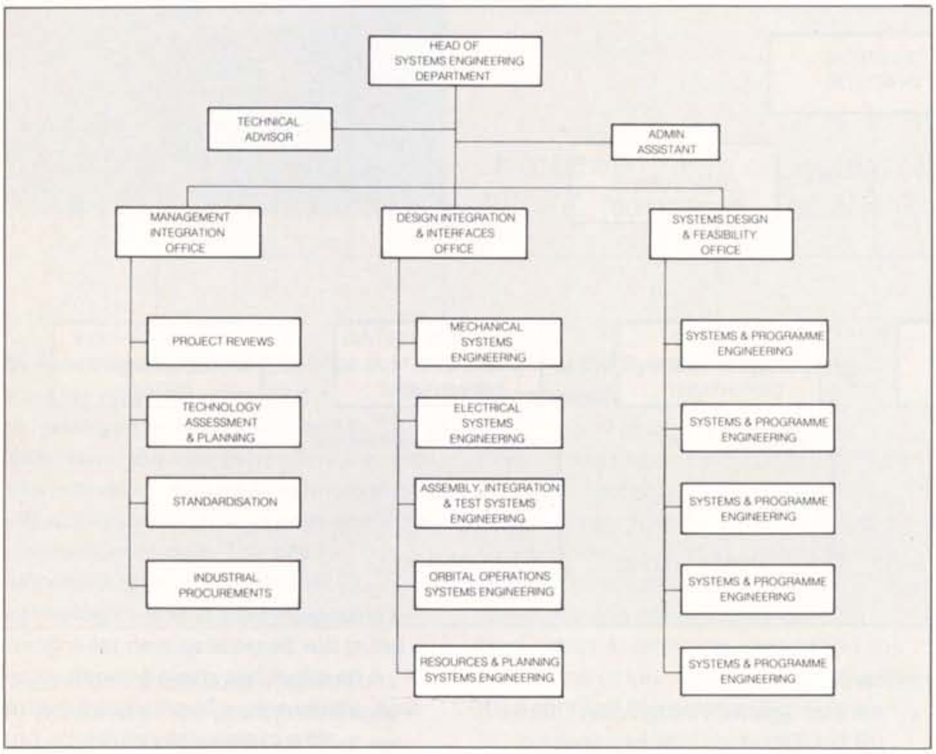
How will SED operate?
A typical systems-engineering analysis starts with the understanding of what, why and how a certain phenomenon (in space) must be measured and then proceeds to the question of how the mission could be shaped to accomplish this. It includes an analysis of, for example, candidate satellite sensors, data-acquisition and formatting modes, data processors, the interaction of this data flow with data from other sensors, the formatting and transmission of this data to the ground, the ground processing of that data for the user, etc. etc. Systems engineering in this context means performing engineering trade-offs to arrive at the technically most simple and most cost effective systems

Technical Directorate's Basic Responsibilities	Systems Engineering Department	Spacecraft-Technology Department	Payload-Technology Department	Assurance, Testing & Mathem. Department
1. Support to Projects	x	(x)	(x)	(x)
2. Technology Research Programme:				
Formulation/Planning	(x)	x	x	x
Execution	–	(x)	(x)	x
3. Standardisation/Normalisation:				
System Level	(x)	x	x	x
Specialities	–	(x)	(x)	(x)
4. Technical Overseeing:				
System Level	(x)	x	x	x
Specialities	–	(x)	(x)	(x)
5. System Studies	(x)	x	x	x

An x in a field indicates a normal responsibility, a dash none at all.
A circle indicates a strong emphasis or a leading role vis-à-vis the other Departments.

Figure 3 – Organigram of the Systems-Engineering Department

Figure 4 – Objectives and tasks of the Systems-Engineering Department



(embracing the space and ground segments and the programmatic approach to designing, developing and testing the relevant hardware, firmware and software) to ensure that the ultimate users obtain their data in the required format at the lowest possible cost.

In carrying out its role, the SED will work closely with the Agency's other technical departments and will collaborate in many of its tasks with the project teams. To quote two examples, the Head of the SED will occasionally be called upon to co-chair project reviews and to elaborate Agency-wide guidelines on the composition of specifications and work statements for requests for proposals to industry. Figure 4 summarises some of the more specific objectives and tasks foreseen for the SED.

TECHNOLOGY PROGRAMME FORMULATION

OBJECTIVES:
1) ENSURE APPLICATION OF LONG TERM PLANNING FOR PREPARING THE TECHNOLOGICAL INFRASTRUCTURE NEEDED FOR FUTURE PROGRAMMES.
2) OBTAIN GOAL ORIENTED STREAMLINING OF THE TECHNOLOGY PROCESS

TASKS:
1) IDENTIFY (TOGETHER WITH PROGRAMMES AND D/PFP) LONG TERM TECHNOLOGY NEEDS FOR FUTURE PROGRAMMES
2) IDENTIFY IMPORTANT FUTURE TECHNOLOGY TRENDS AND NEW TECHNOLOGIES
3) ESTABLISH GOALS AND PRIORITIES FOR THE AGENCY'S TECHNOLOGY PROGRAMME ELEMENTS
4) AMALGAMATE ABOVE INTO AN INTEGRATED MEDIUM TERM PROGRAMME PLAN

(EQUIPMENT) STANDARDISATION

OBJECTIVES:
1) ENSURE COST REDUCTION THROUGH SUCCESSIVE STANDARDISATION OF THE AGENCY'S TECHNICAL PROCESSES, ESPECIALLY AS REGARDS RE-USE OF EQUIPMENT AND APPLICATION OF DESIGN STANDARDS

TASKS:
(1) COORDINATE THE ESTABLISHMENT OF DESIGN REQUIREMENTS STANDARDS
2) COORDINATE THE DERIVATION OF STANDARD INTERFACE AND PERFORMANCE SPECIFICATIONS FOR EQUIPMENTS AND SUBSYSTEMS
3) PROMOTE AND CONTROL THE RE-USE OF QUALIFIED EQUIPMENT FOR NEW PROJECTS
4) ENSURE THE ESTABLISHMENT AND APPLICATION OF STANDARDS IN OTHER TECHNICAL AREAS

PROJECT REVIEWS

OBJECTIVES:
1) ASSURE INDEPENDENT ASSESSMENT OF THE TECHNICAL STATUS OF PROJECTS
2) RATIONALISE THE AGENCY PROCESS FOR PROJECT REVIEWS

TASKS:
1) PARTICIPATE IN ALL MAJOR PROJECT REVIEWS OF THE AGENCY'S PROGRAMMES AND ASSURE IDENTIFICATION AND ASSESSMENT OF ALL IMPORTANT TECHNICAL ASPECTS
2) DERIVE AND PUBLISH AS AGENCY GUIDELINE A STANDARD APPROACH TO PROJECT REVIEWS DURING THE LIFE CYCLE OF ESA PROJECTS
3) COLLECT EXPERIENCES AND ELABORATE AN AGENCY GUIDELINE ON THE MOST EFFICIENT PROCEDURES FOR CONDUCTING SPECIFIC PROJECT REVIEWS

Conclusion

In short, the new Systems Engineering Department will:

- conduct engineering trade-offs across the classical subsystem and technology interfaces in seeking low-cost, user-responsive designs and systems;
- interact in a matrix fashion (horizontal integration) with the other technical departments;
- represent an engineering capability at system level to complement the Technical Directorate's existing technological and subsystems expertise;
- actively pursue standardisation for the Agency's projects;
- act as the focal point for the formulation and planning of technological research activities;
- contribute towards the implementation of uniform professional standards for systems level work in the Agency's projects;
- provide independent advice to the Technical Director and Director General on the status of the Agency's projects and the quality of the procurements to be released to industry;
- contribute towards placing more emphasis on the early phases of programmes, i.e. on the depth and comprehensiveness of the engineering work being carried out by ESA and industry prior to 'go-ahead' decisions for new projects.

The Department is now being formed and it is hoped that it will assume most of its functions by autumn of this year.

PROCUREMENT REVIEWS

OBJECTIVES:

1) ASSURE INDEPENDENT ASSESSMENT OF THE TECHNICAL ASPECTS OF PROCUREMENTS
2) NORMALISE THE AGENCY APPROACH TO INDUSTRIAL PROCUREMENTS (TECHNICAL)

TASKS:

1) REVIEW THE RELEVANT RFP'S FOR TECHNICAL ADEQUACY AND PROFESSIONAL STANDARDS
2) ESTABLISH AN AGENCY GUIDELINE ON TECHNICAL PROCUREMENTS, INCLUDING FORMATS AND TYPE OF CONTENTS FOR SPECIFICATIONS, STATEMENTS OF WORK AND APPLICABLE TECHNICAL STANDARDS

DISCIPLINE ORIENTED SYSTEM ENGINEERING (ELECTRICAL, TECHNICAL, AIT, OPERATIONS, RESOURCES)

OBJECTIVES:

1) ENSURE END TO END ENGINEERING, DESIGN INTEGRATION, AND INTERFACE ALLOCATION FOR THE TECHNICAL WORK OF THE TECHNICAL DIRECTORATE
2) ENSURE APPROPRIATE REPRESENTATION OF ALL TECHNICAL DISCIPLINES TOWARD PROJECT AND PROCUREMENT REVIEWS, STUDIES OF FUTURE PROJECTS, TECHNOLOGY PLANS AND STANDARDISATION

TASKS:

1) ELABORATE AND SUPPORT TECHNICAL TASKS FOR THE TECHNOLOGY PROGRAMME, THE STUDIES AND OTHER SED TASKS FROM THE SYSTEMS ENGINEERING VIEWPOINT
2) DERIVE STANDARDS AND GUIDELINES IN THE VARIOUS FIELDS AS APPLICABLE, E.G.: AIT MODEL PHILOSOPHY, VERIFICATION BY ANALYSIS VERSUS TEST APPROACH
3) INITIATE AND SUPPORT THE IN-ORBIT PERFORMANCE EVALUATIONS OF OPERATIONAL ESA SPACECRAFT AND CONTRIBUTE TO THE DATA DISSEMINATION AND APPLICATION TO ONGOING AND FUTURE PROJECTS

SYSTEM DESIGN AND FEASIBILITY STUDIES

OBJECTIVES:

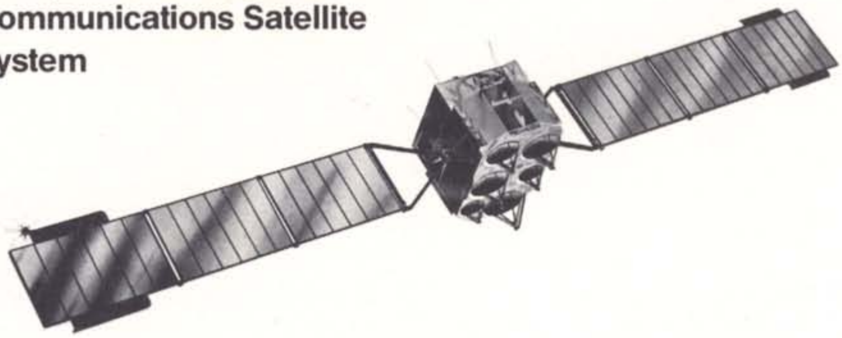
1) ENSURE THE COORDINATED APPLICATION OF ALL TECHNICAL DISCIPLINES AND TECHNOLOGICAL SPECIALITIES TOWARD PROPERLY SUPPORTING THE PREPARATION OF FUTURE PROGRAMMES
2) ENSURE COMPREHENSIVE AND IN-DEPTH TECHNICAL WORK PRIOR TO ENTERING MAJOR INDUSTRIAL COMMITMENTS
3) ENSURE FEEDBACK FROM THE KNOWLEDGE GAINED IN FUTURE STUDIES FOR THE TECHNOLOGY RESEARCH PROGRAMMES AND THE BASIC TOOLS AND INFRASTRUCTURE OF THE TECHNICAL DIRECTORATE

TASKS:

1) PROVIDE SYSTEMS ENGINEERING AND SPECIALIST SUPPORT TO FUTURE PROGRAMMES (PRE-PHASE A, PHASES A AND B)
2) CONDUCT INTERDIRECTORATE AND SPECIAL STUDIES ENTRUSTED TO THE TECHNICAL DIRECTORATE
3) SUPPORT THE PREPARATION OF THE TRP'S, PROJECT- AND PROCUREMENT REVIEWS AND SYSTEMS-ENGINEERING ANALYSES

In Brief

Europe's Own Regional Communications Satellite System



Under the terms of an Arrangement between the European Space Agency and Interim EUTELSAT, an organisation representing the Telecommunications Administrations of 17 countries, Europe will have its own regional communications satellite system, known as ECS, to be integrated in the course of the 1980s into the long-distance intra-European telephony, telex, television and data transmission services network. The Arrangement was signed in Paris on 15 May by Roy Gibson, Director General of ESA, and on behalf of Interim EUTELSAT by Gérard Théry, Director General of the French Telecommunications Administration.

ESA will provide the space segment of the communications system for a period of 10 years (a total of five satellites). Interim EUTELSAT, which will become the owner of the satellites as soon as they are on station in working order, will assume exclusive responsibility for management of the system.

The earth stations that will have access to the space segment will be built and put into service by the Telecommunications Administrations.

Mr. Roy Gibson (left) and Mr. Gérard Théry (right) following the signing of the ECS Arrangement.

It is intended that two ECS satellites will be in geosynchronous orbit at any given time, one being in operation and the other acting as a back-up. They will be capable of carrying up to 12 000 telephone circuits, plus two television channels intended for the Eurovision service of the European Broadcasting Union. The first ECS satellite is to be placed in orbit by Europe's Ariane launcher at the end of 1981, and the second some 10 months later.

The contracts for the first two satellites have already been concluded with the British Aerospace Dynamics Group as leader of the MESH Consortium, which consists of 14 industrial firms from 10 European countries. The contract for the supply of the other three satellites is still under discussion.

ESA at Le Bourget

The ESA pavilion at this year's Le Bourget Air Show in June was given over in large part to the promotion of Europe's Ariane launcher, the first test flight of which is planned to take place from the Ariane launch site in Kourou, French Guiana, in early December. Special emphasis was lent to the broad European co-operation that has characterised the vehicle's development.

A hard mock-up of Spacelab, the first flight model of which will provide European astronauts with the opportunity to work in a laboratory-like environment in space for the first time in 1981, was also on display.

Full scale mock-ups of the Agency's OTS and future ECS telecommunications satellites, and of Meteosat, Europe's first operational meteorological spacecraft, were also on display. Life-size mock-ups of Geos and Exosat and scale models of IUE, ISEE-2 and Cos-B completed the satellite contribution.

Mr Valéry Giscard d'Estaing, President of the French Republic, and Mr André Giraud, the Minister for Industry, were among the early visitors to ESA's pavilion on the opening day of the show.

Mr Valéry Giscard d'Estaing and Mr André Giraud being briefed on the Spacelab programme by ESA's Director General, Mr Roy Gibson. ►

The full-scale mock-up of the Ariane launcher beside the entrance to the ESA pavilion. ►►

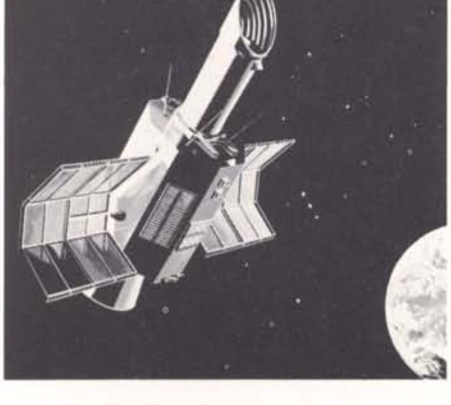
The Scientific Satellite IUE Observes a Supernova

Early in May the IUE satellite was used by a team of European astronomers to observe a supernova first discovered by an American amateur astronomer on 19 April, and located in the Messier galaxy about 100 million light years from Earth. It is the brightest supernova to be observed from Earth since 1971.

The observations with IUE were conducted from the Agency's tracking station at Villafranca (Madrid). Preliminary results from the data analysis made by Dr Nino Panagia of the Bologna (Italy) Radio Astronomy Laboratory, show absorption of the ultraviolet emission of the supernova characteristic of the interstellar gas in our galaxy. In addition, the data show rapid changes in the supernova as the disrupted star expands and cools. At the same time, the expansion itself is giving rise to modifications in the supernova's spectral features.

The flexibility of operation that is such a feature of the IUE mission was a key factor in allowing the supernova to be observed so promptly.

The IUE spacecraft



Prof. Carl Sagan during his Voyager presentation at ESTEC

Voyager-I Results Presented at ESTEC

The well-known American astronomer Prof. Carl Sagan, of Cornell University, presented a summary of the preliminary results from the Voyager-I spacecraft's exploration of Jupiter and its moons to ESA staff on 9 May. Prof. Sagan, visiting ESTEC as the guest of ESA's Space Science Department, was in Europe in connection with the production of a thirteen-part series entitled 'Cosmos' to be completed in 1980, and devoted to presenting the wonders and mysteries of space exploration and astronomy to television audiences throughout the world.

Nobel Prizewinner Visits ESTEC

Professor Hannes Alfvén, renowned Swedish scientist and Nobel prizewinner in 1970, visited ESTEC in May, primarily for discussions with the staff of ESA's Space Science Department. In the course of his visit, Prof. Alfvén gave a presentation on 'Plasma Phenomena in the Magnetosphere and Heliosphere', and also made a tour of the ESTEC facilities.

A month later, in June, Prof. Alfvén participated in the Sydney Chapman Conference 'Magnetospheric Boundary Layers' in Alpbach, Austria, organised jointly this year by Max-Planck-Institute (MPI Garching, Germany), the Austrian Solar and Space Agency (ASSA, Vienna) and ESA. There Prof. Alfvén delivered a further paper on his electric-current model of the Earth's magnetosphere.

Prof. Alfvén in discussion with Mr H L Westin of ESTEC's Test Services Division during his visit to the Centre's test facilities. ►

Prof. Alfvén pictured in the course of his Alpbach presentation.

COSPAR Resolutions and Recommendations

The XXII meeting of COSPAR, the Committee on Space Research established by the International Council of Scientific Unions, was held in Bangalore, India this year, from 29 May to 9 June.

The meeting was opened by the Hon. Mararjii Desai, Prime Minister of India, who is also the Minister of Space.

Four specialised Symposia and a Workshop constituted the major part of this year's programme:

- COSPAR/UN/ITU/COSTED Vikram Sarabhai Symposium on Space and Development
- COSPAR/IAU/IUPAP Symposium on Non-Solar Gamma-Rays
- COSPAR/IAGA (IUGG)/IAMAP (IUGG)/URSI Symposium on Low-Latitude Aeronomical Processes
- COSPAR/ICSU/IAHS/COWAR/COSTED/UN/UNESCO/WMO Symposium on the Contribution of Space Observations to Water Resources Studies and the Management of these Resources
- COSPAR/IGCP (IUGS/UNESCO)/GSI/ISRO/UN Workshop on Remote Sensing and Mineral Exploration.

In addition there were a number of Open Meetings of COSPAR Working Groups and Panels, and meetings of the COSPAR Bureau and Executive. The following is a brief report drawn up by the COSPAR Secretariat on the Resolutions and Recommendations adopted by COSPAR's Executive Council and the XXII Plenary Meeting:

Decision No 1/79
proposed by Interdisciplinary Scientific Commission D.

Recognising the considerable experimental effort that has been expended in many countries in order to make observations during the International Magnetospheric Study (IMS), and *noting* the difficulties experienced in certain countries in obtaining funds for the data analysis of experimental data, COSPAR *strongly recommends* that funding agencies provide sufficient resources for carrying out efficient and rapid data analysis and physical interpretation of IMS data to realise the scientific goals of this international programme, and further *recommends* that Coordination Data Analysis Workshops as demonstrated by the IMS Satellite Situation Center in December 1978, be supported in the IMS Data Analysis Phase 1980–85.

Decision No 2/79
proposed by the Panel on Potentially Environmentally Detrimental Activities in Space.

Considering that the increase of satellite weight and size increases the danger of unwanted effects during atmosphere re-entry, eg localised atmospheric pollution by burn out or damage to human property or even lives by re-entering debris, COSPAR *urges* the launching agencies to be cognisant of these effects and to make appropriate provisions to have such debris impact in areas where no damage to human activity is expected.

Decision No 3/79
proposed by the Advisory Panel on Space Research and Developing Countries.

COSPAR, *considering* the importance of encouraging in developing countries the growth of technologies relevant to the field of space sciences, and *noting* the proposal of the Workshop held at Ooticamund, India last April, *recommends* to the concerned national institutions and international organisations to take the necessary actions with appropriate authorities to support the proposal to establish an international institute for space studies and electronics and to erect a giant radio telescope at an equatorial location, and *further recommends* that early attention be given by the participating parties to the problem of training and building up an adequate number of scientific and technical personnel to adequately staff the facilities.

Decision No 4/79
proposed by Interdisciplinary Scientific Commission C.

Noting the approval by ICSU of the Middle Atmosphere Program (MAP) which requires extensive and detailed sounding of the stratosphere and mesosphere for the preparation of the necessary high altitude maps of the region, and *noting* the indispensable role played by the world-wide meteorological rocket networks, COSPAR *views* with concern the proposed reduction in the US Meteorological Rocket Network from 14 to 6 launching sites, and *urges* the US Academy of Sciences to bring to the attention of the relevant US agencies the need to maintain the present or preferably increase the frequency of meteorological rocket soundings, at least until the completion of the MAP at the end of 1985.

New ESA Brochure on Biology and Medicine in Space

This publication constitutes an 'invitation to biological, medical and behavioural investigators in Europe to participate in the planning and execution of experiments on board ESA's space laboratory (Spacelab) of the 1980s'.

After an introductory chapter on biology and medicine in space, Spacelab and areas of research opportunity, the other topics covered are:

- Human Physiology
- Cell and Developmental Biology
- Radiobiology
- Exobiology
- Bioengineering

with two annexes on:

- ESA Organisation – Submission of Proposals and Review Process
- Spacelab Environmental Control and Life Support Subsystem.

'Biology amd Medicine in Space' (Ed. Prof. H. Bjurstedt) is available as ESA BR-01, from ESA Scientific & Technical Publications Branch. (For availability, see page 75; 56 pages, A4 – Price 50 FF).

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table inside the back cover and using the Order Form on Page 75.

ESA Journal

The following papers were published in Vol. 3, No. 2:

AN ELECTRIC-CURRENT MODEL OF THE MAGNETOSPHERE
ALFVEN H

INVESTIGATION OF ELECTROSTATIC DISCHARGE PHENOMENA ON THE METEOSAT SPACECRAFT
HOGE D/LEVERINGTON D

IN-ORBIT CALIBRATION OF METEOSAT AND ITS POSSIBLE EXTENSION TO OTHER APPLICATIONS AND FIELDS
ANTIKIDIS J P/REYNOLDS M

PLASMA-PHYSICS INVESTIGATIONS ON THE FIRST SPACELAB PAYLOAD – 'PICPAB'
BEGHIN C

SOLVING GYROSCOPIC EIGENVALUE PROBLEMS WITH A REAL SYMMETRIC MATRIX OF THE SAME DIMENSION
BOLAND PH/JANSSENS F

OPTIMISATION DE LA PHASE INTEGRATION ET ESSAIS DES SATELLITES D'APPLICATION
VIDONI N

Special Pubblications

ESA SP-142 MATERIAL SCIENCES IN SPACE. PROCEEDINGS OF THIRD EUROPEAN SYMPOSIUM, SPONSORED BY ESA, CNES AND CEA, GRENOBLE, FRANCE, 24-27 APRIL 1979
GUYENNE T D (ED)
PRICE CODE C3

ESA SP-148 MAGNETOSPHERIC BOUNDARY LAYERS – A SYDNEY CHAPMAN CONFERENCE. PROCEEDINGS OF A CONFERENCE CO-SPONSORED BY THE AMERICAN GEOPHYSICAL UNION, THE EUROPEAN GEOPHYSICAL SOCIETY, THE EUROPEAN SPACE AGENCY, THE AUSTRIAN SOLAR AND SPACE AGENCY AND MAX-PLANCK-INSTITUT FUR EXTRATERRESTRISCHE PHYSIK, ALPBACH, AUSTRIA, 11-15 JUNE 1979 (AUGUST 1979)
BATTRICK B (ED)
PRICE CODE C3

ESA SP-149 EARTHQUAKE PREDICTION RESEARCH. PROCEEDINGS OF A SEMINAR ORGANISED JOINTLY BY THE EUROPEAN SPACE AGENCY AND THE PARLIAMENTARY ASSEMBLY OF THE COUNCIL OF EUROPE, STRASBOURG, 5-7 MARCH 1979 (MARCH 1979)
GUYENNE T D (ED)
PRICE CODE C1

ESA SP-1016 CATALOGUE OF ESA PUBLICATIONS IN 1977 AND 1978 (JULY 1979)
BATTRICK B (COMPILER)
PRICE: NO CHARGE

Scientific and Technical Reports

ESA STR-203 SOLAR MEV PROTONS RECORDED WITH EXPERIMENT S99 ON BOARD ESRO-IV IN 1973 (APRIL 1979)
VAN BEEK H F/ET AL
PRICE CODE C1

Scientific and Technical Memoranda

ESA STM-211 ICROSCOPIC INVESTIGATION OF ELECTROSTATIC DISCHARGE PHENOMENA ON NONCONDUCTIVE OPTICAL SOLAR REFLECTORS WITH A CONDUCTIVE ADHESIVE (MARCH 1979)
BOSMA S J
PRICE CODE C1

Technical Translations

TT-483 OPTICAL SURVEY OF THE DFVLR RADIO INTERFEROMETER
REISER R/WEPPNER R, DFVLR, GERMANY

TT-497 SPECTRAL PROBLEMS IN VIBRATION MECHANICS
BOUJOT J, ONERA, FRANCE

TT-489 CONTRIBUTIONS ON TRANSPORT PHENOMENA IN FLUID MECHANICS AND RELATED TOPICS
HAASE W, ED, DFVLR, GERMANY

TT-515 ENERGY LOSSES IN HIGH-ENERGY ROCKET ENGINES WITH THRUST VARIATION
STERNFELD H, DFVLR, GERMANY

TT-519 INVESTIGATION OF SELF-ORGANIZING CONTROL LAWS AND POSSIBILITIES FOR THEIR REALISATION
SCHNITTGER H-J, DFVLR, GERMANY

TT-520 MEASURING AND EVALUATION PROGRAMS OF HOT WIRE SIGNALS USING THE TGM 3 TURBULENCE LEVEL METER DEVELOPED BY THE DFVLR
FROEBEL E/VAGT J-D, DFVLR, GERMANY

TT-521 EFFECTS OF THE ENVIRONMENT ON THE ELASTIC-PLASTIC PROPERTIES OF ADHESIVES IN METAL BONDED JOINTS
ALTHOF WIKLINGER G/NEUMANN G/ SCHLOTAUER J, DFVLR, GERMANY

TT-522 LA RECHERCHE AEROSPATIALE – BIMONTHLY BULLETIN, 1978-3,
ONERA, FRANCE

TT-523 FLIGHT TESTING OF THE BUFFETING BEHAVIOUR OF COMBAT AIRCRAFT
REDEKER G, DFVLR, GERMANY

TT-524 ON THE PROBABILITY OF CRACK PROPAGATION IN A UNIDIRECTIONAL COMPOSITE WITH A SINGLE FIBER BREAKAGE
STELLBRINK K, DFVLR, GERMANY

TT-527 THE SUPERPOSITION OF TWO-DIMENSIONAL ERROR FIELD AND ITS INFLUENCE ON FLIGHT SAFETY OF AIR TRAFFIC
WEBER O, DFVLR, GERMANY

TT-528 DEVELOPMENT OF THE LASER TWO-FOCUS METHOD FOR NON-INTRUSIVE MEASUREMENT OF FLOW VECTORS, PARTICULARLY IN TURBOMACHINES
SCHODL R, DFVLR, GERMANY

TT-529 A SIMPLE PROCEDURE FOR SIMULATION OF HOMOGENEOUS MARKOV CHAINS ON A COMPUTER
DAHLEM T, DFVLR, GERMANY

TT-549 PSEUDO-UNSTEADY METHODS FOR TRANSONIC FLOW CALCULATIONS
VIVIAND H/VEUILLOT J-P, ONERA, FRANCE

Contractor Reports

ESA CR(X)-1123 AEROSAT COORDINATED PROGRAMME – DEVELOPMENT OF AVIONICS/PHASE 0 FINAL REPORT; VOLUME I: OUTLINE OF CONCLUSIONS; VOLUME II: DETAILED REPORT (FEB 1978)
MBB, GERMANY

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