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EUROPEAN SPACE AGENCY
AGENCE SPATIALE EUROPEENNE

8–10, rue Mario Nikis
75738 Paris Cedex 15, France

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 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 and Meteorological Satellite Programmes; the Director of Communication Satellite Programmes; the Director of the Spacelab Programme; the Technical Inspector; the Director of ESTEC and the Director of ESOC.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

EUROPEAN SPACE RESEARCH INSTITUTE (ESRIN), Frascati, Italy.

Chairman of the Council for 1976: Dr. W. Finke (Germany).

Director General: Mr. R. Gibson.

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'ASE 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:

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

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

Le Directoire de l'Agence est composé du Directeur général, du Directeur des Programmes futurs et des Plans, du Directeur de l'Administration, du Directeur des Programmes de satellites scientifiques et météorologique, du Directeur des Programmes de satellites de communications, du Directeur du Programme Spacelab, de l'Inspecteur technique, du Directeur de l'ESTEC et du Directeur de l'ESOC.

Le SIEGE de l'ASE est à Paris.

Les principaux Etablissements de l'ASE sont:

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

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

L'INSTITUT EUROPEEN DE RECHERCHES SPATIALES (ESRIN), Frascati, Italie.

Président du Conseil pour 1976: Dr. W. Finke (Allemagne).

Directeur général: M. R. Gibson.

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European Space Operations Centre (ESOC), Darmstadt, Germany

Introduction

This issue of the ESA Bulletin will introduce the reader to the facilities and techniques employed in the field of satellite operations by the European Space Agency's Space Operations Centre (ESOC) at Darmstadt. In addition, in order to leave the reader with a more comprehensive picture of European capacity in this field, ESA Member States were invited to provide contributions describing the comparable facilities established by them for their national space programmes; three such articles were provided and are included.

Introducing this issue of the Bulletin provides a rare opportunity to review briefly the nine years that have elapsed since the establishment of the European Space Operations Centre at Darmstadt in Germany. Operations started at the Centre on 17 May 1968 with the launch of ESRO-II, the first satellite in the ESRO programme, to be followed in the same year by the launches of ESRO-IA and HEOS-1. The excitement of this first year with its three launches was to be repeated, after a single launch (ESRO-IB) in 1969, in 1972 with the launching in quick succession of the HEOS-2, TD-1 and ESRO-IV satellites. In 1974, the Centre supported the launch and operation of the Dutch Astronomical Satellite (ANS), while 1975 saw the launch of ESA's COS-B satellite, which is still being operated.

This operational programme comprising eight ESRO/ESA satellites and one satellite from a national programme has allowed ESOC to accumulate 18 'satellite years' of operational experience since 1968.

A basic network of VHF ground stations installed between 1965 and 1967 has been utilised throughout the programme, supplemented as occasion demanded by the Norwegian station at Tromsø (used until the decay of ESRO-IV in 1974) and the interferometers operated by CNES at Pretoria (South Africa) and Kourou (French Guyana).

The trend away from low-altitude polar-orbiting spacecraft made it possible in 1974 to close the Spitzbergen and Falkland Islands stations, two of the original four ESRO VHF stations, while the Redu and Fairbanks stations are still in use for COS-B.

Satellite operations were conducted from 1968 to 1971

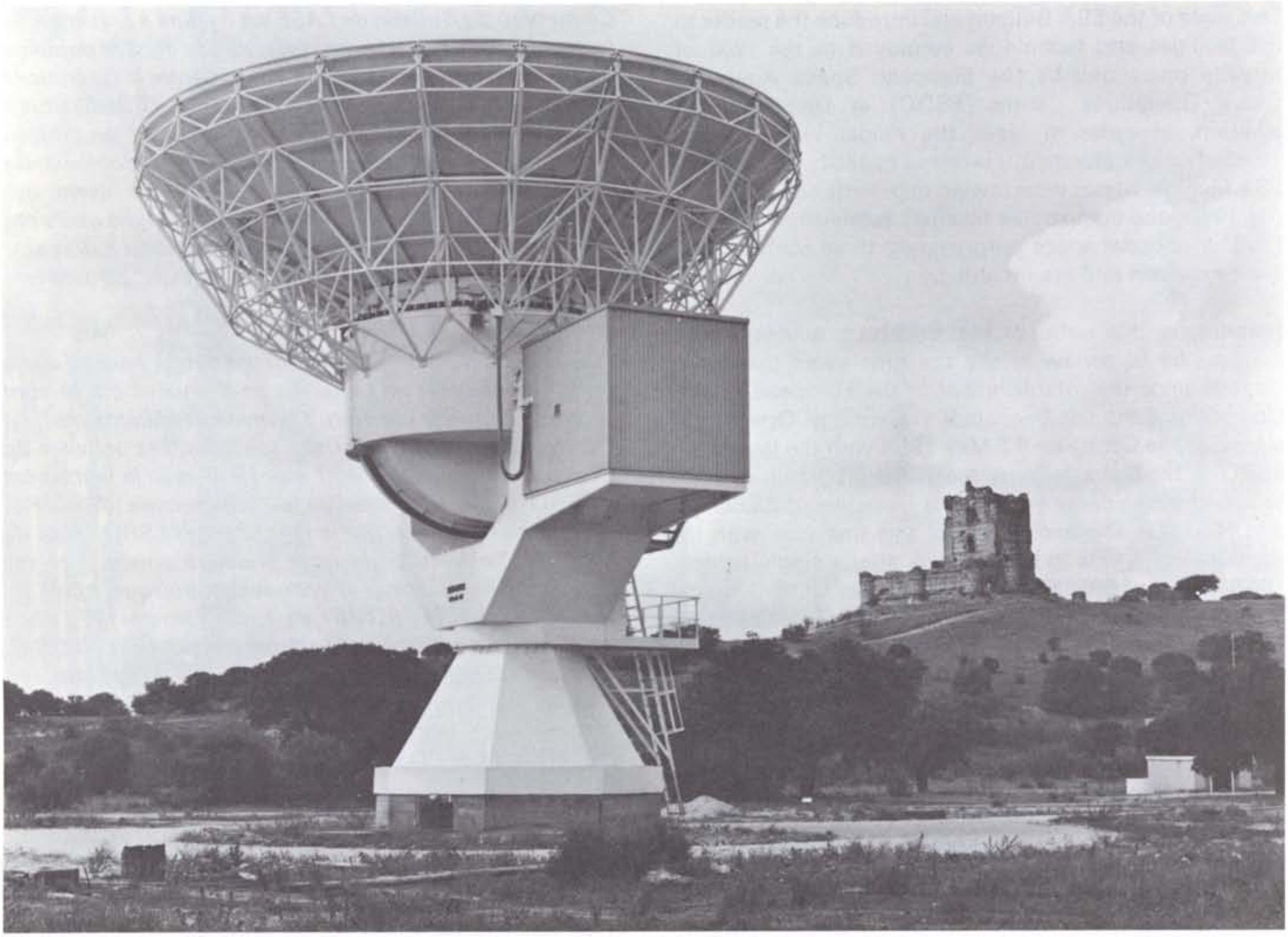
Ce numéro du Bulletin de l'ASE est destiné à présenter au lecteur les moyens et techniques utilisés dans le domaine de l'exploitation des satellites par le Centre d'Opérations spatiales de l'Agence spatiale européenne, l'ESOC, situé à Darmstadt. En outre, pour que le lecteur ait un tableau plus complet du potentiel européen dans ce domaine, les Etats membres de l'Agence ont été invités à fournir des articles décrivant les installations du même type qu'ils ont mises sur pied pour leurs programmes spatiaux nationaux; nous avons reçu trois de ces articles que l'on trouvera dans ces pages.

Présenter ce numéro du Bulletin me donne l'occasion de passer rapidement en revue les neuf années qui se sont écoulées depuis la création, à Darmstadt (Allemagne), du Centre européen d'Opérations spatiales. Les activités du Centre ont commencé le 17 mai 1968 avec le lancement d'ESRO-II, premier satellite du programme du CERS, suivi la même année par le lancement d'ESRO-IA et de HEOS-1. La fébrilité de cette première année avec ses trois lancements devait se renouveler, puisque, après un seul lancement (ESRO-IB) en 1969, l'année 1972 vit le lancement à des dates rapprochées des satellites HEOS-2, TD-1 et ESRO-IV. En 1974, le Centre a apporté son soutien au lancement et à l'exploitation du satellite astronomique néerlandais ANS, tandis qu'en 1975 fut lancé le satellite COS-B de l'ASE, qui fonctionne toujours.

Ce programme opérationnel de huit satellites CERS/ASE et d'un satellite national a permis à l'ESOC d'accumuler 18 'années-satellites' d'opérations en orbite depuis 1968.

Tout au long de ce programme on a utilisé un réseau de stations sol VHF installé entre 1965 et 1967, occasionnellement renforcé par la station norvégienne de Tromsø (utilisée jusqu'à la rentrée dans l'atmosphère d'ESRO-IV en 1974) et par les interféromètres exploités par le CNES à Prétoria (Afrique du Sud) et à Kourou (Guyane française).

L'orientation vers des satellites parcourant des orbites autres que polaires à basse altitude a permis de fermer, en 1974, les stations du Spitzberg et des îles Falkland, deux des quatre premières stations VHF du CERS, alors que les stations de Redu et de Fairbanks sont toujours utilisées pour COS-B.



ESA's Villafranca del Castillo ground station.

from a control centre housed happily but uncomfortably in converted office accommodation on the ESOC site. Conditions were improved in 1972 with the completion of a building specifically designed to house the spacecraft control, communications and network control activities.

Computer support for operations was provided at ESOC, from 1967 onwards, by a US-manufactured configuration comprising two small process control computers for 'real time' tasks, backed by a medium-sized general-purpose machine.

Les opérations de satellites ont été menées, de 1968 à 1971, à partir d'un centre de contrôle installé de façon sympathique mais inconfortable dans d'anciens bureaux transformés, sur le site de l'ESOC. Ces conditions s'améliorèrent, en 1972, avec l'achèvement d'un bâtiment spécialement destiné aux activités de contrôle des véhicules spatiaux, de communications et de contrôle de réseau.

Le soutien calcul aux opérations fut assuré à l'ESOC, à partir de 1967, par un ensemble d'équipements fabriqués

Expansion of the ESRO/ESA programmes to include geostationary scientific and applications satellites presented a new technical and operational challenge to ESOC. It was necessary to establish sound operational concepts for such missions and to inaugurate a period of transformation of the Agency's facilities. Ground stations, computer facilities and control centres had to be redesigned to operate continuously (twenty-four hours per day) and at low cost. The use of a 2 GHz and higher frequency bands called for new technology at the ground stations and the greatly increased data yield of scientific and meteorological satellites called for on-line data reduction in order to avoid the accumulation of irreducible 'data mountains.'

Solutions had to be found which took into account a number of conflicting general requirements, such as:

- the need to minimise the number of ground stations in order to reduce operational running costs
- the need to locate some data-acquisition facilities as close as possible to the control centre in order to reduce the rental cost of the high-capacity communication links required
- the need to obtain long-term guarantees of freedom from radio-frequency interference at the reception frequencies and permission to transmit without restriction at the command frequencies
- the need to procure the new computer systems required by the control centre from the computer industries of Member States, and
- the need to ensure maximum usefulness of the facilities to be provided for the long-term future programme.

Considerations of this nature led to the decision to construct a new ground station at Michelstadt, some 40 km southeast of Darmstadt, to accommodate the S-band reception equipment for GEOS and the S-band reception and transmission facilities required by Meteosat, both to be launched in 1977.

Failure to obtain the necessary guarantees on frequencies elsewhere led to the selection of a second site at Villafranca del Castillo near Madrid to accommodate further S-band reception equipment required for the IUE satellite (launch 1977) and the Ku-band and C-band equipment needed for Marots (launch 1978) and Aerosat

aux Etats-Unis et comprenant deux petits calculateurs de conduite de processus pour les tâches en 'temps réel', renforcés par un ordinateur universel de moyenne capacité.

L'extension des programmes du CERS/ASE à des satellites géostationnaires scientifiques et d'applications a constitué pour l'ESOC un nouveau défi technique et opérationnel. Il a fallu définir de solides concepts opérationnels pour des missions de ce type et entamer une période de transformation des moyens de l'Agence. Il fallait revoir la conception des stations sol, des installations calcul et des centres de contrôle pour que ceux-ci fonctionnent continuellement (24 heures sur 24) et pour un coût modéré. L'utilisation de bandes de fréquences de 2 GHz et au-delà nécessitait le recours à une nouvelle technologie pour les stations sol, et l'accroissement considérable de la quantité de données provenant des satellites scientifiques et météorologiques imposait un dépouillement direct des données de façon à éviter l'accumulation de 'montagnes' de données infranchissables.

Il fallait trouver des solutions qui tiennent compte de plusieurs impératifs généraux contradictoires tels que:

- *la nécessité de réduire au minimum le nombre de stations sol de façon à réduire les coûts d'exploitation;*
- *la nécessité de situer certaines installations d'acquisition des données aussi près que possible du Centre de Contrôle de façon à réduire le coût de location des liaisons de communications à haute capacité nécessaires;*
- *la nécessité d'obtenir d'une part des garanties à long terme que les fréquences de réception seraient à l'abri des interférences radio-électriques et d'autre part la permission d'émettre sans restriction sur les fréquences de télécommande;*
- *la nécessité d'acquérir, des industries d'informatique des Etats membres, les nouveaux systèmes de calcul exigés par le Centre de Contrôle;*
- *et la nécessité d'utiliser au mieux les installations requises dans le cadre du programme futur à long terme.*

Ce sont des considérations de cet ordre qui ont amené à prendre la décision de construire une nouvelle station sol à Michelstadt, à environ 40 km au sud-est de Darmstadt, (launches 1979 and 1980). The distance between Villafranca and ESOC is such that IUE's scientific data could not be processed on-line at ESOC with sufficiently rapid turn around and Villafranca had therefore to be equipped with a medium-sized computer of its own.

In parallel with these new developments in the ground-station field, it was decided to equip ESOC with two new computer systems supplied by European industry. The first, sized to meet the GEOS data-handling requirement and the launch and transfer-orbit support requirements of the other geostationary missions in the ESA programme, consists of a network of small process-control computers linked to two medium-sized general-purpose machines. The second, sized for Meteosat's data-handling requirements, also comprises a network of small process-control machines, but linked in this case to two large general-purpose computers and a variety of special-purpose hardware.

This change from the earlier single-supplier policy for operational computers to one under which the various elements of complex configurations were to be procured from several manufacturers, highlighted the difficulty and the importance of establishing an orderly software development policy. It has also focussed attention on the high cost of computer programs and has led to a general recognition of the importance of software as an investment item in the Agency's inventory of facilities.

In this context, mention should be made of ESOC's pioneering work in software procurement by departing from the tradition of in-house software development in favour of entrusting to industry the development and supply of the large suites of programs that are needed.

These activities, along with the installation, jointly with Telespazio, of a Ku-band station for the OTS satellite (launch in 1977) at Telespazio's site at Fucino (Italy) and the development of communication systems to link Darmstadt with the new sites, have considerably enhanced ESOC's system design and procurement role over the last four years.

Investment, which has been maintained at 10 MAU per annum over the past three years, will fall in 1978. The investment in ground facilities will, it is hoped, represent a

pour y installer l'équipement de réception en bande S destiné à Geos ainsi que les installations de réception et d'émission en bande S exigées par Météosat, ces deux satellites devant être lancés en 1977.

L'impossibilité d'obtenir ailleurs les garanties indispensables sur l'utilisation des fréquences requises a amené à choisir un deuxième site à Villafranca del Castillo, près de Madrid, pour y installer l'autre équipement de réception en bande S nécessaire pour le satellite IUE (lancement en 1977) ainsi que les équipements en bande Ku et en bande C pour Marots (lancement en 1978) et Aérosat (lancements en 1979 et 1980). La distance qui sépare Villafranca de l'ESOC est telle que les données scientifiques du satellite IUE ne pourraient pas être transmises à l'ESOC à une cadence suffisamment rapide pour y être traitées en temps réel. C'est pourquoi il a fallu équiper Villafranca d'un calculateur de capacité moyenne.

Parallèlement à ces nouveaux développements dans le domaine des stations sol, il a été décidé d'équiper l'ESOC de deux nouveaux systèmes de calculateurs fournis par l'industrie européenne, Le premier, dont la capacité permet de répondre aux impératifs de traitement des données de Geos ainsi qu'aux impératifs de soutien au lancement et à la mise sur orbite de transfert des autres missions de satellites géostationnaires du programme de l'ASE, est composé d'un réseau de petits calculateurs de conduite de processus reliés à deux ordinateurs universels de moyenne capacité. Le deuxième, dont la capacité répond aux besoins en matière de traitement des données de Météosat, comporte également un réseau de petits calculateurs de conduite de processus mais, dans ce cas, reliés à deux grands ordinateurs et à divers matériels spécialisés.

Ce changement de politique qui a amené, an lieu de n'avoir qu'un seul fournisseur pour les calculateurs opérationnels, à acheter les divers éléments de configurations complexes chez différents fabricants, a mis en lumière la difficulté et l'importance de la mise au point d'une politique systématique de développement du logiciel. Il a également attiré l'attention sur la cherté des programmes de calculateurs et fait prendre conscience de l'importance du logiciel dans la gamme des investissements de l'Agence. Il faut noter, à cet égard, que l'ESOC, rompant avec la politique traditionnelle de réalisation

Prof. Gianni Formica, Director of ESOC.

significant contribution to the preparedness of European industry to supply the facilities that will be required for the operation of future commercially exploited applications satellites. Only minor investment should be needed to 'tune' these facilities to the specific requirements of such satellites as Exosat (to be launched in 1980) and Geosari (to be launched in 1979).

As in the past, emphasis will continue to be placed on re-use of the facilities provided, and matching of the missions flown to the type and capacity of the ground facilities available. Application of this policy in the future will take into account not only the facilities of ESA, but also those of its Member States, several of which have large inventories of facilities which were procured to operate the satellites of their national programmes.

The current ESA scientific and applications satellite programme will certainly be more demanding than ever before; the new operational activities presently being defined and the conceptual, organisational and technical challenges presented by the provision of suitable facilities for Spacelab, earth-resources satellites and fully operational communications and meteorological satellites will undoubtedly mould the role of ESOC in the coming years.

Prof. Gianni Formica

interne du logiciel, a décidé de confier à l'industrie la fourniture des grands ensembles de programmes qui seront nécessaires.

Ces activités, ajoutées à l'installation, en coopération avec Telespazio, d'une station en bande Ku pour le satellite OTS (lancement en 1977) sur le site de Telespazio à Fucino (Italie), et le développement de systèmes de communications destinés à relier Darmstadt aux nouveaux sites, ont considérablement accru au cours des quatre dernières années le rôle de l'ESOC dans le domaine de la conception et de la fourniture de systèmes.

Les investissements, qui se sont maintenus au niveau de 10 MUC par an pendant les trois dernières années, diminueront en 1978. On espère que les investissements en installations au sol auront contribué de façon non négligeable à préparer l'industrie européenne à fournir les équipements destinés à l'exploitation commerciale de futurs satellites d'application. Désormais, seuls des investissements mineurs sont à prévoir pour adapter les installations terriennes aux impératifs propres de satellites tels qu'Exosat (qui sera lancé en 1980) et Géosari (qui sera lancé en 1979). Comme par le passé, l'accent sera mis sur la réutilisation des installations existantes et sur l'adaptation des missions au type et à la capacité des installations au sol disponibles. La mise en oeuvre de cette politique dans l'avenir devra tenir compte non seulement des moyens dont dispose l'Agence, mais également de ceux de ses Etats membres, dont beaucoup se sont dotés d'importants moyens matériels pour exploiter les satellites de leurs programmes nationaux.

Le programme actuel de satellites scientifiques et d'applications de l'ASE sera certainement plus exigeant qu'auparavant; les nouvelles activités opérationnelles en cours de définition et le défi que constitue sur le plan de la conception, de l'organisation et de la technique, la fourniture d'installations qui conviennent à Spacelab, aux satellites écographiques ainsi qu'à des satellites météorologiques et de communications pleinement opérationnels détermineront, à n'en pas douter, le rôle de l'ESOC dans les années à venir.

□

Organisation of an Operations Centre

B.M. Walker, Office for Co-ordination and Management, ESOC

The European Space Operations Centre, being charged with the operation of satellites in orbit, manages that part of ESA's budget allocated to this activity. In recent years, the Agency has set aside 19% of its labour and 9% of its total budget for satellite operations. The basic management task, to accomplish which the ESOC organisation has been designed, can be illustrated by examining the relationship between the cost of operations and the likelihood of their being successful.

Satellites in orbit are operated from the ground. Increasing the amount spent on the ground, either initially, in investments, or later in running costs (preferably not in both!) should increase the likelihood of the satellite producing the results it was designed to produce. As might be expected, the relationship between operational costs and this likelihood of success (Fig. 1) tells us that money spent on the ground can, if spent to improve the security of ground operations, increase the chances of success, up to a point. Beyond this point, spending more on the ground achieves nothing in terms of likelihood of success. This is because the maximum possible chance of success is controlled by other factors, the most obvious one being the finite chance of an irreparable failure on board the satellite. The cost of ground operations which produces a likelihood of success close to this maximum achievable can be called the 'maximum useful cost.'

ESOC's task can therefore be formulated as being:
- to design a method of conducting satellite operations which keeps the maximum useful cost of operations as low as possible, and
- to conduct satellite operations ensuring that the maximum useful cost of operations is not exceeded.

This formulation of the task in two parts allows the importance of the process of selecting the appropriate operational facilities to be emphasised.

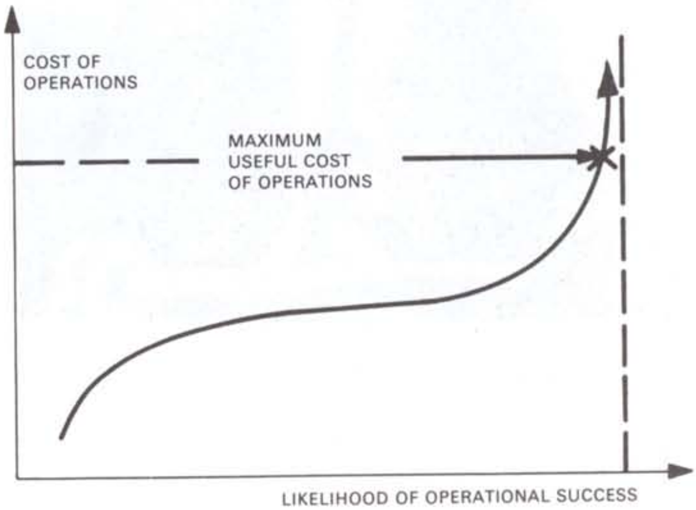


Figure 1 – Operational costs as a function of likelihood of success.

RESOURCES AND THEIR DEPLOYMENT

The productive time of appropriate facilities and the productive working time of suitably qualified and trained personnel are the two basic resources available to ESOC for the execution of its task.

Elsewhere in this Bulletin can be found descriptions of the facilities available to ESOC. It suffices for the purposes of this discussion to note that ground facilities can be classified as:
- those having low zero-load period costs*, e.g. a control centre where equipment is simple, usually purchased, and requires low preventive maintenance effort, and
- those having high zero-load period costs, e.g. large computers, but where the capacity installed can be matched to the load with acceptably low adjustment costs (i.e. rental contracts with low cancellation charges, low installation charges, etc.)

The ground stations for telemetry, telecommand and tracking currently fall into a third class characterised by high zero-load period costs but where load-capacity matching cannot be readily achieved due to such factors as high installation costs, high closure costs, high preventive maintenance costs and, in some cases, high permanent communications costs. Facilities for telemetry, telecommand and tracking are therefore an important,

* 'Period costs' is used here to denote those costs that vary predominantly with time and not with work load.

TABLE 1

	Designs characterised by low zero-load period costs	Designs characterised by high zero-load period costs
Networked stations	**A** Short-duration operations limited to the acquisition of spacecraft 'health and safety' data with low command rates e.g. transfer-orbit operations for geosynchronous satellites	**B** Long-duration operations where the successful acquisition of a high proportion of payload data is required e.g. scientific or earth-observation satellites in close earth orbit
Single stations	**C** Long-duration operations limited to spacecraft maintenance objectives e.g. on-station control of operationally simple geostationary spacecraft, such as telecommunications satellites	**D** Long-duration operations where the successful acquisition of a high proportion of payload data and, possibly, high command rates are required e.g. geosynchronous scientific or earth-observation satellites

high-cost resource, the deployment of which requires the utmost care.

It is of interest to draw attention to a further resource not universally looked upon as a facility – the computer programs. The interest lies in the realisation that defective investment planning in this field (e.g. preparation of software in a manner that restricts its usability to one particular type or model of computer) can make load-capacity matching of large computers very difficult.

This, if allowed to develop, rapidly places the computers into the third, undesirable class occupied by the ground stations, namely that of high zero-load period costs with severe restrictions on load-capacity matching.

Thus, decisions on the deployment of facilities can be 'tactical' for control centres and computers either because they result in low zero-load period costs or because load-capacity matching can be achieved with low financial penalties.

Decisions to invest in software can also be regarded as 'tactical' provided severe design requirements ensuring transportability are imposed and met. If this is not the case, software investment decisions can become 'strategic' due to the probability of being forced to retain computer hardware to match the software rather than the work load.

Investment decisions on ground stations are to be regarded as 'strategic' unless low zero-load period cost designs can be implemented, which is certainly the case for simple systems.

Categorisation of facilities in terms of their zero-load period costs (the cost to the Agency of having unused facilities) provides useful guidelines for employment decisions. An example of this process is given in Table 1 where satellite operations of various types are mapped against high or low zero-load period cost designs and networked (interdependent) or single (independent) ground stations. This mapping allows us to say that for operation types A and C the possibility of breaks in the satellite programme can be tolerated, because these facilities cost little when doing nothing, whereas for operation types B and D continuity of the satellite programme is, or should be, secured before a decision is made to invest on the ground.

The productive working time of suitably qualified and trained personnel, the second basic resource to be deployed, is available from two sources; the Agency's employees and industry. Industrial manpower is secured under one or other of three basic contract types:

a. Contracts for specialised manpower, e.g. a contract with company X for the services of Mr. Y, a specialist in field Z.
b. Contracts for services, e.g. a contract with company X to operate and maintain a ground station over a given period.
c. Contracts for products, e.g. a contract with company X to deliver an antenna.

Generally, labour from all sources is a high zero-load period cost resource; idle personnel cost, roughly speaking, as much as productively employed personnel, but productively employed personnel are chargeable to a customer.

Manpower from the two sources (Agency/industrial employees) provides different load-capacity matching possibilities. Agency employment permits matching only in the case of increasing load in that, with more work, more people can be employed. Work-force reduction, however, is not controlled by falling work load, but by the terms of the employment contract. Thus, adding to the work force in times of high work load increases the Agency's zero-load period costs for manpower.

In the Operations Centre, where the work load is to a large extent controlled by factors outside the scope of the Centre's management (delivery of a satellite for launch, failure of a satellite in orbit, etc.), a means has to be found of regulating the manpower supply to those activities sensitive to changes in the operational work load. This regulation is achieved by drawing a large proportion of the manpower required for the operation of facilities from industrial sources under contracts for services. These contracts transfer the load-capacity matching problem (and also the skill-maintenance problem) to the industrial companies who are required to be able to respond rapidly to work-load changes. This means, of course, that the company concerned must have a large 'base' of non-ESA work requiring similar personnel skills to achieve rapid 'move in' and 'move out' of personnel when requested. Contracts of this type are used by ESOC to provide manpower for the operation of all ground stations, computers and control centres.

Throughout the above we have employed the notion of 'productive time', the definition of which is, to say the least, controversial. For the Agency's purposes, indirect methods are used to estimate productive time requirements (estimates are made against approved task descriptions at the lowest level of a project work breakdown structure). Time sheets (another indirect method) are used to record time spent against the same task references. These methods, employed over a period of years, allow the *maximum* productive time yield per employee to be estimated; it has been found to be between 75 and 80% at ESOC.

Utilisation of industrial staff under service contracts transfers the productive time estimation and control problem to the contractor – the contract specifies what is to be done and to which standard of performance.

ORGANISATION

Care has been taken at ESOC to group facilities and manpower resources into manageable units, which require:

- a clear boundary, without 'fuzzy edges' where the work of one unit fades imperceptibly into that of another
- control of the facilities and resources appropriate to the task to be undertaken
- a defined source (or sources), external to the unit, capable of authorising the work of the unit (and a procedure for this in order to identify and record such authorisations)
- a defined destination (or destinations) for the unit's products
- a definition of which external units must (or can) be called upon for specialised services (and, of course, a defined procedure for doing this).

The above list, although not exhaustive, identifies characteristics that would be recognised as desirable features in almost any organisation. These particular characteristics are selected here as criteria for the manageability of organisational units at a Space Operations Centre knowing that failure to achieve organisational clarity can have severe consequences. Destruction or damage of valuable equipment on the ground or irreplaceable equipment in orbit can result from trivial operational errors. Doubts about 'who is responsible' – always offered as an excuse for doing nothing – can lead to failure to acquire unique data. The list of consequences can be extended but it already serves to illustrate that, whereas organisational deficiencies can, in many fields, be 'covered up' or their consequences are correctable by special management action, in satellite operations deficiencies are demonstrated instantly, and publicly, by failure. 'Fire brigade' action to recover may simply not be possible or, if possible, is likely to be prohibitively expensive.

Having grouped facilities and manpower into manageable units it remains to organise the work to be performed. The organisation of work can be usefully defined as the process of translating an 'objective' into a list of tangible 'things to be done', the division of these into subactivities which can be grouped in sets falling completely within the activity domains of the executive units, the allocation of specific responsibilities for the subtasks, the main tasks, and the objectives and the arrangement of the tasks in logical chains or cycles.

Why chains or cycles? Chain arrangement implies that the tasks are not repetitive; this is the case, of course, in development and occasionally in operations. Chains such as: *write specifications – select a manufacturer – monitor the manufacture – monitor the installation and test – transfer to user* are quite familiar. Chains such as: *separate satellite from rocket – despin – erect solar arrays – stabilise at desired attitude – switch on payload* occurring in satellite operations may be less familiar. Cyclic tasks occur in ground-facility operations and also in development programmes. A development programme cycle such as

→ Compute schedule for the coming month
Work and report actual completion dates ←

occurring in schedule control is parallelled by

→ track satellite for one week
in order to
compute orbit
in order to
predict satellite position throughout next week
in order to
schedule ground-station operations
in order to

Both development and operational activities are to be found at ESOC. Development or procurement is undertaken when the need arises to improve or replace items in the facility inventory, or when additions to the inventory have to be made. In other words, development can be triggered by a mismatch between the operational facilities and the operational requirement (in the area of performance or capacity) or by a decison to replace existing equipment in order to reduce period costs.

Development activities require that special arrangements be made to assure (or maximise the probability of) compatibility being achieved between the initial concept and the actual state of affairs attained at the end of the development programme.

The nature of the problem can be visualised by introducing a high level of simplification. Taking as a first step the approach of the customer to the Space Operations Centre with a document describing:
- the sort of satellite he intends to launch at date X
- the objectives to be achieved by operating the satellite
- the type of in-orbit surveillance foreseen by the satellite design
- the arrangements for communicating between the satellite in orbit and its ground system
- the planned duration of satellite operations and other useful data of a similar nature.

TABLE 2

			CUSTOMER REQUIREMENTS AND CENTRE OBJECTIVES	
			Office for Co-ordination and Management	
			OPERATION	DEVELOPMENT OR PROCUREMENT
AGENCY INVESTMENT AND FACILITY UTILISATION POLICY	Office for Co-ordination and Management	GROUND STATIONS CONTROL CENTRES & COMMUNICATIONS	Operations Department	Ground Equipment Engineering Division
		COMPUTER PROGRAMS	Operations Department & Information Handling Dept.	Information Handling Dept.
		COMPUTING EQUIPMENT	ESA Computer Department	ESA Computer Department
		SATELLITES	Operations Department	Customer Activity

The Space Operations Centre will, after a certain period of introspection, respond. Examination by the Space Operations Centre, during the period of introspection, of the customer's requirements leads to the formulation of an operational concept, examination of the facility inventory for suitability for the customer's operations, and an assessment of the facility loading in the period in question, all of which condition the response to the customer.

We will assume that the customer's requirements create a performance or capacity mismatch with the planned state of the inventory at date X (the customer's delivery date). In this case the response to the customer will be:

'Yes we can undertake to operate your satellite for the period in question (date X onwards) at an annual operating cost not exceeding Y monetary units, but *to do so we need to expand our capital equipment inventory at a cost of Z monetary units, which you as customer will have to pay.'*

Assuming the customer accepts these conditions, he goes away to build his satellite with the date X (the launch date) and the amounts Y (the maximum useful cost of operations) and Z (the cost of inventory changes) firmly established in his mind.

Clearly the integrity of the customer's programme depends now on the Space Operations Centre doing what it has undertaken to do and thus firm control of objectives during the development period is required. Were there only one customer to be dealt with, this task could be entrusted to him as part of his overall programme control. In practice, however, the ESA programme presents several customers simultaneously to the Space Operations Centre. In addition the Centre is, as we have already noted, charged with the responsibility within the Agency of minimising the zero-load period costs. In other words, it is the Space Operations Centre which is primarily concerned with the questions of reusability of the capital investment and the cost to the Agency of unused facility capacity. These aspects of ESA policy are, of course, of limited interest to the customer. He could be excused for thinking, occasionally, that consideration of these factors leads to an excessively complex response to what he considers to be a simple, well expressed operational requirement.

ESOC therefore maintains, in addition to those units charged with the custody of the manpower resources appropriate to the development and operation of facilities and with the custody of the facilities themselves, a unit charged with the establishment and control of objectives. These objectives relate primarily, of course, to service to

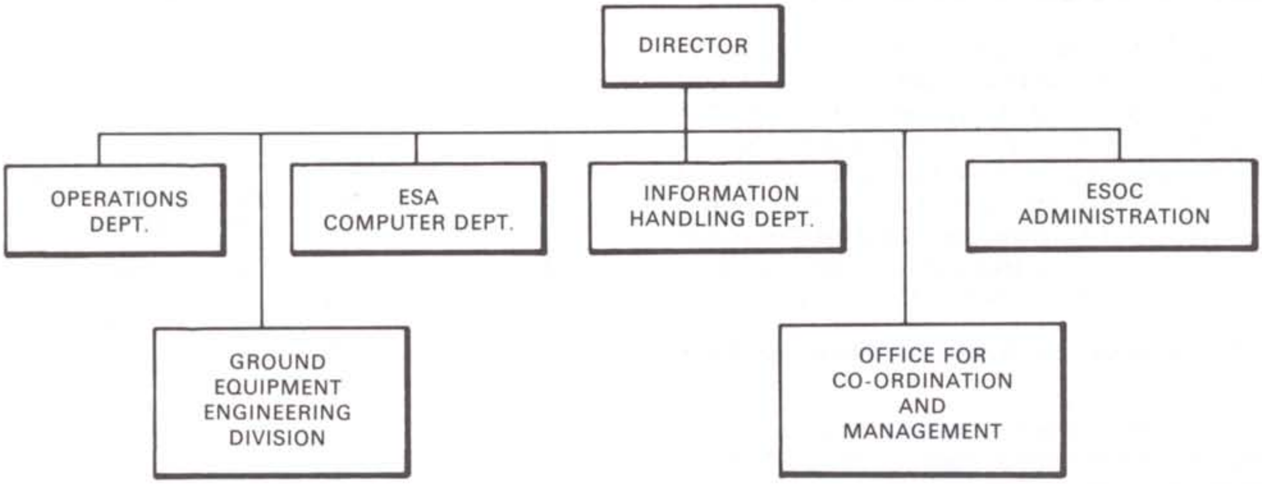


Figure 2 – ESOC organisational structure.

the customer, but are modulated by the directives reflecting the Agency's long-term investment and operating cost policy.

Summarising then, we find three types of organisational unit at ESOC covering the three tasks of the Centre (Fig. 2, Table 2):

- identification of customer requirements and the establishment and control of the Centre's objectives as derived from these requirements
- supply of ground facilities for spacecraft operations and data processing to the Agency's capital inventory
- operation of the Agency's facilities and satellites.

The current organisation of the European Space Operations Centre reflects a certain level of adjustment to the tasks to be performed. The adjustment process is, however, a continuous one which must proceed in step with the evolution of these tasks.

Establishing a satisfactory definition of the tasks in the field of facility management and space operations in terms of the Agency's future programmes is not easy. It must, however, be attempted, because it is this definition which must be used to guide the evolution of the current organisation at ESOC. It is too easy to set up an organisational structure to match the tasks of yesterday.

The current consideration by ESA's Member States of such questions as the role of the Agency in the management of operational applications satellites, the operational utilisation of Spacelab, and a European earth-resources programme will lead to decisions which, when taken, can be expected to have a profound effect on the tasks and organisation of the Agency's Space Operations Centre. □

The Control Centre and Spacecraft Control

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The Control Centre represents the central element of the overall ground network and has the task of defining and co-ordinating all the network activities required to support the space mission. This article outlines the functions, facilities and personnel requirements of such a centre, before going on to describe how the Control Centre at ESOC has evolved in the context of the ESA programme (from ESRO II to Meteosat).

The Control Centre can be seen as the focal point for co-ordinating the activities that support mission operations. The operations system itself (Fig. 1) represents the combination of four prime elements: hardware, software, procedures, and personnel, and its design determines which functions are assigned to each category. Once the system has been realised, its functioning and application for a particular mission are the responsibility of the Operations Control Centre (OCC), the tasks of which embrace the following activities (see Fig. 2):

- surveillance of the technological status of the satellite, by analysis of the telemetry data that it transmits
- telecommanding of instruments on-board the spacecraft according to a pre-determined programme (by sending coded signals to the satellite, which are decoded on-board and correspond to modifications in the operating configuration of the instruments).
- control of spacecraft dynamics (orbit and attitude)
- evaluation of operations system performance
- surveillance of mission implementation with the objective of maximising return to users
- processing and distribution of data to payload specialists
- maintenance and operation of ground equipment.

FACILITIES

The type and diversity of the facilities required to perform the operations mentioned above will, of course, vary depending on the complexity of the particular mission. In general, however, a Control Centre can be seen as resulting from the integration of:

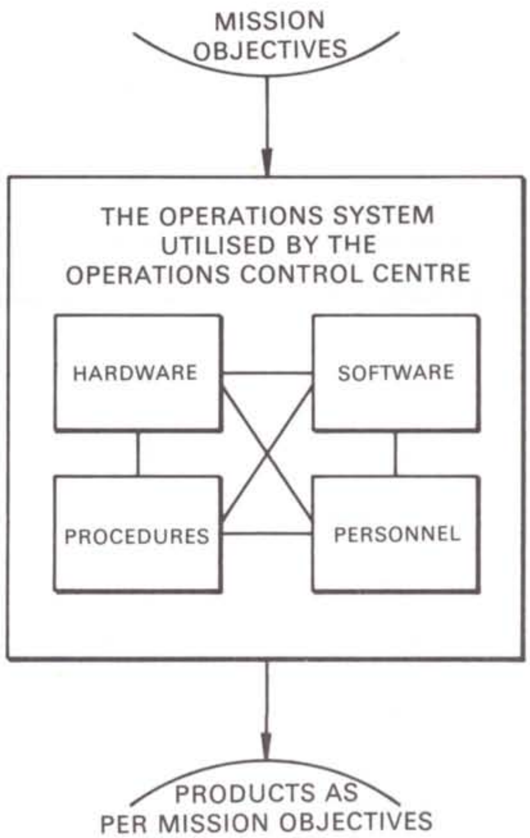

Figure 1 – The operations system of the Control Centre.

- A communication centre to manage voice, data and teletype messages.
- A data processing centre to accept, calibrate, process, display and archive telemetry data and to support spacecraft control operations.
- Telemetry equipment to provide an interface, when necessary, with the on-line computer and to display unprocessed satellite telemetry (digital and analog).
- A control room equipped with communications, telemetry and computer consoles, and housing the personnel in charge of operations.
- Operational procedures governing execution of the various tasks by the personnel.

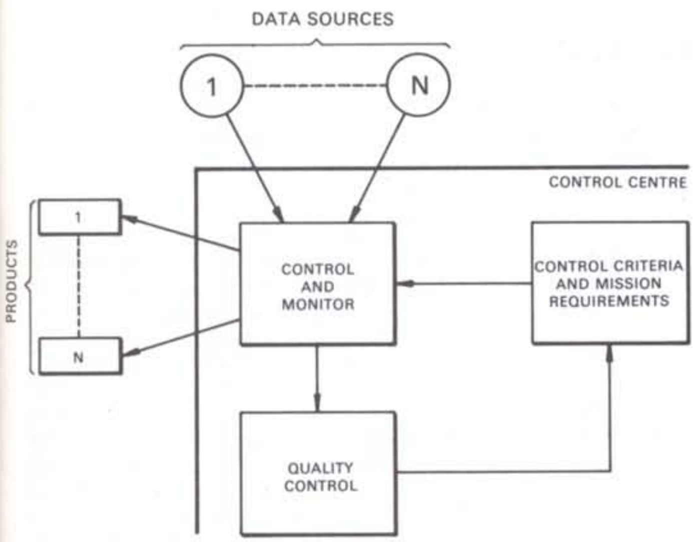

Figure 2 – The tasks of the Control Centre.

PERSONNEL

The Control Centre staff are usually organised around two main spheres of activity:

Pre-Launch/Launch Activities

During this phase, Control Centre personnel work with other Operations Centre specialists responsible for:

- analysing mission requirements
- definition, development and testing (using in-house and industrial expertise)
- preparing operational procedures, training personnel to execute them, simulating operations and, ultimately, supporting the launch.

They are responsible for establishing the Centre's degree of readiness and for committing both facilities and staff to the mission. The pre-launch activities relating to the design and procurement of the various elements of the operations system are described elsewhere in this Bulletin.

Post-Launch Activities

After the satellite has been checked out in orbit, the Control Centre's work becomes more routine for its staff of:

- network controllers, who co-ordinate ground-station and Control Centre operations
- spacecraft controllers, who implement the operations and monitor the technological status of the satellite
- schedulers, who prepare the schedule of operations
- ground-station controllers, who monitor and, when applicable, control the status of the remote ground stations
- computer operations and maintenance technicians
- engineers who supervise and manage operations.

HISTORICAL EVOLUTION

The complexity of any mission is reflected in the nature of the operations that must be performed at the Control Centre; three main items must be considered:

(i) the overall telemetry load or total data throughput, expressed in bits and calculated from the bit rate and data-availability requirement
(ii) the telecommand density, obtained from the mission profile
(iii) the complexity of the processing required to define a telecommand action.

A mission which requires, for example, that the payload data be analysed before a telecommand action be authorised is classified as 'demanding'. Other typical factors are not strictly mission related, but are nevertheless important when considering the overall workload of the Control Centre. There is, for instance, the number of missions that the Centre must support simultaneously, a consideration that often leads to rationalisation of the support facilities. Another factor in the same category is the diversity in the disciplines that have to be supported; this has a considerable influence on the skills and numbers of personnel required for support.

With this basis for 'mission analysis' in mind, we can examine how and why the present spacecraft support system has been developed. Its evolution can be divided into three phases, the first of which dates back to the early European satellites ESRO-II, ESRO-IA/B and HEOS-1/2. This generation of spacecraft was characterised by a low

TABLE 1

Historical Evolution of Control Centre

MISSIONS	TELEMETRY load (Mbit/day)	TELECOMMAND FREQUENCY	TIME RESPONSE	TELECOMMAND PROCESSING	MISSION/ORBIT TYPE	CONTROL CONCEPT
PHASE 1						
ESRO-II	~ 12, LOW	LOW	NORMAL	SOME	Science/LO	– Simple missions. Manual involvement high. Level of automation very low. On-line support very seldom.
ESRO-I A/B	~ 30, LOW	LOW	NORMAL	LITTLE	Science/LO	
HEOS-1/2	~ 3, LOW	LOW	NORMAL	LITTLE	Science/HE	
PHASE 2						
TD-1A	~ 170, LOW	LOW	VERY FAST	SOME	Science/LO	– More demanding missions still not very complex. Manual involvement still high. Level of automation still low but on-line support very much increased.
ESRO-IV	~ 15, LOW	LOW	FAST	SOME	Science/LO	
COS-B	~ 25, LOW	LOW	NORMAL	MUCH	Science/HE	
PHASE 3						
GEOS	~ 8000, HIGH	HIGH	VERY FAST	VERY MUCH	Science/G	– This phase contains very complex missions. Level of automation is high. Dedicated or very much improved on-line support.
OTS	~ 15, LOW	LOW	FAST	LITTLE	Applic/G	
METEOSAT	~14000, HIGH	MEDIUM	VERY FAST	VERY MUCH	Applic/G	
		<50/day=LOW 50—500/day = MEDIUM >500/day=HIGH	>1 hr = NORMAL 1 hr—5 min = FAST <5 min = VERY FAST		LO= LOW ORBITER HE= HIGH ECCENTRIC G = GEOSTATIONARY	

telemetry load and little need for real-time processing (Table 1).

The down-link (satellite-to-ground) data rate ranged from 12 bit/sec (HEOS-1) to 320 bit/sec (ESRO-I), with bursts of up to 10 kbit/sec (ESRO-IA playback). Spacecraft surveillance was effected by (i) digital displays at the ground stations, communicated by telex to the Control Centre, and (ii) computer printouts giving the technological status of the satellite, obtained from transmissions of data samples to the Centre. Telecommands were communicated by voice and telex to the ground stations. In summary, this was the era of manual operation, with an absolute minimum of support facilities (telemetry displays at the stations and Communication Centre, off-line computer printouts).

The second phase can be regarded as starting in March 1972 with the TD-1 mission and continuing through until COS-B. Although TD-1 transmitted 1700 bit/sec the overall telemetry load for this second generation of European satellites was still low. However, what distinguished this phase from the first was the increased requirement on time response to telecommand operations and associated real-time processing for TD-1 and ESRO-IV. Subsequently, the COS-B satellite also brought the new requirement of near-real-time processing of payload data for on-board instrument purposes, a feature to be repeated later for the GEOS and Meteosat missions.

There have been two notable landmarks in this second evolutional phase: the first was the building of a new Control Centre to support the TD-1 mission, and the

Figure 3 – The operations control room during the count down for the launch of the Dutch ANS satellite.

second the decision by the scientific community responsible for the COS-B mission to operate their spark chamber from the Control Centre, requiring almost totally dedicated facilities (control room, real-time computer and batch computer) to optimise exploitation of their experiment. Personnel involvement is nevertheless still high, despite the considerable increase in computer support.

The third phase in the development of the Agency's satellite support system will commence with the launch in April 1977 of GEOS, the world's first scientific geostationary satellite. It represents an extreme example of the mission complexity that we are facing, since it transmits about 100 kbit/sec, has a telecommand frequency of up to 4×10^4 telecommand/day, has a time response down to 12 sec and, last but not least, requires the processing of high-rate payload data for the definition of telecommand instructions (Table 1). The complexity of the ground facilities that are being installed to support such missions results to a large extent from the transfer of what have previously been on-board functions to the ground centres.

SPACECRAFT CONTROL IN 1977

The 'new' missions, namely those spacecraft due for launch in 1977, represent a major step forward compared with previous European ventures in that

(i) the data rate involved is one/two orders of magnitude higher

(ii) the bulk of the incoming data needs to be preprocessed on-line (for example, correction of images for Meteosat, spectral analysis of wave experiment data for GEOS)

(iii) several of the new applications satellites have a pre-operational character.

After careful analysis of the requirements, it was decided to procure a dedicated system for Meteosat (Meteosat Ground Computer System), a mission too specialised and demanding to allow the sharing of hardware and software with other spacecraft, and to set up a Multi-Satellite Support System (MSSS) designed around GEOS's requirements but also capable of serving the OTS, Marots and other low-bit-rate satellites. These two systems are described in more detail in the article on ESA's computer facilities.

CONCLUSIONS

One intention of this article has been to show, by way of a review of the differing requirements of the satellite missions of the last decade, how the facility and personnel needs of a Control Centre are very much dependent upon mission complexity. Much attention will have to be paid to mission characteristics in the coming years if optimum development of ground support facilities is to be assured. Future missions are in many instances different both in nature and in motivation from those that have gone before. Utilisation of NASA's Space Transportation System (Shuttle) in conjunction with the Agency's Spacelab and the future exploitation phase of the Ariane launcher will lead to more frequent and more varied missions, while efficiency in the exploitation of telecommunication payloads will undoubtedly be a consideration of prime importance. Only an approach in which an improved degree of definition of future missions is matched by equal concern in considering the impact that those missions will have in the context of the overall programme, will ensure the stable evolution of the Control Centre's facilities and allow the Agency to provide an optimum service to the European community interested in the utilisation of space for purposes of both research and application. □

Satellite Data Acquisition and Processing

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One of ESOC's main tasks is to collect information, in the form of satellite telemetry, orbit, attitude, time and astronomical data, process it, and distribute it to the centre's 'customers' in a form suitable to their needs. The receivers of the information are primarily experimenters who have payloads on board the satellite, and also those Control Centre staff who require data for monitoring the spacecraft's orbital path and performance. This article outlines the various steps involved in data acquisition and processing, beginning with the techniques currently in use.

ACQUISITION

The term 'acquisition' embraces all activities concerned with making data available in the Operations Centre at ESOC. The procedures used are mainly determined by orbit geometry and radio-frequency propagation conditions, which for all frequencies used in satellite communications (VHF or higher frequencies) require visual contact between transmitter and receiver.

In the past, all satellites have had near-earth polar or highly eccentric orbits, with apogees close to the polar axis. A satellite in a highly eccentric orbit can be seen for most of the time from any station at a sufficiently high latitude. Similarly, for near-earth polar orbits, all orbits intersect near the poles, and therefore a few stations at high latitudes are sufficient to provide at least one contact ('pass') during almost every orbit. This is reflected in the geographical distribution of the ground stations used for the Agency's earlier satellites (e.g. Redu, Spitzbergen, Fairbanks).

Whereas for highly eccentric orbits contact between ground station and spacecraft may last a day or more, the duration of a 'pass' for a near-earth satellite is of the order of 20 min. These satellites are therefore usually equipped with an on-board tape recorder with a capacity of about 100 min of data, the duration of a full orbit. During a pass over a ground station, the tape is played back at vastly increased speed (typically 32 times faster than recorded), so that most of the data can be recovered. The transmission technique commonly used is called 'Pulse Code Modulation' (PCM). All information is gathered in digital form on-board, and the digital information is modulated onto a carrier wave in a fixed time sequence – the telemetry format.

In the early days of satellite data acquisition, data were recorded on instrumentation tape drives at the ground station. With this recording technique, also called 'analog recording', the demodulated signal was immediately fed into a tape recorder running at constant speed. Later, these recordings had to be played back on special conversion equipment at the Operations Centre and converted to standard digital tapes. This procedure introduced a considerable delay in the delivery of data to customers. After the installation of minicomputer systems which operate reliably in the harsh environment of a ground station, data could be recorded directly on digital tapes, bypassing the intermediate conversion.

The new data acquisition technique is currently being used with the Agency's COS-B satellite (ESA Bulletin No. 2). The digital magnetic tapes are transported from the ground stations to the Operations Centre for processing. In addition, samples of the data are transmitted in real time via communication lines to the Centre for 'quick-look' inspection and monitoring, e.g. verification of the correct execution of telecommands.

Frequently, the scientific value of a measurement depends on its accurate timing, the required precision sometimes being $\pm$ 10 ms or better. The ground stations must therefore be equipped with a clock of this precision, synchronised to a global time standard. The precise time of arrival is recorded at the beginning of each telemetry frame together with the data. Maintenance of such good timing is one of the most demanding tasks in data acquisition.

The activities of the ground stations are co-ordinated by the Operations Centre. Data acquisition at the stations must be scheduled on the basis of orbit predictions, and considerable organisational effort and great discipline are required to maintain these routine activities throughout the lifetime of a satellite. The crisis that occurred during

Par contre, l'utilisation de la bande de 12 GHz, bien que pénalisée d'un affaiblissement des ondes radio-électriques plus important que celui des deux autres bandes de fréquences disponibles, n'est pas assujettie à une limitation de la puissance rayonnée, ce qui peut réduire d'une manière considérable le coût des installations de réception. Le spectre des fréquences disponibles est assez large pour satisfaire aux besoins de tout le monde. Enfin il est possible de réaliser des faisceaux d'antenne étroits permettant la couverture nationale, même dans le cas des pays relativement petits.

CHOIX DE LA CLASSE DU SATELLITE

Comme il a été évoqué précédemment, un des facteurs économiques les plus importants est le coût des terminaux de réception. Pour minimiser ce coût, il est nécessaire de maximiser la puissance de transmission des émetteurs installés à bord du satellite.

D'autre part, le coût de la mise en orbite du satellite est suffisamment élevé pour justifier le développement de satellites ayant une durée de vie opérationnelle excédant au moins 5 ans. Ceci conduit à un accroissement de la masse du satellite tant par la redondance supplémentaire à prévoir, que par la quantité d'ergols nécessaires pour le contrôle de l'orbite.

En tenant compte du besoin de rayonner plus d'un canal de télévision afin que le système soit attrayant pour les utilisateurs, même un calcul sommaire indique que les types de satellites correspondant aux lanceurs ayant une capacité équivalente à celle de TD 3914 sont soumis à des contraintes importantes soit en ce qui concerne leur durée de vie opérationnelle, soit en ce qui concerne leur capacité exprimée en nombre de canaux et/ou puissance.

La classe de satellite qui semble être techniquement et économiquement la plus attrayante se situe aux environs de 750 kg en orbite géostationnaire. Aller au-delà de cette limite présenterait des risques économiques, du moins jusqu'à ce que les techniques spatiales permettent la réparation en orbite des satellites, ce qui ne paraît pas envisageable avant les années 90.

ACTIVITES DE L'ASE DANS CE DOMAINE

L'Agence spatiale européenne a commencé en 1971 l'étude des divers systèmes de radiodiffusion par satellite possibles. Ces études ont couvert le segment spatial du système, le segment récepteur dans toutes ses variantes, ainsi que la technologie requise pour la réalisation de ce type de satellite.

Les programmes de développement technologique de l'Agence et de ses Etats membres ont débouché sur des réalisations importantes en ce qui concerne la conception et les performances des sous-systèmes nécessaires pour la réalisation de satellites de radiodiffusion de haute puissance fonctionnant dans la bande de 12 GHz.

Il est probable que ce type de mission soit mis en orbite à la fin de cette décennie ou au début des années 80.

CONCLUSIONS

L'ensemble des travaux d'études menées par l'Agence indique que les caractéristiques techniques et économiques des satellites de radiodiffusion sont bien meilleures que celles des systèmes terrestres équivalents surtout dans les pays en voie de développement. L'utilisation à cette fin de la bande de fréquences de 12 GHz offre des avantages incontestables par rapport à toute autre bande de fréquences actuellement assignée à ce service.

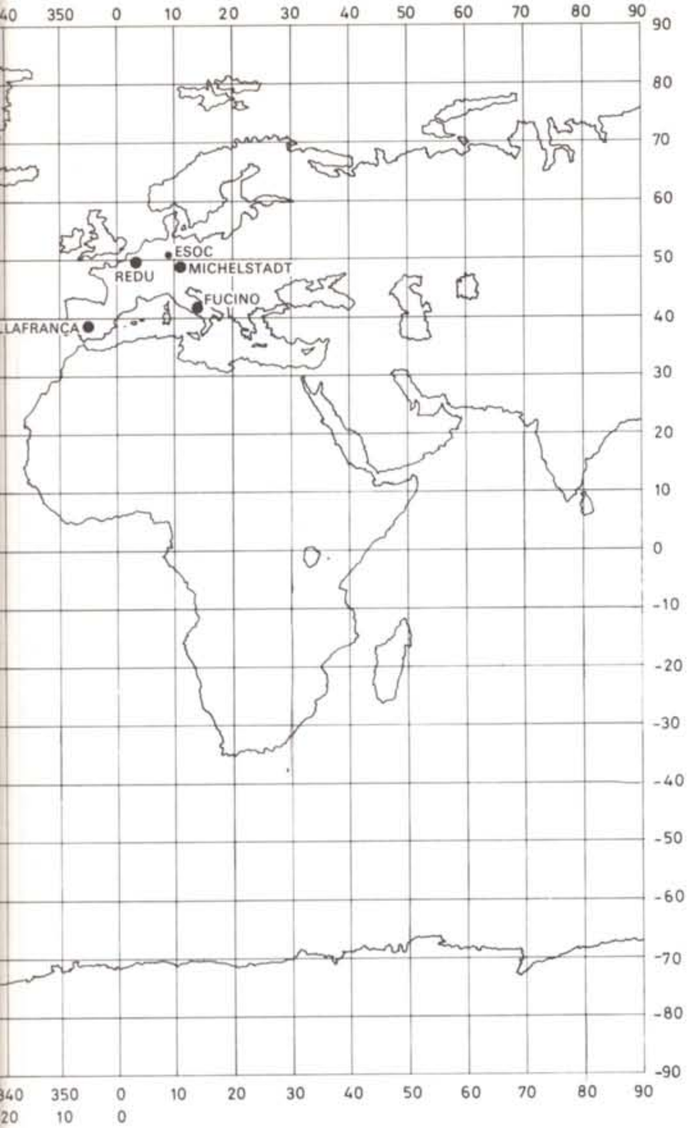
Une large coopération interdisciplinaire entre les utilisateurs potentiels et l'Agence est indispensable pour la définition détaillée du satellite.

Dans la phase initiale d'introduction de ce nouveau système, la coopération internationale peut jouer un rôle important sur plusieurs plans:

- entre pays industrialisés et pays en voie de développement: assistance technique, transferts de technologie, etc;
- entre pays en voie de développement: coopération dans le domaine de la production de logiciels et, par exemple, utilisation en partage du temps d'un satellite, permettant ainsi, lors de la phase initiale, d'importantes économies;
- pendant la phase pleinement opérationnelle de tels systèmes spatiaux, des économies appréciables pourraient être réalisées par une utilisation rationnelle du segment spatial et des moyens de contrôle des satellites.

Enfin, avec le lanceur lourd Ariane, l'Agence disposera après 1980 d'une capacité indépendante de mise en orbite de satellites libres de contraintes, ce qui assurera la viabilité, sur le plan technique et surtout économique, de la radiodiffusion visuelle et sonore par satellite.

□



Examples of such 'auxiliary data' are timing, position and attitude of the spacecraft, and geophysical or astronomical information, such as the earth's magnetic field and the co-ordinates of stars. They are retrieved from data bases (e.g. star catalogues), computed from mathematical models (geomagnetic field), or derived by complex computations from the telemetry (e.g. spacecraft attitude).

The major part of the processing relies on classical data-processing techniques: the input data are written to a large direct-access disk file and then 'decommutated' — in other words, the telemetry and auxiliary data for an individual experimenter are selected from the direct-access disk file and written to separate tapes. Very great care is needed to ensure that the computer and its file management software are used efficiently, and it must be stressed that the above is an oversimplification of what is actually a very complex and involved task.

RECENT TRENDS

The service that has been outlined has fulfilled experimenters' needs for all past ESA projects, but it would be inadequate for the projects currently under development, the main reason being that much higher data bit rates will have to be handled. For the first ESRO satellites, rates of 10 to 1000 bps were usual, and data recovery was sometimes much less than 100%. GEOS, by contrast, will provide a continuous bit rate of about 100 000 bps.

The current COS-B satellite project, while still providing a relatively low bit rate, is already making much better use of the real-time communication link between the ground station and ESOC. Approximately 20% of all data is transmitted to ESOC by playing back newly recorded digital tapes at the ground station. These data are made available to the experimenters' 'Fast Routine Facility', a suite of programs for the complete scientific analysis of this 20% sample, the results from which provide a rapid feedback to allow the experiment to be kept in its optimum mode. For GEOS this service will be further extended (see previous article).

A particular problem with GEOS is that the data rate in the 'high speed' stream is so high that no one experimenter can hope to analyse all of it. The procedure of automatically despatching and archiving all data has therefore been replaced by a more flexible system, whereby all data are recorded initially by ESOC, and the experimenter may, at any time during the lifetime of GEOS, select 'interesting periods' of a few minutes duration each. The selection process is facilitated by the production of 'compressed' data in real time (data which has undergone scientific processing), all of which is examined by the experimenter (Fig. 2).

Another new service provided by ESOC for GEOS will be the Daily Summaries and Experimenter Summaries . Means of presenting large amounts of data in such a way that their meaning can be visually appreciated, such as three-dimensional plots using intensity modulation, have been studied and are being discussed with the scientists.

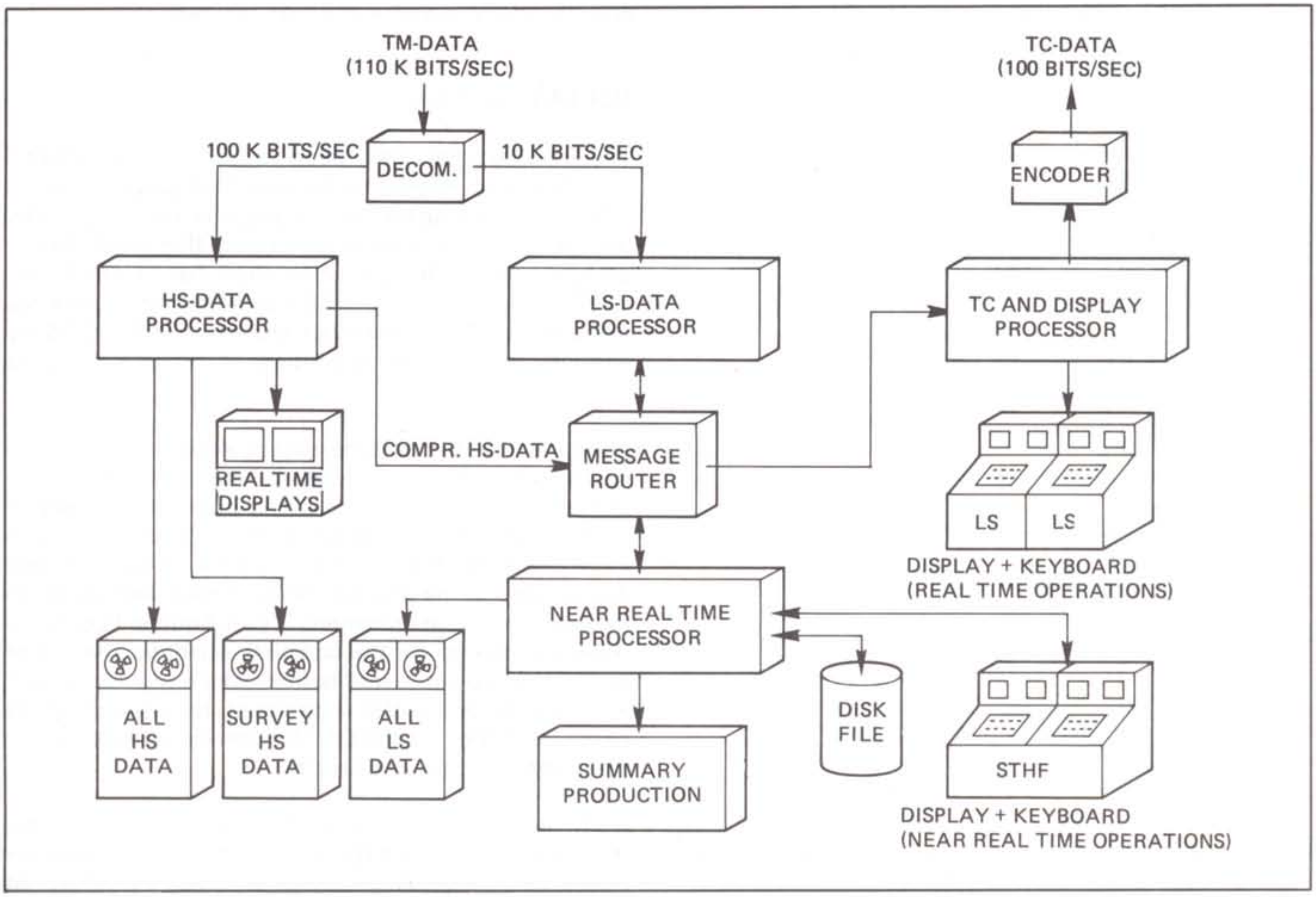


Figure 2 – GEOS spacecraft-control and data-handling facilities available at ESOC.

For Meteosat, acquisition from 'Data Collection Platforms' via the satellite is one new task; another is the dissemination of processed data to users by transmission over a data link or by using the satellite as a relay.

CONCLUSIONS

The examples given above are meant to show how 'classical' satellite data processing has had to be partially integrated with the real-time processing in order to cope with the more demanding projects now under development. The article has perhaps given the impression that each satellite requires its own special data-processing techniques: this is only partly true. There are very many data-processing functions that are common to all projects, and this has led to the development of the 'Multi-Satellite Support System', a computer network for which software of general applicability has been produced. This system, described elsewhere in this Bulletin, should greatly facilitate data handling for the Agency's projects during the coming years. □

Some Aspects of Mission Analysis

H.A. Kellner, Mission Analysis Division, ESOC

At the moment of lift-off, when a launch vehicle carries a spacecraft into the skies, a considerable part of the project has already been accomplished. All mission-analysis work has been completed to permit launch at the right moment and a lengthy and complex development effort has been expended. The project itself has usually been selected from various competing proposals, for which preliminary feasibility studies have been undertaken. In general terms, the mission-analysis work contributes to the task of optimising a space system on the basis of the initial scientific study requirements, or technological ones in the case of applications missions. Numerous constraints must be carefully respected, and acceptable trade-offs have to be found to reconcile disparities.

A basic system breakdown serves to provide some insight into the problems of mission analysis in the course of project definition and development.

Launcher	Spacecraft	Experiment Package	Data Acquisition	Data Utilisation

In order to arrive at an overall, workable system for achieving the mission objectives, the functional requirements for these five subsystems have to be established. The relations between the subsystems across the interfaces have to be identified and investigated, always taking into account any constraints. The entire system resulting has then to be checked and, where necessary, compromises have to be introduced, and the procedure repeated at subsystem level.

Although the changing of any one feature of the system can have far reaching repercussions, we will concentrate on the orbital aspects of the mission. At the time when a specific project is proposed, there is already a general concept of the type of orbit needed to accomplish the aims of the mission. Satellites designed to probe the high atmosphere, for example, require low orbits, whereas highly eccentric trajectories, carrying a spacecraft far away from the earth, are needed to investigate the boundary between the earth's environment and interplanetary space. On the other hand, continuous meteorological observations on a global scale can best be performed from a satellite in geostationary orbit.

The constraints arising from celestial mechanics have the greatest impact on the feasibility of the space system to be implemented. The basic problem to be solved is: at what time and at what point in space which velocity vector must be imparted to the probe to ensure that none of the constraints are violated and the mission's aims are accomplished. The fundamental importance of celestial mechanics in mission analysis arises from the fact that the

$$\Delta_{33}\underline{E}$$

$$\Delta_{33}i = -\frac{5}{16}\frac{\mu_k}{\mu}\left(\frac{a}{P_k}\right)^5 \frac{T^2}{\sqrt{1-e^2}} \Bigg\{ 3\left[\frac{\pi}{3}\left(1+\frac{41}{4}e^2+\frac{9}{2}e^4\right)+\frac{1}{\pi}\left(\frac{1}{2}-16e+\frac{31}{32}e^2-\frac{4256}{225}e^3-\frac{85}{48}e^4+\frac{112}{45}e^5+\frac{3}{8}e^6\right)\right]\cos\ \omega\frac{d^2\delta_5}{dt^2}$$

$$-3(1-e^2)\left[\frac{\pi}{3}\left(1+\frac{3}{4}e^2\right)+\frac{1}{\pi}\left(-\frac{1}{2}-\frac{15}{32}e^2+\frac{256}{225}e^3+\frac{5}{24}e^4\right)\right]\sin\ \omega\frac{d^2\delta_4}{dt^2}-7\left[\frac{\pi}{3}\left(\frac{3}{4}+9e^2+6e^4\right)+\frac{1}{\pi}\left(\frac{17}{32}-\frac{1072}{75}e\right.\right.$$

$$\left.\left.+\frac{55}{24}e^2-\frac{352}{15}e^3-\frac{15}{4}e^4+\frac{16}{3}e^5+e^6\right)\right]\cos\ \omega\frac{d^2\varepsilon_6}{dt^2}+21(1-e^2)\left[\frac{\pi}{3}\left(\frac{1}{4}+\frac{3}{2}e^2\right)+\frac{1}{\pi}\left(-\frac{1}{32}-\frac{128}{75}e-\frac{65}{48}e^2+\frac{128}{45}e^3\right.\right.$$

$$\left.\left.+\frac{5}{8}e^4\right)\right]\left(\sin\ \omega\frac{d^2\varepsilon_7}{dt^2}-\cos\ \omega\frac{d^2\varepsilon_8}{dt^2}\right)+7(1-e^2)^2\left[\frac{1}{4}\pi+\frac{1}{\pi}\left(-\frac{15}{32}+\frac{128}{75}e+\frac{5}{12}e^2\right)\right]\sin\ \omega\frac{d^2\varepsilon_9}{dt^2}\Bigg\}$$

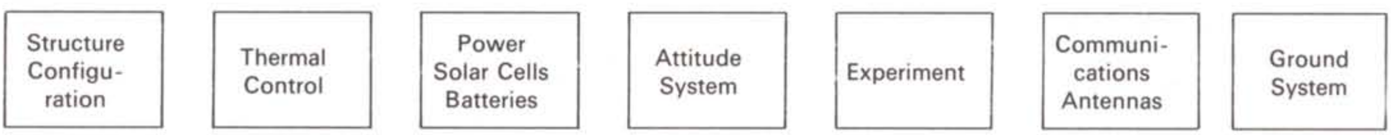
Figure 1 – Analytical perturbation theory in celestial mechanics can reduce computer requirements for mission analysis to only a few hours. The expression shown, part of the inclination perturbation, provides an indication of the underlying algebra.

equations of motion govern a deterministic system. From the theory of differential equations, it follows that a unique solution for the trajectory exists and can be computed, given the initial values. The most striking illustration of trajectory prediction is the question of stability for highly eccentric orbits under the effect of luni-solar perturbations. Under all circumstances, the perigee must always remain above some threshold altitude during the desired mission lifetime, which will otherwise be cut short by re-entry of the satellite into the earth's atmosphere. Such behaviour, as distinct from perpetual Kepler motion along an ellipse, may be a result of the underlying four-body problem of celestial mechanics, involving the satellite itself, the earth, the sun and the moon. The calculations rely on data sets holding ephemerides of these celestial bodies. Apart from the luni-solar perturbations, the marked deviation of the earth's gravity field from full spherical symmetry must be taken into account in computing the satellite's motion, including the flattening and higher order irregularities. Apart from straightforward integration, using advanced numerical methods, sophisticated analytical solutions have been developed in celestial mechanics which reduce the computer time needed to calculate launch windows, for example, from hundreds of hours to no more than a few hours (Fig. 1).

A more detailed breakdown of the relevant features of the spacecraft into subsystems helps one to appreciate the implications of trajectory selection for the various subsystems. There are a large number of interrelations, many via the trajectory.

The aim in any mission is, of course, not to achieve just a workable system, but an optimised one. When the overall mass to be put into orbit is considered, for example, the total mass of all systems required in space to fulfil the mission is limited by the payload capability of the launcher available. Moreover, the trajectory into which the launcher inserts the spacecraft must be compatible with all other constraints. Although the differential equations of motion will have a unique solution, a further complication has to be considered for the launcher, as neither the nominal injection point nor the required velocity at burnout of the last stage can be predicted with absolute accuracy; consequently, launcher 'dispersions' must be taken into account. The real trajectory will lie, with a certain probability, within a more or less sharply defined set. All possible orbits reached in this way must be in line with the mission constraints.

The hardware structure and configuration of the spacecraft must be compatible with its orbit, as regards distribution of solar cells, attitude sensors, pointing direction of experiment and antennas, etc., taking into account the various possible attitudes of the probe in space. The temperature, its changes and distribution within a spacecraft depend on attitude as well as on orbital characteristics. During attitude manoeuvres or encounters with the earth's shadow, transients will occur. Subject to some idealisation, the points of intersection of the probe in a Keplerian orbit with the shadow and their times have to be computed; the shadow may be cylindrical, or conical if umbra and penumbra are to be distinguished in a more refined analysis. Incidentally, the



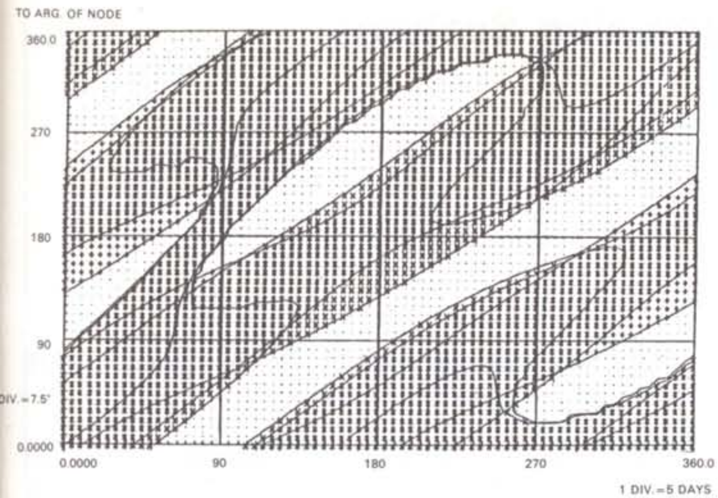


Figure 2 – Launch window into transfer orbit for a synchronous satellite, open in the lightly dotted regions which comply with all constraints.

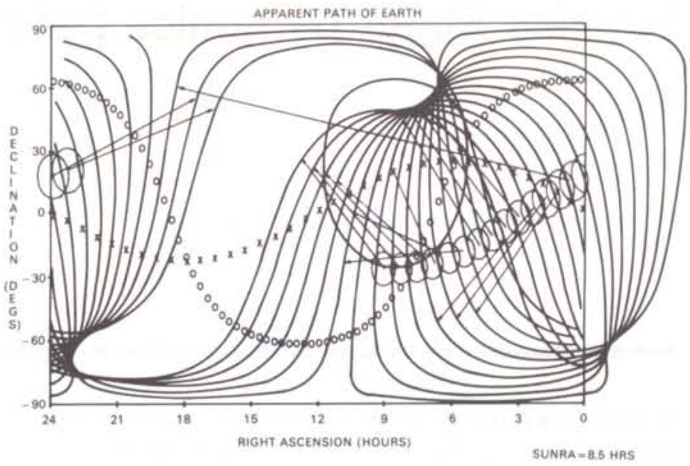


Figure 3 – Computer graphics generates the regions of sky obscured from a satellite in orbit. The envelope of the occulting earth's disc, enlarged by a safety zone, and the hazard caused by the sun are shown.

same occultation software can be used to calculate the rising and setting times of satellites orbiting other planets as seen from the earth in the case of interplanetary missions. Here the ephemeris data of the planet involved are required as an input. For the eclipses of terrestrial satellites, the solar ephemeris is sufficient. Obviously, data sets containing the solar and lunar co-ordinates have to be available anyway to calculate the orbital perturbations in the four-body problem of celestial mechanics involving the earth, satellite, sun and moon.

Eclipse behaviour has serious repercussions for the satellite's power subsystem. Whilst the spacecraft moves in shadow, its solar cells do not generate power and batteries have to be carried to bridge the gap, causing a considerable increase in satellite mass. During operation of the satellite, energy can be saved by switching off part of the equipment. After some initial trade-offs, at some stage in the project a maximum tolerable eclipse duration can be specified. The subsequent mission-analysis studies then have to discard any orbits which at some point in the mission would lead to eclipses exceeding this limit.

To take another example, still related to power supply, we can consider a satellite with spin-stabilised attitude and solar cells on its cylindrical surface. During injection into orbit, the satellite's spin axis will be co-linear with that of the launcher. Ideally, it should be at right angles to the sun's direction so that not the top of the satellite, but the solar cells on its circumference are illuminated, to guarantee optimal power production. Although some tolerance in this ideal direction (typically about $\pm 30°$) is acceptable, a considerable number of otherwise acceptable orbits have to be discarded for cell-illumination reasons.

Once all orbits violating the various constraints have been discounted during mission analysis, those remaining will constitute the set of permissible orbits. This set is then specified in the form of a 'launch window', giving the days and times at which lift-off may occur. In some cases, it proves very difficult to establish any feasible orbit at all, so that trade-offs have to be applied to reconcile conflicting requirements. Sufficiently separated opening and closing times for the launch window may be possible only on some days of the year. Computer graphics can be used to plot the launch windows automatically. The example in Figure 2 is for the transfer orbit of a geosynchronous satellite under realistic assumptions, including eclipses and solar aspect angle. The launch window situation is shown for one year and the ordinate gives the node of the orbit, the only parameter left, which is determined by the precise moment of the launch.

For the first day, the launch window can be seen to be open for node arguments in the range 80° to 135° with a further possibility between 250° and 300°. To convert these to time data, it must be remembered that the earth rotates through 360° every 24 hours, so that 15° correspond to one hour. Hence, the overall launch time available on the day in question will be about seven hours.

Any mission-analysis studies in support of project development, dealing with technology, research and applications, contribute in some way to the fulfilment of an eternal dream of mankind, namely to vanquish space and exert a degree of control over an ever-expanding environment. That this has now become possible in technological and engineering terms is due in no small part to the spiritual and intellectual accomplishments in earlier centuries of such illustrious Europeans as Copernicus, Tycho Brahe, Galileo, Kepler, Huygens, Newton, Euler, Lagrange, Laplace and Gauss. □

Satellite Flight Dynamics Data-Handling Systems

H. Kummer, Orbit/Attitude Division, ESOC

A satellite control centre requires information on the dynamics of the satellites it is handling, and it must therefore have at its disposal a data-processing system that receives tracking and telemetry data and produces satellite position and attitude data, including that needed for the preparation and monitoring of orbit and attitude manoeuvres. Specialised systems for these functions have been developed by and are used at ESOC.

The satellite orbit and attitude data handling systems that supported the first ESRO satellites were founded on sound theoretical knowledge, but only limited practical experience. Although the systems always served their purpose and no critical failures occurred during operations, their original structure was not always in keeping with the principles of modern data-handling concepts. They have however been improved with each successive satellite project, starting with ESRO-II and culminating, for the time being, with COS-B. Automatic task sequencing and data handling were introduced and by the launch of COS-B last year, the systems could compete in performance with ESOC's new Multi-Satellite Support System (MSSS). The latter, however, has two important additional features, namely the ability to support several satellite missions simultaneously and the possibility of easy extension for additional satellites.

The MSSS system has been designed on the basis of ESOC's experience in servicing nine previous satellites of very different types, supplemented by the anticipated operational requirements of the Agency's future applications satellites. Consequently, not only the reliability of the system has been increased, but also its degree of automation to allow low-cost operations for satellites with long lifetimes. In particular, considerable extensions have been made to the orbit attitude manoeuvre support subsystem, which now embraces all optimisation tasks usually encountered during the various phases of geostationary satellite operations. The new system, which can provide parallel services to between five and ten satellites, depending on their type, will be used for the first time under operational conditions for the Agency's GEOS spacecraft, to be launched next April.

In the following paragraphs the key functions of the four main subsystems of the orbit attitude system in the new MSSS will be described; these are the subsystems for orbit determination, attitude determination, orbit attitude manoeuvre support and that for monitoring the overall system (Fig. 1).

ORBIT DETERMINATION

The movement of a satellite in space can be described by tabulating its position as a function of time. To generate this table, a function is needed which allows the position of the spacecraft to be calculated at any moment in time. This function is provided by the theory of celestial mechanics and is usually known as the 'orbit generator'. In addition to time, as an independent variable, it contains parameters that characterise the form of the orbit, its orientation in space, and other quantities affecting the path of the satellite. The task of orbit determination is to calculate these and some other parameters appearing in the so-called 'measurement equations'. These latter equations provide a relation between the position of the satellite at a given time and the quantities that should be measured by the equipment tracking it, such as the distance between a ground station and the satellite. The orbit-determination process involves calculating the corrections that have to be applied to periodically update these slowly varying parameters. This is achieved by evaluating the differences between the tracking measurements and the corresponding quantities calculated from the parameters of an earlier orbit, using the orbit generator and the measurement equations. The corrections are varied systematically until the difference is so small that it can be explained by measurement errors and approximations made when deriving the orbit generator and measurement equation. This approach is usually called the 'differential correction method'.

We will now consider some typical elements of any orbit-determination subsystem in further detail (Fig. 2). The tracking data preprocessing converts tracking measurements into quantities corresponding to those generated by the aforementioned measurement equations. An

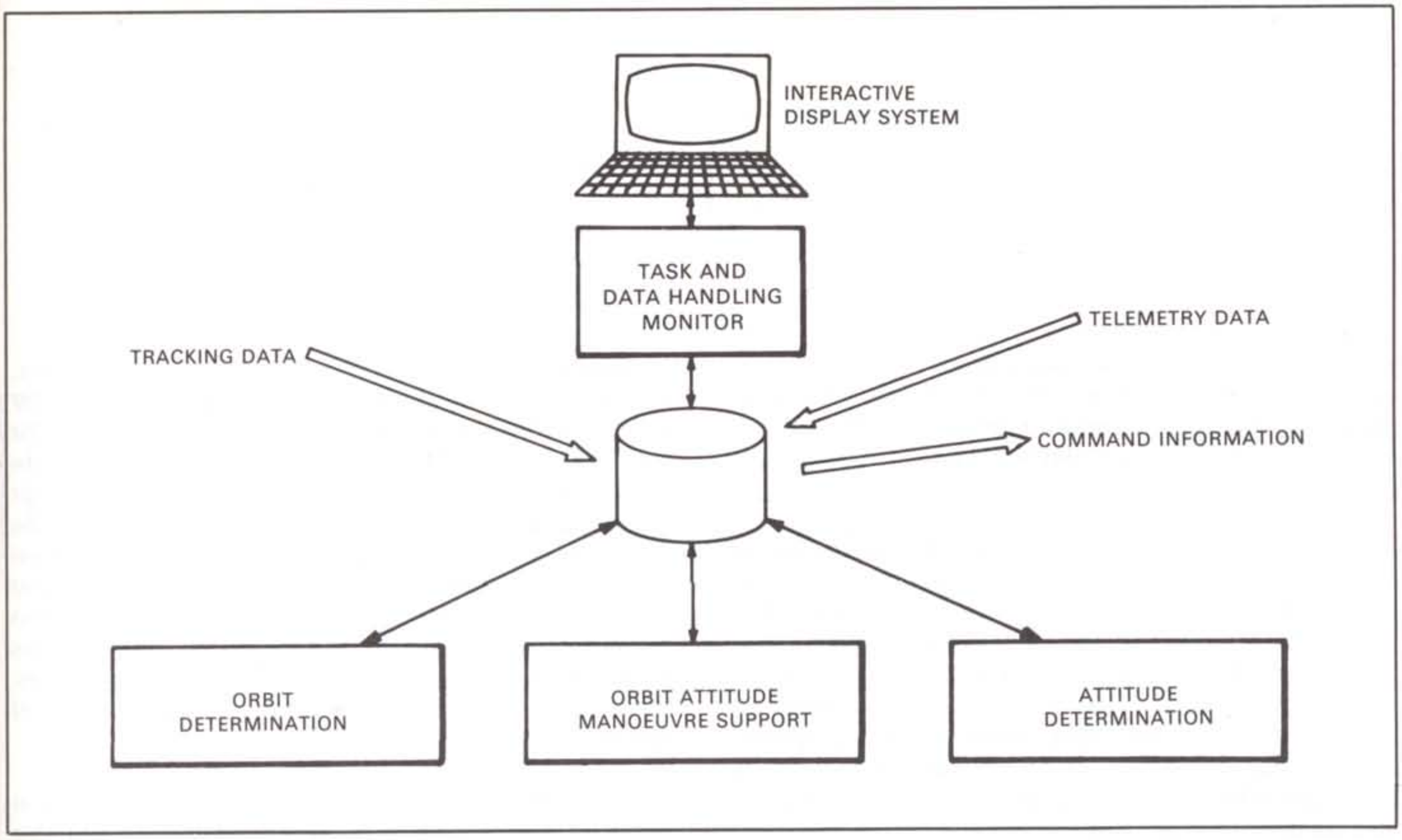


Figure 1 – MSSS orbit attitude system.

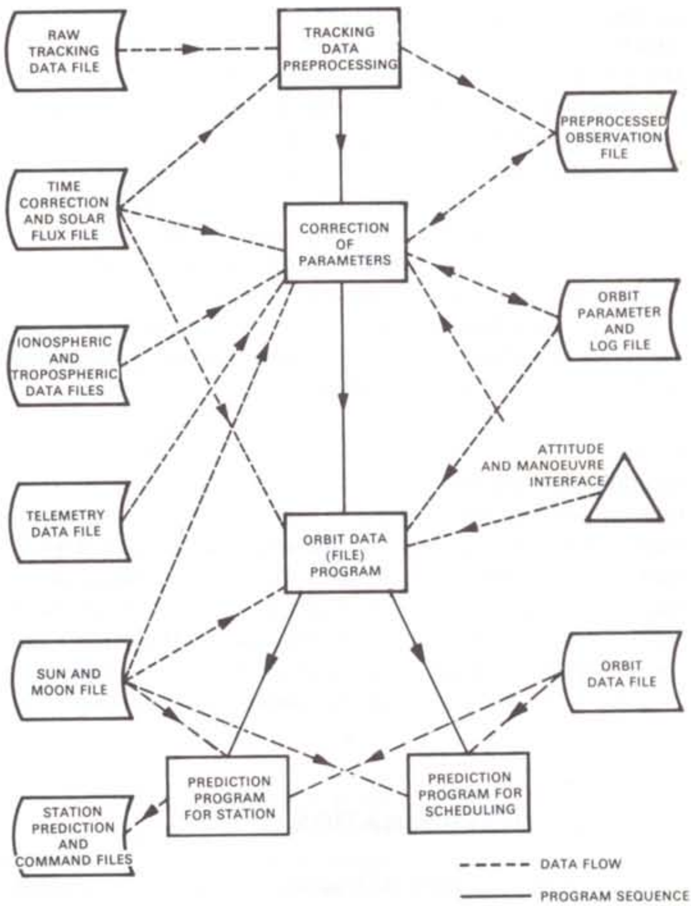


Figure 2 – MSSS orbit determination subsystem.

essential part of this preprocessing consists of proper smoothing by means of suitable mathematical functions, which also permit the rejection of incorrect measurements. Methods have been developed which make use *inter alia* of positional information about the satellite from previous orbit determinations.

During 20 years of spaceflight, a number of different tracking systems have been developed, and an advanced tracking data preprocessing system must therefore be able to handle data from a variety of equipment. The MSSS orbit determination subsystem processes different types of interferometer data (i.e. the measurement of the angle between the tangent plane to the earth's surface and the station – satellite direction), Estrack tone ranging data, different types of S-band ranging data, and range and range rate data from Goddard Space Flight Center.

The accuracy of the orbit-determination process depends primarily on the accuracy, distribution and number of the measurements and on the location of the tracking stations with respect to the satellite orbit. Equal attention must be paid, however, to the orbit generator and the measurement equations. In ESOC, generators have been developed which use as basic elements the classical Keplerian elements, the so-called equinoctial or other elements, as well as the cartesian co-ordinates at an epoch, the most suitable elements for the determination process or the orbit generator depending on the type of orbit (elliptic or circular, inclination large or almost zero) being considered.

Additional determinable parameters in the generator are those describing molecular drag, radiation pressure and the influence of orbit and attitude manoeuvres. The measurement equations contain determinable parameters that represent errors in ground and on-board tracking-system components, in tracking-station co-ordinates, in timing and in the models that characterise the ionospheric and tropospheric states. The co-ordinates of the earth's poles (polar motion) and universal-time corrections can also be taken into account.

The correction of such elements is followed by an updating of satellite positional predictions, the accuracy of which depends on the quality of the orbit generator and the predictability of the parameters. In particular, those representing molecular drag may, in the case of near-earth satellites, lead to considerable deviation of the real orbit from that predicted. Protracted experience in the use of quantities describing and predicting the state of the magnetosphere, as published by various institutions, has, however, served to reduce 'unforeseeable events' to a minimum, so that typical accuracies for time-along-track predictions are now 10 sec/week in the case of near-earth satellites and one order of magnitude better for satellites with perigee higher than 1000 km.

Typical 'users' of the predicted satellite positions are the satellite attitude-determination modules in as far as they make use of earth sensors, all orbit and attitude manoeuvre preparation modules and those units in ESOC that have to prepare station activities and therefore need accurate satellite-pass predictions. Finally, all information on the position of the satellite throughout the lifetime of the payload must be made available to the units that operate the payload and to those that evaluate its performance.

ATTITUDE DETERMINATION

For most missions, attitude stability of the satellite in orbit is essential. It can be achieved by active control systems, which usually act about all three satellite axes, or by passive systems employing gravity gradient, magnetic or spin stabilisation. The latter methods require extensive ground support for attitude determination, whereas for actively controlled satellites ground tasks can normally be restricted to control monitoring. Of the passive control methods, spin stabilisation has been most important, and for the time being the MSSS attitude determination subsystem will contain in addition to the modules necessary to support three-axis stabilised satellites, means of determining the spin axis and nutation angles of spinning satellites.

The spin-axis direction of a satellite can be expressed in terms of two angles in a suitable inertial co-ordinate system. It is not determined by using ground measurements as in the case of orbit determination, but by evaluation of on-board measurements acquired by a suitable sensor system, usually of the angles between the spin axis and the sun and earth directions. These angles define two cones, one about the sun-satellite line and one about the earth-satellite line. The lines of intersection of these two cones give solutions to the attitude-determination problem. As the spin-axis direction varies only slowly, a differential correction process similar to that applied for orbit determination may be used. Consequently, information obtained from a large number of measurements can be utilised and statistical techniques applied to obtain best estimates.

The principal elements of the MSSS attitude-determination subsystem are shown in Figure 3. As in the case of the tracking-data preprocessing described earlier, the attitude measurements received with the satellite telemetry have to be converted into angles and 'smoothed'. This process can take into account such parameters as the triggering delays in or geometrical misalignments of the sensors, and system errors of a similar nature. This part of the attitude determination subsystem is the only element which is satellite specific as telemetry formats and decoding mechanisms differ for different satellites. All other elements are largely satellite-independent.

As regards the attitude-determination methods proper, the requirements of satellite operations support dictate

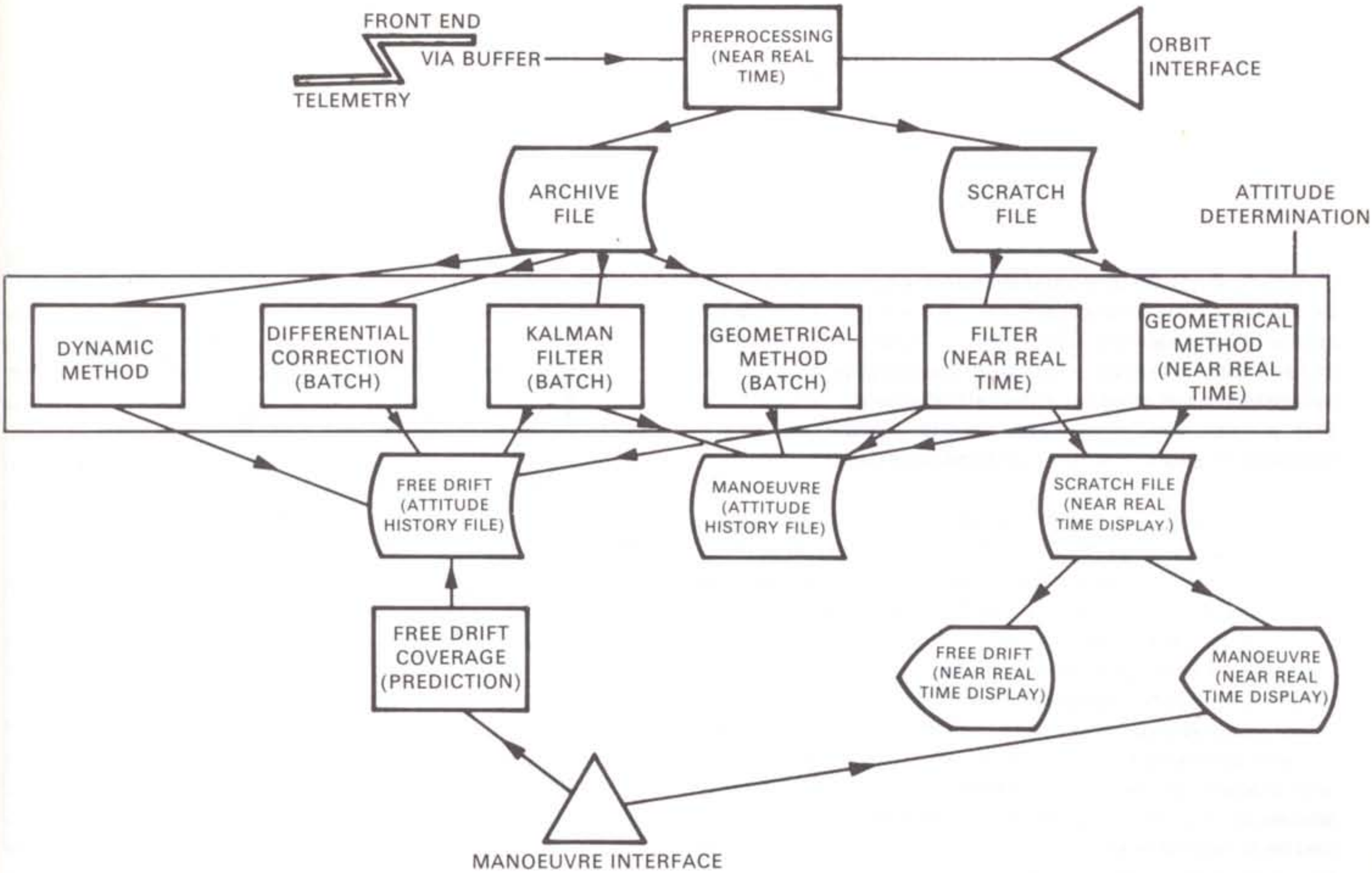


Figure 3 – MSSS attitude determination subsystem (spin-stabilised satellites).

that basically two different attitude-determination methods must be implemented. These are sequential methods, which allow spin-axis direction to be determined in near real time (e.g. for monitoring an attitude manoeuvre) and methods based on a series of measurements covering a certain period of time, usually called batch methods. The MSSS attitude-determination subsystem contains two types of sequential method: the geometrical method, which works directly from each set of on-board sun and earth direction measurements, and a so-called filter method which allows the application of statistical techniques. As far as the batch method is concerned, both the differential correction and a filter method are implemented.

ORBIT AND ATTITUDE MANOEUVRE SUPPORT

The majority of modern satellites rely on on-board equipment for modification of their dynamic state. In the case of orbit manoeuvres, the pertinent activities are always initiated from the ground, whereas attitude manoeuvres are either performed automatically on-board, or manually and semi-automatically from ground facilities.

The thruster configurations of spacecraft do not usually allow pure torques and pure forces to be applied to the satellite in isolation, so that in principle orbit and attitude manoeuvres cannot be treated independently. For most manoeuvres the two are nevertheless regarded as 'decoupled' to reduce the inherent mathematical problems. The influences of torques and forces are then taken into account consecutively, rather than simultaneously.

Orbit manoeuvres are performed to change the shape of an orbit and the orientation of its plane in space and in most cases also to achieve a new predetermined satellite position at a particular moment in time. A manoeuvre preparation subsystem must therefore predict appropriate thrust levels and directions as functions of time to be applied to the satellite. There are normally a large number of such thrust functions that fulfil the conditions, and the subsystem must select mathematically those possibilities that do not violate operational and satellite hardware constraints and consume a minimum of fuel.

A special case of orbit manoeuvre support is the optimisation of apogee boost motor firing for geostationary satellites. Here, the thrust level is known but the timing and direction of the thrust have to be selected so as to minimise fuel consumption during the satellite's subsequent near-synchronous orbit. All algorithms used for thruster optimisation, and especially that for apogee boost motor firing, suffer from a lack of reliability in certain thruster performance parameters, such as exact direction and amount of thrust. Consequently, stochastic calculations expressing the probability with which a new orbit can be achieved without exceeding the fuel budget for the manoeuvre must also be considered.

Geostationary orbits have gained more and more in importance and the elements for orbit manoeuvre support in the MSSS are closely following this trend. These are modules for apogee boost motor firing optimisation and for optimising the strategy of orbit manoeuvres in the near-synchronous orbit. The latter task involves particular difficulties in the case of spin-stabilised satellites if the influence of attitude manoeuvres on the orbit cannot be neglected during optimisation. Techniques have been developed to consider and even take advantage of this effect, thus further reducing fuel consumption in near-synchronous orbit.

In addition to developing methods for choosing an optimal initial synchronous orbit, ESOC has also developed more general modules for the support of one-burn and two-burn station-keeping manoeuvres. The theory that had to be developed for their design will form the basis for studies on the optimisation of long-term station-keeping strategies.

Besides the aforementioned application to nominal missions, the orbit manoeuvre support subsystem is equipped for strongly non-nominal transfer orbits.

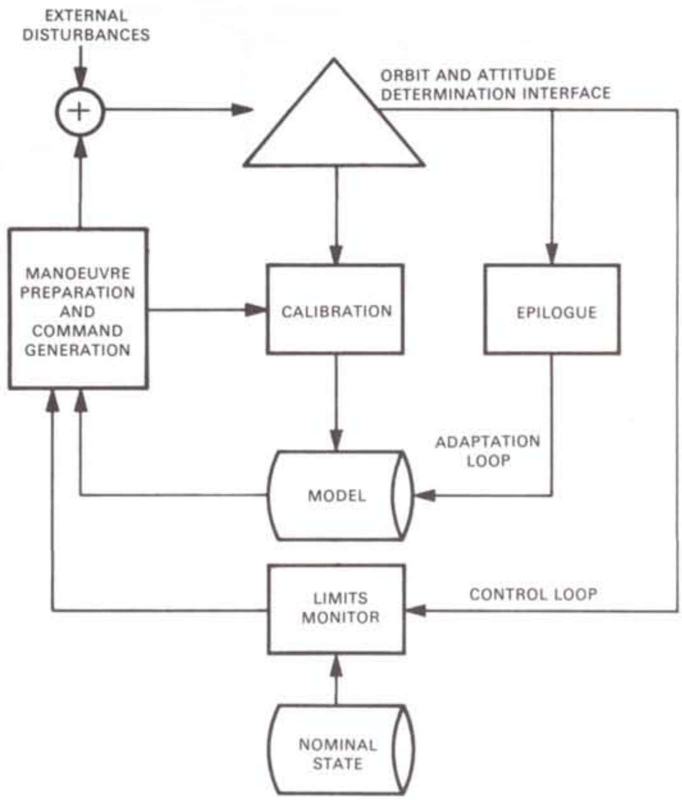


Figure 4 – Control flow for the orbit attitude control system.

Modules are available to prepare transfer-orbit perigee and apogee raising manoeuvres, the economy of the latter being checked against that of non-nominal corrections in the near-synchronous orbit. Furthermore, a module has been implemented for optimising the arrest of a drifting satellite at geostationary altitude by a series of one-burn manoeuvres.

Contrary to orbit manoeuvres, attitude manoeuvres do not usually lend themselves to studies of minimisation of fuel consumption, as the mode of turn for change of spin-axis direction is prescribed by the thruster system and its control features. The on-board manoeuvring systems usually rely on pulsed operation of the thrusters, triggered once per revolution at a certain phase angle with respect to the sun crossing of a certain satellite meridian. During a manoeuvre supported by this system, the trace of the spin-axis direction on the unit sphere follows a 'rhumb line', or 'loxodrome' characterised by constant angles to all meridians crossed (unit sphere with the sun at the north pole). This line does not, however, constitute the shortest distance between two points on this unit sphere, which is established by a great circle. Lengthy manoeuvres which do not follow a meridan or the equator of the unit sphere are therefore conducted in several legs.

The task of preparing for a particular manoeuvre is undertaken by a number of different program modules, which are initiated either manually or by a limits monitor which checks automatically whether certain parameters, such as the longitude of the geostationary satellite, are within predetermined operational limits. The output of these modules is then transferred to a 'target strategy file' from which the necessary sequence of commands is obtained. These commands are transmitted (on or off-line) for checking and confirmation by the spacecraft controller. The command generator module requires as essential working information data on a number of parameters characterising the state of that satellite hardware that affects the manoeuvre preparation process, such as thrust levels, moments of inertia and misalignments in thrust direction. To improve knowledge of these parameters during operations, epilogue and calibration modules are activated after each manoeuvre which update their values (Fig. 4).

DATA PROCESSING ASPECTS

In the previous paragraphs, we have described the various elements of a satellite orbit attitude data-handling system as implemented at ESOC for both satellite and payload operations. The system has to be operated under certain constraints, largely established by three factors: the mission and subsequent Control Centre schedule, the restrictions imposed by the computer environment, and the need to operate the software economically. The first factor establishes, for example, which modules must work when, and therefore the proper sequence of module execution and which modules must be operated in parallel. The second constraint will dictate such conditions as which modules may be operated in parallel due to computer resource allocation and which can only be run in sequence. Finally, the economic aspect demands that system operations be performed at a minimum cost, which includes using as small a computer as possible.

A very efficient task handling subsystem must form part of basic system design; it must support such activities as priority handling, conditional task sequencing, task synchronisation, system recovery, job security and system monitoring. All of these are so specific to a particular application that the computer's basic software is not able to cope, and a task-handling subsystem specially adapted to satellite orbit attitude data handling has had to be developed for the MSSS system.

An orbit attitude data-handling system is not usually used for the processing of large amounts of data, but the critical role of the system in satellite operations during certain phases, e.g. the transfer orbit of a geostationary mission, necessitates a special effort to ensure secure and efficient data handling. This must encompass the organisation of data movements in connection with all types of data sets on tapes, disks and drums, those for alphanumeric and graphic displays, printouts and paper tape, as well as card input and output. The task-handling subsystem is therefore supplemented by modules for data handling, similar in design principle to those for task handling as regards the specific requirements for a satellite orbit attitude-data handling system as part of a satellite control centre.

CONCLUSION

ESOC's experience in the treatment of orbit and attitude data for the Agency's previous satellites and in the development of the pertinent data-handling systems has been fully exploited in the design and implementation of the new Multi-Satellite Support System (MSSS) which meets Control Centre and Payload Data Processing requirements for the next generation of ESA satellites. It has the capacity to support different types of satellites simultaneously and can be extended to serve new satellites at low cost. The system is largely automated in its functions and therefore economic in operation. It is based on modern theories for orbit and attitude determination, orbit and attitude manoeuvre optimisation and on advanced concepts of task and data handling. □

ESA Computer Facilities

K. Debatin, ESA Computer Department, ESOC

It is certainly not by chance that realisation of the ambitious spaceflight programmes of the last 15 years has coincided with a rapid development in computer technology and there is no doubt that these programmes would not have been possible without the help of the computer. Although ESRO's own computer requirements were relatively modest during the organisation's early years, between 1965 and 1972, when support was given to the ESRO-II, ESRO-IA, ESRO-IB, HEOS-1, HEOS-2 and TD-1 satellites, they have since grown rapidly with the increasing demands of later satellite projects – so much so that the computer systems currently in use by the Agency are valued at approximately 28 Million Accounting Units ($ 30 000 000).

Satellite Mission Support

The ground computing support for satellite missions, which constitutes about 80% of the Agency's overall computing work load, can be divided between three major tasks:

- support of mission and spacecraft control
- support of flight dynamics (determination and control of attitude and orbit)
- processing of satellite payload data.

The first of these three tasks represents the interactive services that must be provided in real time to monitor the performance of the systems on board a spacecraft. The flow of associated housekeeping data is normally relatively low, and therefore a minicomputer equipped with appropriate peripherals, including adequate disk storage for historical files, is sufficient in most cases to support this task. For back-up purposes, a second computer may be required as a stand-by, which can also be used as a test facility for future developments.

Flight dynamics support is normally provided by a general-purpose computer of medium size. In addition, there must be sufficient back-up capability to cover critical periods of spacecraft operations, for example during the transfer and near-synchronous orbital phases of geosynchronous missions (GEOS, OTS, Marots and Meteosat).

The third task, the processing of payload data, includes the correlation of payload data with auxiliary data such as attitude and orbit parameters, the formatting of the data, its evaluation, and the dissemination of the resulting data to the users (customers). The processing requirements are defined by the volume of data to be handled, the degree of evaluation needed, and the mode of operation (real time, interactive, etc.) and they vary considerably from mission to mission. For OTS and Marots, for example, they are relatively small, whereas Meteosat requires a large dedicated computer system.

General Support

General computing support, which accounts for the remaining 20% of ESA's computing, is associated with studies and simulations, and with the development of aids and methods in data processing and space dynamics. It also includes the computerised support of the Agency's financial and personnel management information systems (PMC, FMS, PPPF).

The RECON information retrieval system at ESRIN can also to be regarded as belonging to this category.

CONCEPT OF THE GROUND COMPUTER CONFIGURATION

The configuration of the seven major computing systems currently being used by ESA is shown in Figure 1. They are:

- an ICL 4/72, at ESOC
- an ICL 4/72, at ESTEC
- a network of two CII 10070's, eight Siemens 330's and special hardware to be used as a Multi-Satellite Support System (MSSS), at ESOC
- a network of two ICL 2980's, six Siemens 330's, two Nova 830's and special hardware making up the Meteosat Ground Computer System (MGCS), at ESOC

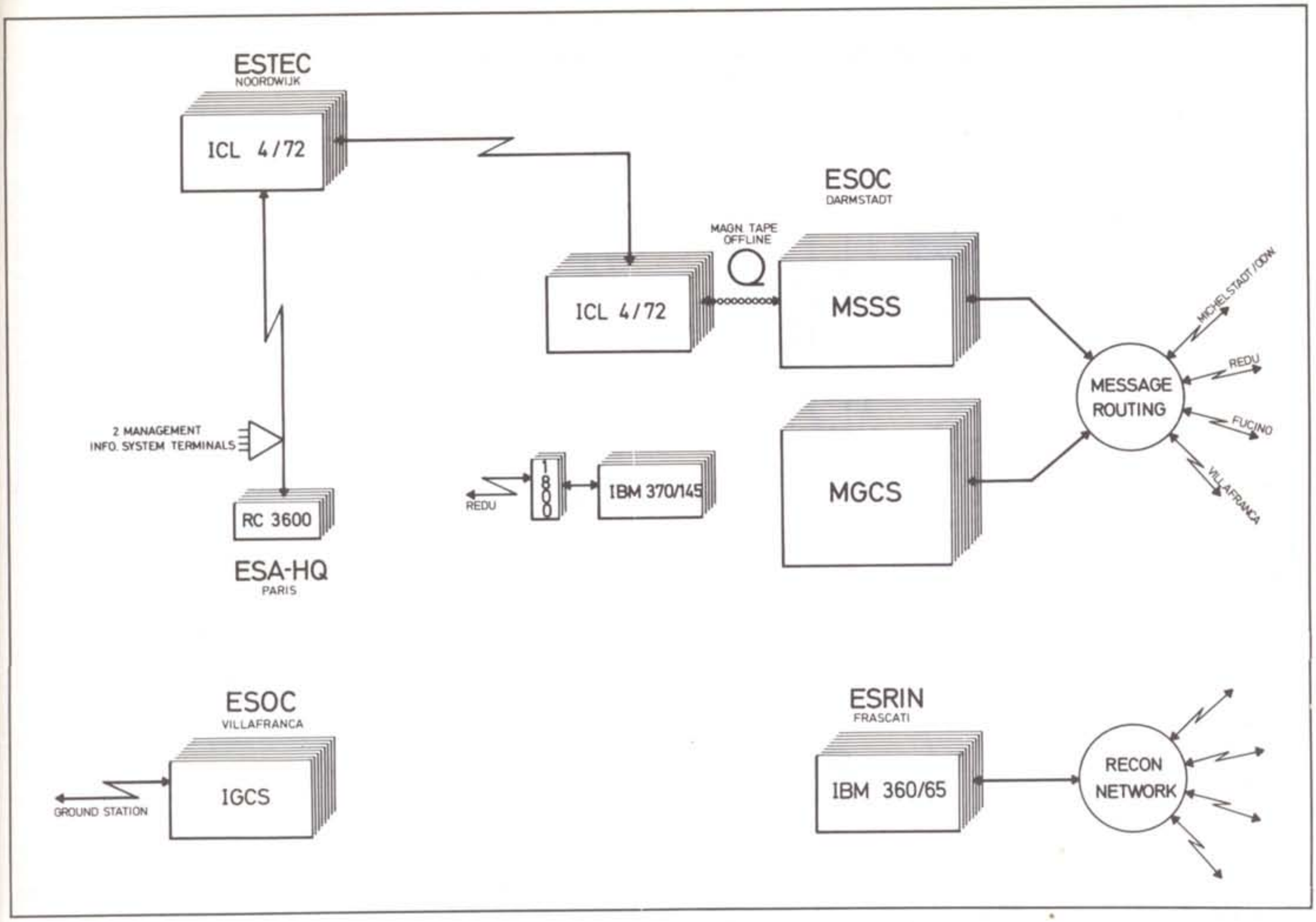


Figure 1 – ESA computer configuration in 1976.

- a Sigma 9, model 3 to be used as IUE Ground Computer System (IGCS), at the Villafranca ground station
- an IBM 370/145 – 1800, dedicated to the support of COS-B, at ESOC
- an IBM 360/65 dedicated to the support of RECON, at ESRIN.

Two fundamental criteria have determined the nature of the overall configuration:

(i) From a technical and operational point of view, it is desirable to separate the real-time data processing from those applications not subject to the constraints of an orbiting satellite, and hence to distinguish between computer systems 'on-line' and 'off-line' to the spacecraft.

(ii) The second criterion stipulates the centralisation of computing power, which normally results in a better cost/performance ratio.

In addition, the Agency's procurement policy of supporting European industry has favoured a configuration based on medium-sized computers, as Europe has effectively only been competing in the large-scale-computer market since 1975.

The move of the Space Documentation Service to Frascati, together with the expansion of the RECON network itself, called for a dedicated IBM 360/65 installed at ESRIN. The computer at the IUE ground station in Villafranca had to be a Sigma 9 for reasons of compatibility with NASA.

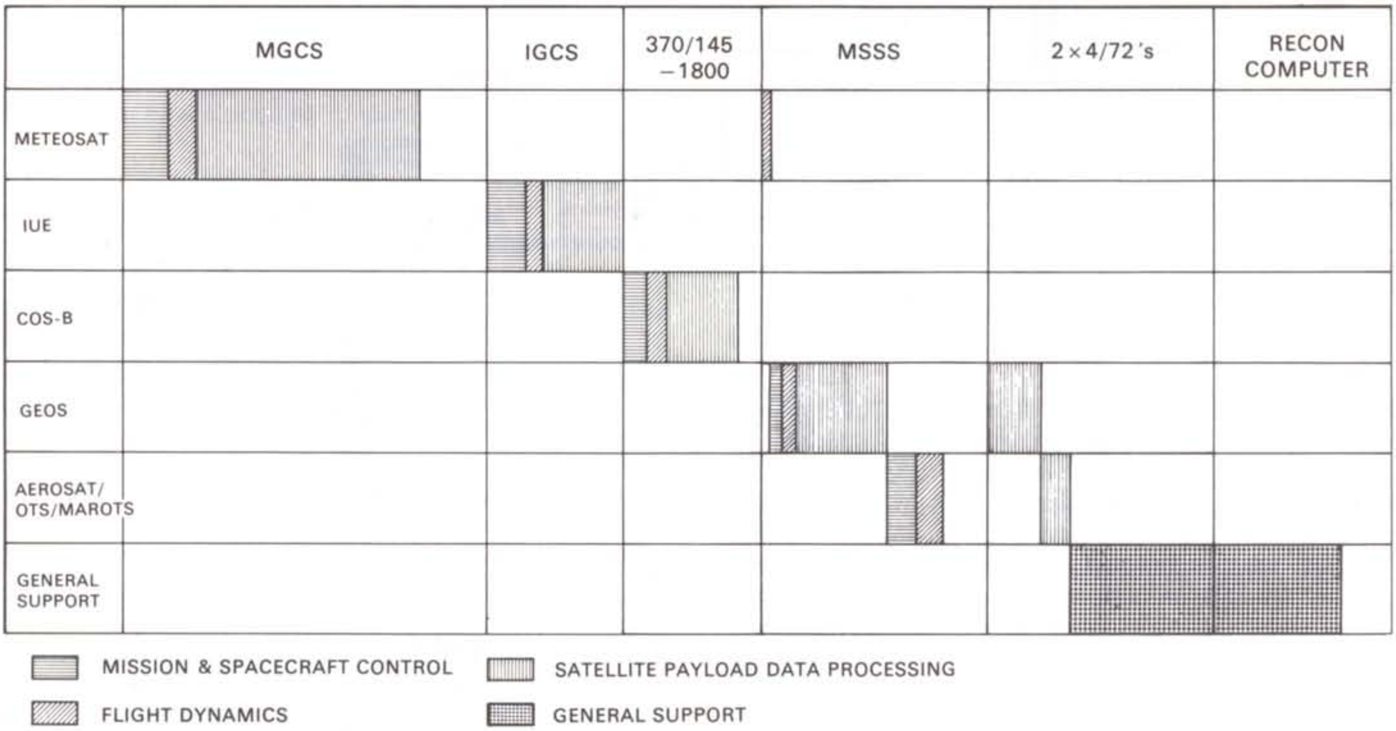
Table 1 provides an indication of the expected utilisation of the computer systems allocated to the various Agency projects in support of mission and spacecraft control, flight dynamics, satellite payload data processing and general applications, in the period 1976 – 1979.

INSTALLATION OF EXISTING COMPUTER FACILITIES

All of the computer systems now in use have been

TABLE 1

Computer System Utilisation (averaged over period 1976–79)



acquired within the last two to three years. Installation of the two ICL 4/72's and the implementation of the Multi-Satellite Support and Meteosat Ground Computer Systems proved to be rather difficult undertakings and deserve special mention.

The two 4/72 machines replaced two IBM computers used as off-line systems. The changeover necessitated the conversion of the software in use by the Agency, and some additional program support packages and language processors had to be developed to match the level of computer support that had previously been provided. This presented the computing centres and the users with quite a challenge in that very few comparable hardware changeovers had previously been attempted in Europe.

To facilitate the changeover, the ICL 4/72 and IBM machines were operated side by side for an overlap period of 4-5 months, until early 1975, by which time the two 4/72's had achieved a satisfactory standard of operation. Major difficulties were encountered in converting the financial and personnel management information systems, while the conversion of some mathematical programs for high-precision computations caused problems because of the somewhat lower accuracy of the arithmetic unit of the ICL machines.

The experience gained as a result of the changeover has shown that the state of the art of software portability as reflected in numerous publications is of little practical relevance. Rather, the following guidelines should be applied:

- Critical software modules should be rewritten rather than submitted to the conversion process. (Modules should be identified as critical when they are strongly computer-system dependent, or when they involve numerically sensitive computations if the target machine has a lower arithmetical accuracy.)
- The software should be properly documented prior to conversion (this is vital if the programs are not to be converted by their authors).

The difficulties encountered during the installation of the MSSS and MGCS networks were associated with the development and the integration of the numerous special hardware and software components, and with the integration of the different standard computer systems into a homogeneous network. The lack of a common international standard for computer/computer interfaces made implementation of the two networks particularly difficult. It was also very much complicated by the low reliability which the standard computer systems have shown as a result of their limited European customer base.

Nevertheless, much valuable experience has been gained in ESOC as a result of the installation of the MSSS and MGCS systems, which in complexity reach far beyond the relatively simple data-processing tools previously used to support ESRO's satellite missions. A comparable gain in experience has undoubtedly accrued to European industry, in the course of the changeover.

DESCRIPTION OF THE COMPUTER SYSTEMS

ICL 4/72's

The two ICL 4/72 machines, at ESOC and ESTEC, are used for general data processing and to satisfy those requirements not associated with the real-time support of satellite missions.

Each of the two systems, which are linked together (via a leased 4800 baud line) for load-sharing purposes, has 1 Mbyte of core storage, a disk storage capacity of 660 Mbytes, and is equipped with magnetic tape units and other peripheral devices. Some 25 terminals are attached to each system to provide a conveneint man/machine interface for users at both sides.

Users at ESA's Paris Headquarters have access to the two systems via four interactive terminals and a remote job-entry station.

Multi-Satellite Support System (MSSS)

The MSSS has been configured to perform time-critical transfer-orbit operations for geosynchronous satellite missions, including GEOS, OTS, Marots, Meteosat and Aerosat. In addition, it will support routine GEOS, OTS, Marots and Aerosat spacecraft operations, and GEOS experiment data processing to the extent that this must be carried out in real time. The MSSS will be linked directly with the ground station at Michelstadt, Redu (GEOS), Fucino (OTS), and Villafranca (Marots, Aerosat). During transfer-orbit operations, additional stations will be temporarily linked with the system.

The system, shown in Figure 2, consists of a network of six Siemens 330 computers (HS1, HS2, OP1, OP2, DT1,

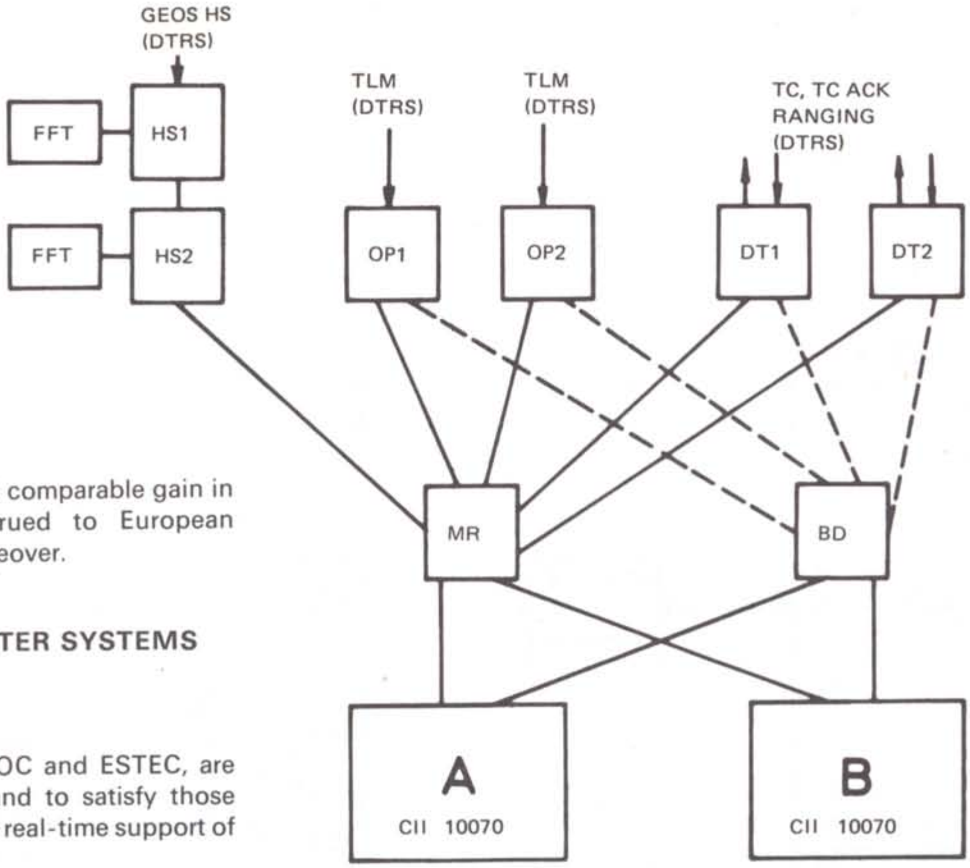


Figure 2 – The MSSS computer configuration.

DT2) as a 'front end' to two CII 10070's (A and B). Two additional Siemens 330's are used as a 'back-end' (BD) to the 10070's and as a Message Router (MR), which monitors the network and registers breakdowns in the system. The star concept makes the system very flexible and temporary reconfigurations required as a result of a partial breakdown, for example, can easily be arranged by appropriate re-routing of the data paths through the Message Router. An additional computer can be added to the configuration simply by adding another connection to this Router.

The Message Router is backed-up by the 'back-end' (BD) computer which in normal mode drives some graphical devices attached to both 10070's. The HS1 and HS2 machines are dedicated to the S300 experiment on GEOS, and will receive and process telemetry input data at a rate of some 100 kbit/sec. Both are supported by a Fast Fourier Transform processor (FFT) supplied by Logica. A magnetic tape unit attached to HS1 archives all data received for selection for subsequent processing on the ICL 4/72.

Computers OP1 and DT1 are mainly dedicated to spacecraft monitoring and control tasks. OP1 is used for telemetry data acquisition and preprocessing of house-

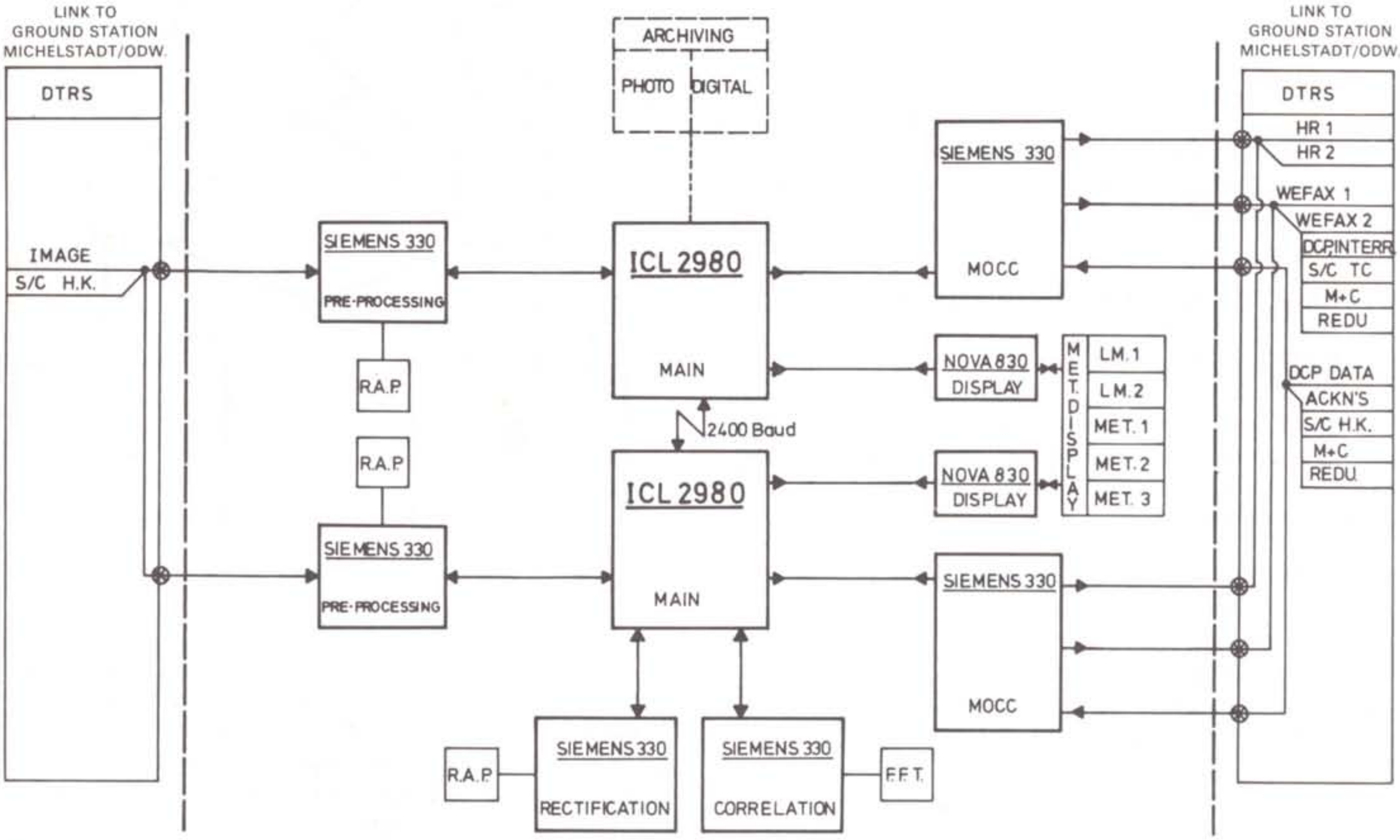


Figure 3 – The MGCS computer configuration.

keeping data and GEOS low-speed data, while DT1 provides for display and telecommand handling. OP2 supports special operations (e.g. attitude/orbit manoeuvres) and will also be used for parallel software developments and as a back-up for OP1. DT2 will back-up DT1 and will also be used as a software test and maintenance facility.

A set of 12 interactive display terminals with hardcopy devices can be switched between DT1 and DT2. The terminals provide the interface to the users who monitor the performance of the systems and experiments on-board the spacecraft.

The two 10070's have been configured symmetrically. One will be used for support of flight dynamics, and one for the processing and evaluation of the GEOS experiment data in near real time.

Implementation of the MSSS has required a considerable investment in special software, and the following developments merit mention:

- An interactive terminal system with time sharing (roll-in/roll-out) capabilities to support the terminals attached via the 330's to both 10070's.
- Additions to the 10070 operating systems to provide 'subtasking'.
- A message routing and network monitoring system.
- A graphical support package for three different types of graphical devices.
- Various network utilities.
- A CPL/1 cross compiler and a cross assembler for the 330's.
- A special operating system for HS1 and HS2.

The software has been designed and specified by the

Agency and has been implemented partly in-house and partly under contract.

Meteosat Ground Computer System (MCGS)

The MGCS will perform the processing tasks associated with the Meteosat Ground Facilities, including the Meteosat Operations Control Centre (MOCC), the Data Referencing and Conditioning Centre (DRCC) and the Meteorological Information Extraction Centre (MIEC).

The configuration of the system, which is linked directly with the Michelstadt ground station, is shown in Figure 3. It comprises two large ICL 2980 computers, six Siemens 330 satellite processors, and other dedicated hardware. Two Nova 830 minicomputers drive interactive displays provided by CIT Alcatel. A digital and photo archiving subsystem from Christian Rovsing will be added in 1977.

The links between the various computers of the system allow for data transmission rates of 200 000 byte/sec. All satellite computers can be switched between the two main computers, thus allowing reconfiguration in the case of a partial system breakdown.

The two 2980's will monitor the data flow between the various computers of the configuration and will maintain a common data base. In addition, they will perform the bulk of the processing tasks associated with surveillance of the mission, together with the handling of the preprocessed image data and the support of the MIEC.

The two Siemens 330's at the front end of the system will accept and pre-process the image data in a stand-by configuration, and for this purpose both are reinforced by special array processors with very fast multiply/add arithmetic (0.3 μsec), from Christian Rovsing. The two 330's at the back-end of the system will be used to monitor the spacecraft and control dissemination of the processed data via the satellite.

Two further Siemens 330 computers, backed by a special Rovsing processor (rectification) and by a hard-wired Fast Fourier Transform (correlation), perform specific computations involved in the rectification and correlation of image data.

The display subsystem consists of three 'MIEC consoles' and two 'landmark consoles' driven by two Nova 830 computers. Each of the MIEC consoles includes an image display.

The archiving subsystem will include two high-density tape recorders to store all image and associated auxiliary data, arriving at a rate of 35 Mbytes per half hour. The subsystem will also have a photo-recorder for the high-speed production of accurate photographs.

IBM 370/145

This computer is dedicated to COS-B, supporting spacecraft control and performing orbit and attitude determinations. Payload data is processed in two modes: the 'Fast Routine Facility' provides results within 24-48 hours of data-acquisition, while in the delayed mode detailed results are produced in a 4 to 8 month cycle.

The 370/145 is linked with the Redu ground station and is connected to the telemetry chain by means of a front-end processor (type 1800) which also supports the spacecraft control devices. The fast memory has a capacity of 1 Mbyte and the disk storage is 10^9 bytes. Five magnetic tape units are used for dissemination of the processed experiment data.

IUE Ground Computer Support System (IGCS)

The IUE system will be operated continuously, the first 8 hours in every 24 being dedicated to spacecraft control and manoeuvres associated with identification of the target stars in the sky and with the subsequent image data acquisition. For the remaining 16 hours, the system will support the processing and reduction of image data.

The IGCS system has been configured to be compatible with NASA's ground computing system for the IUE mission. It consists of a medium-size Sigma 9 computer, equipped with 512 kbytes of core storage, with 100 Mbytes of disk storage, and some additional peripheral devices. The Bendix image display subsystem attached to the Sigma 9 merits special mention here. It consists of two TV-like displays, driven by two minicomputers (PDP 11/35's), which will allow the astronomers to identify their target star, and facilitate interactive reduction of the spectra received from the satellite.

RECON Computer

Some 30 dedicated terminals and 300 dial-up terminals throughout Europe have access to RECON's data bases, which are stored in a dedicated IBM 360/65 at ESRIN, in Frascati (Italy).

The RECON computer has been configured to provide sufficient input/output performance and storage capacity (1 Mbyte) to support the system. It is equipped with one multiplexer channel and three selector channels, with a transfer rate of 1.2 Mbyte/sec each. The two communication controllers can cope with 20 high-speed (2400 baud) lines and 38 low-speed lines. Its most remarkable feature is the capacity of the direct-access storage; 8 data cells are currently employed with a total on-line capacity of 3.2×10^9 characters. In addition, two fast drums and disk storage are attached with a capacity of 1.6×10^9 characters.

Figure 4 – ESRIN's computer room.

FUTURE PROSPECTS

Significant parts of the present computer configuration (including MGCS and MSSS) will remain in use at least until the end of 1980. Changes to follow programme requirements will gradually be introduced, leading to a new configuration in the 1980's. This configuration will depend primarily upon the requirements of the Agency's future space projects and the way in which these projects are implemented. It will also be influenced by the developments in computer technology, where minicomputers and microcomputers will play an increasingly important role.

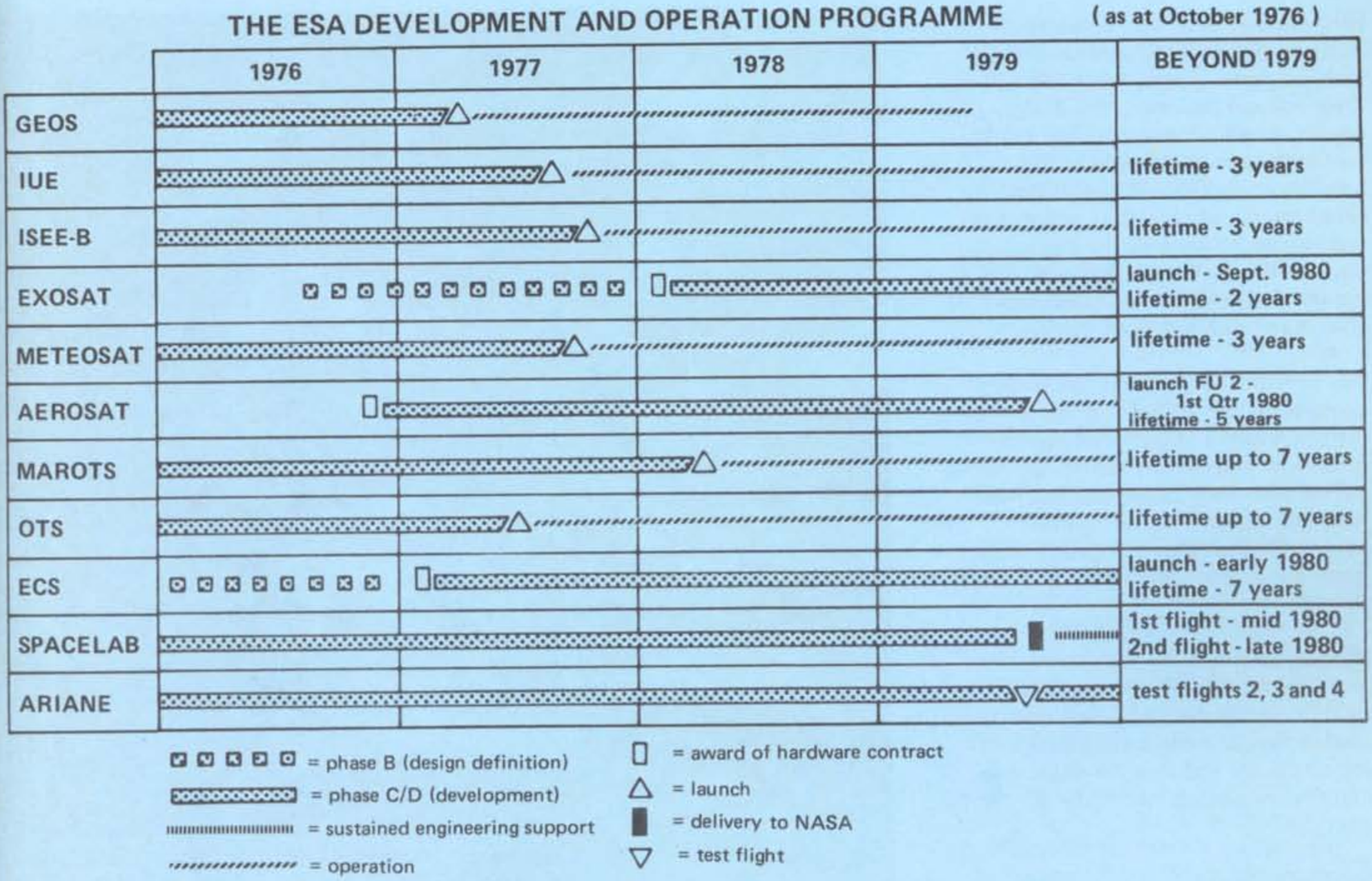
The support of space missions does not require the full range of facilities provided by the classical medium size or large computer for all functions. With the MSSS and MGCS, it has been demonstrated that spacecraft control, front-end functions, special input/output control functions and intensive and repetitive computations are most economically performed by minicomputers. Even the highly intensive computations involved in image processing cannot be carried out efficiently by large computers alone.

Undoubtedly, future support of spacecraft missions will be oriented towards increasing use of such mini- and microcomputers. The large computer will, however, remain indispensable in those areas that minicomputers cannot service in the foreseeable future – namely the management of large volumes of data and the provision of proper facilities for program development.

It would be of doubtful value to speculate further at this time on the Agency's computer configuration in the 1980's, but the trend favouring mini- and microcomputers at least gives us reason to believe that future investments will not need to be as high as those in the past. □

Projects under Development

Projets en cours de réalisation



GEOS

Programme status

The programme is well on schedule. The qualification model has completed all its formal qualification tests, and the first and major phase of acceptance tests for the flight model has been completed.

The *qualification model* has successfully undergone mass-properties-determination, vibration, separation shock, and spin acceleration testing.

The mass-properties programme included use for the first time of the sensitive vacuum facility at ESTEC for the measurement of inertia. The agreement between results and predictions was extremely good for all properties, including parameters critical for dynamic behaviour in orbit.

The series of vibration tests was particularly arduous as it required 11 high-level exposures with, finally, a hydrazine system pressurised to 30 bar. The spacecraft did not suffer any failures.

The boom-deployment spin tests at maximum and minimum spin rates identified some deviations from flight standard in hardware which might otherwise have escaped detection; these have now been corrected. An ESA review of the qualification tests is planned for the end of September. System compatibility testing with the qualification model at the ground station (Michelstadt) will commence in October.

The flight model has undergone 7 days of solar simulation testing (to check the thermal balance), followed by 14 days of thermal vacuum testing (to check engineering behaviour at extreme temperatures). The spacecraft behaved very well, and operated correctly in all simulated mission phases with only one or two minor anomalies, and confidence in the design has increased accordingly. The vacuum exposure brought to light a possible corona problem with one experiment, and corrective action has been taken. In general, the scientific payload has performed very well during the extensive testing, and valuable experience has been gained.

The acceptance vibration test was completely successful, and the spacecraft proceeded to antenna-pattern tests, with satisfactory results. Spin deployment tests concluded the first phase of acceptance. Experiment units will now be exchanged to allow spare units to be fully tested and calibrated.

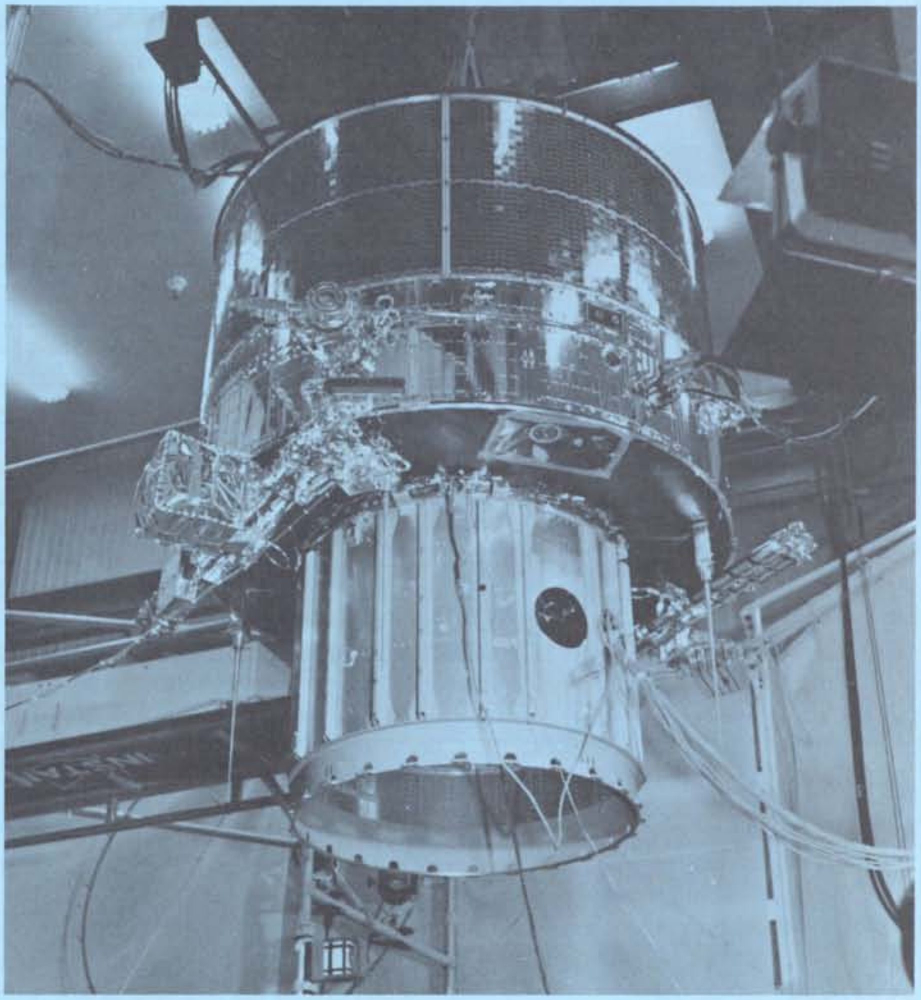
Apogee motor
The final Acceptance Review was held in September and it was concluded that all motors were performing uniformly and that the flight and flight spare models were fully acceptable.

Ground segment
Acceptance tests at the Michelstadt ground station were carried out during August, and the station was officially inaugurated on 14 September 1976 by the German Minister of Research and Technology, Mr. Matthöfer, in the presence of the Director General of ESA, the Director of ESOC and the local dignitaries.

The GEOS Dedicated Control Room equipment at ESOC also completed acceptance tests during August.

Compatibility tests using the GEOS suitcase model were conducted satisfactorily at DFVLR's Weilheim ground station to test (in particular) the compatibility of the interferometer with the satellite's VHF antenna pattern. The latter was simulated on the basis of recent antenna-pattern measurements. These tests were followed by a VHF telemetry and telecommand compatibility test at the ESOC test station which is representative for the functions of the Redu ground station. Tests on the UHF high-speed telemetry link will continue during September at the Michelstadt station.

For the closed-loop compatibility test with the satellite qualification model, which will take place during October at Michelstadt, basic data processing software will be available and will control part of the scientific payload. As other parts of the software become available later this year, a further test, involving a more complete closed-loop system, is envisaged for December.



GEOS qualification model separation test.

Modèle de qualification de GEOS lors des essais de séparation.

GEOS

Situation du programme

Le programme se poursuit conformément au plan. Le modèle de qualification a subi tous ses essais de qualification; la première et la plus importante phase des essais de recette du modèle de vol est terminée.

Le modèle de qualification *a subi avec succès des essais de détermination des caractéristiques de masse, de vibration, de choc à la séparation et d'accélération en rotation.*

Pour le programme de détermination des caractéristiques de masse, on a utilisé pour la première fois la chambre à vide de haute sensibilité de l'ESTEC pour les mesures d'inertie. La comparaison entre les résultats et les prévisions a été extrêmement satisfaisante pour toutes les caractéristiques, y compris des paramètres qui sont critiques pour le comportement dynamique en orbite.

La série des essais en vibration a été particulièrement difficile puisqu'elle a exigé l'application à onze reprises de niveaux très élevés avec, à la fin, un système à hydrazine pressurisé à 30 bar. Le véhicule spatial n'a eu aucune défaillance.

Les essais de déploiement des bras en rotation du satellite effectués aux vitesses de rotation maximales et minimales ont permis de relever dans le matériel certains écarts par rapport aux normes de vol qui auraient pu ne pas être détectés et ont maintenant été corrigés. Un examen ASE des essais de qualification est prévu pour la fin septembre. Des essais de compatibilité des systèmes avec le modèle de qualification démarreront en octobre à la station sol de Michelstadt.

Le modèle de vol *a subi sept jours d'essais de simulation solaire (pour vérifier le bilan thermique) suivis de 14 jours d'essais sous vide thermique (pour vérifier son comportement mécanique aux températures extrêmes).*

Le véhicule spatial s'est très bien comporté et a fonctionné correctement au cours de toutes les phases simulées de la mission (mises à part une ou deux anomalies mineures), ce qui a renforcé considérablement la confiance dans le bien-fondé de la conception du satellite. L'exposition au vide a fait apparaître qu'un problème d'effet corona pourraît se poser pour une expérience, et des mesures correctives ont été prises. Dans l'ensemble, la charge utile scientifique s'est très bien comportée au cours de ces mises à l'épreuve intensives qui ont en outre permis de tirer des enseignements très précieux.

L'essai de recette en vibration a donné entière satisfaction et les résultats des mesures de diagramme d'antenne auxquelles on a procédé sur le véhicule spatial sont également satisfaisants. Les essais de déploiement en rotation ont mis fin à la première phase de la recette, on procèdera ensuite à l'échange des unités des expériences de façon à pouvoir procéder aux essais complets et à l'étalonnage des unités de rechange.

Moteur d'apogée

L'examen de recette définitif s'est déroulé en septembre et a permis de conclure que tous les moteurs avaient la même performance et que l'unité de vol et l'unité de réserve étaient pleinement acceptables.

Secteur sol

Les essais de recette se sont déroulés en août à la station sol de Michelstadt qui a été officiellement inaugurée le 14 septembre 1976 par M. Matthöfer, Ministre allemand de la Recherche et de la Technologie, en présence du Directeur général de l'ASE, du Directeur de l'ESOC et des autorités locales.

Les essais de recette des équipements de la chambre de contrôle réservée à GEOS se sont également terminés en août.

Les essais de compatibilité utilisant le modèle 'valise' du satellite ont été effectués à la station sol de la DFVLR de Weilheim; ils avaient pour but de tester en particulier la compatibilité de l'interféromètre avec le diagramme d'antenne VHF du satellite. Le diagramme d'antenne a été simulé sur la base des récentes mesures effectuées. Ces essais ont été suivis d'un essai de compatibilité de télécommande et de télémesure VHF effectué à la station d'essais de l'ESOC qui est représentative des fonctions de la station sol de Redu. Des essais de la liaison UHF de télémesure à grande vitesse se poursuivront en septembre à la station de Michelstadt.

Pour les essais de compatibilité en boucle fermée avec le modèle de qualification du satellite qui doivent se dérouler en octobre à Michelstadt, on disposera du logiciel de base de traitement des données, ce qui permettra de contrôler une partie de la charge utile scientifique. Les autres éléments du logiciel étant disponibles plus tard dans l'année, on envisage pour décembre d'autres essais portant sur un système en boucle fermée plus complet.

IUE

Réseau solaire

Le réseau solaire — qui représente la participation de l'ASE au projet — a été intégré en juillet au modèle de vol du véhicule spatial au Centre spatial Goddard. Il ne subira pas d'autres

IUE

Solar array
ESA's contribution to the spacecraft – the solar array – was successfully integrated with the flight spacecraft in July at Goddard Space Flight Center. No further tests on the array are scheduled until the spacecraft vibration tests early in 1977.

Ground system
Substantial progress has been achieved with the ground station at Villafranca (Spain). The microwave repeater tower has been completed, telephones have been installed, and provisions are being made to improve the access road.

The station will be operated and maintained partly by contract and partly by ESA staff. The Agency's Industrial Policy Committee has approved the placing of the contract with INTA (Spain) and final negotiations are under way. Recruitment of ESA staff for the station is in hand but is proving somewhat difficult.

The first version of the Operations Control Centre software has been successfully implemented on the Sigma 9 computer.

ISEE

ISEE-B spacecraft
As forecast in the last issue of the Bulletin, the initial delay in starting assembly of the integration model has been compensated by intensified activity during the last two months and the programme is now on schedule. The first Integrated System Test commenced as planned in the week ending 10 September and is due for completion on 24 September. Although, as is normal in a development programme, some minor defects and errors have been encountered, no major problem has arisen on the spacecraft to date and there is every expectation that its test programme will be completed on schedule early in 1977.

The flight-unit subsystems are being manufactured at the various co- and sub-contractors and, generally speaking, progress is acceptable. Two exceptions are the hinge booms and the gas tank, where serious delays have occurred in final development and manufacture, respectively. Both problems are being actively pursued at senior management level.

Scientific payload
All experimenters delivered their units in time for integration into the integration model spacecraft, although a fault found in one led to its urgent return to the USA for correction. A certain number of software incompatibilities had to be resolved, but no more than usual at the first mating of experiments and spacecraft. One more serious problem concerning the inrush current at switch-on was found and this is presently under investigation.

None of the experimenters report serious problems in meeting their required delivery dates for the flight unit.

ISEE-A spacecraft
Work continues at Goddard Space Flight Center on the integration of the ISEE-A flight spacecraft. All of the subsystems are assembled and working, and experiment integration is now in progress. No schedule, technical-performance or weight problems have been reported.

Launch and operations
The planning of the launch and in-orbit operation of the ISEE-A/B mission is now under way with NASA. A visit has been made to Eastern Test Range and the facilities which it is planned to use for the launch identified. A Joint Working Group on Operations has been established by NASA and ESA and an in-orbit operating philosophy devised. At the next meeting, which will take place in Europe, it is hoped to work out the technical details of this philosophy.

EXOSAT

Replies from industry to the Invitation to Tender (ITT) were received in ESTEC on 2 August. Study of these proposals, by an evaluation board and ten specialist evaluation panels, ensued in the following five weeks. The object of this first phase of evaluation was to select a maximum of two proposals, and to prepare a list of points which the Agency wished to negotiate with the potential contractors before being in a position to agree the terms of a detailed contract for the Phase-B work and a preliminary contract for Phase C/D work.

Internal studies have continued in parallel on the feasibility of using the Ariane launcher for the Exosat mission. A first assessment of the technical and financial implications has been made, and summarised in a paper to facilitate discussion at meetings of the SAC, SPC and Council in September and October. A final decision on the use of either a Delta or Ariane launch vehicle is to be made in December.

Exosat is ESA's first scientific satellite project in which development of the scientific payload is also funded and managed by the Agency. Documentation for the calls for tender for the experiment hardware is in preparation. The date of issue of the ITT is essais avant les essais de vibrations du véhicule spatial lui-même, prévus pour début 1977.

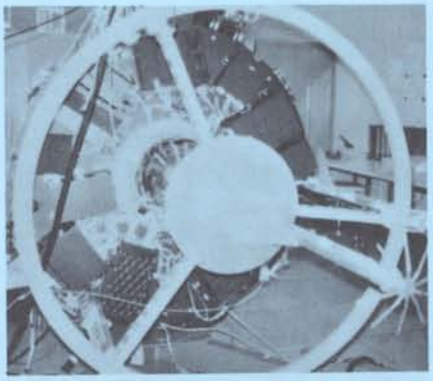
Secteur terrien
La construction de la Station sol à Villafranca (Espagne) a progressé à grands pas, tandis que la tour du répéteur hyperfréquences est achevée. Les téléphones sont installés et la voie d'accès à la station est actuellement en réfection.

Le fonctionnement et l'entretien de la Station sol seront assurés en partie par le contractant, en partie par le personnel ASE. Le Comité de Politique industrielle a donné son accord pour attribuer le contrat correspondant à INTA (Espagne) et les dernières négociations sont en bonne voie. Le recrutement du personnel ASE est en cours mais se révèle quelque peu malaisée.

La première version du logiciel du Centre de Contrôle des Opérations a été implantée dans le système de calcul Sigma 9.

ISEE

Véhicule spatial
Comme prévu dans le dernier numéro du Bulletin, le retard initial de l'assemblage du modèle d'intégration a été rattrapé grâce à une intensification des activités au cours des deux derniers mois et le programme se déroule maintenant conformément au calendrier. Le premier essai du système intégré a commencé, comme prévu, au cours de la semaine se terminant le 10 septembre et doit s'achever le 24 septembre. Bien que certaines déficiences et erreurs mineures aient été rencontrées, ce qui est normal dans un programme de développement, aucun problème grave ne s'est posé à ce jour pour ce véhicule spatial et il y a tout lieu de penser que le programme d'essais sera terminé, conformément au calendrier, début 1977.



Modèle d'intégration d'ISEE pendant les essais du système intégré chez Dornier.

ISEE integration model during integrated system test at Dornier.

Les sous-systèmes de l'unité de vol sont actuellement en cours de fabrication chez les différents co-contractants et sous-traitants et, dans l'ensemble, l'état d'avancement est satisfaisant. Deux exceptions toutefois: le système de bras articulé, et le réservoir de gaz, pour lesquels des retards sérieux sont intervenus respectivement dans les derniers travaux de développement et dans la fabrication. Dans ces deux secteurs, de gros efforts sont en train d'être déployés au plus haut niveau pour remédier à la situation.

Charge utile scientifique
Tous les expérimentateurs ont fourni les unités à temps pour permettre l'intégration dans le modèle d'intégration du véhicule spatial, bien qu'un défaut, affectant l'une des unités, ait obligé à renvoyer celle-ci d'urgence aux Etats-Unis pour y remédier. Certaines incompatibilités en matière de logiciel ont été constatées – et généralement résolues – mais leur nombre n'était pas supérieur à ce qu'il est normal de trouver lors de la première installation des expériences sur le véhicule spatial. Un problème plus grave a été décelé: il concerne le courant d'entrée au moment de la mise sous tension et il est actuellement à l'étude.

Aucun expérimentateur n'éprouve de difficulté sérieuse pour fournir ses expériences à temps pour le modèle de vol.

Véhicule spatial ISEE-A
Les travaux se poursuivent au Centre spatial Goddard sur l'intégration du prototype de vol du véhicule spatial A. Tous les sous-systèmes sont assemblées et fonctionnent et l'intégration des expériences est actuellement en cours. Aucun problème n'est signalé quant au calendrier, à la performance technique ou au poids.

Lancement et opérations
Le planning du lancement et des opérations en orbite pour la mission ISEE A/B est actuellement en cours d'établissement en coopération avec la NASA. Une visite commune a été faite à l'Eastern Test Range et les installations qu'il est prévu d'utiliser pour le lancement ont été recensées. Un groupe de travail mixte sur les opérations a été créé et une stratégie en matière d'exploitation en orbite a été définie. La prochaine réunion se tiendra en Europe et l'on espère que les modalités techniques détaillées correspondantes pourront y être élaborées.

conditioned to a certain degree by the availability of test data from the scientific model, but will in any case fall in the last quarter of this year.

ESOC continued to assist with mission analysis studies and supported the tender evaluation. Further specific studies were devoted to trade-offs between alternative star-tracker configurations. The definition of orbit, launch windows and coverage for a launch by Ariane has been completed. Scientific coverage is slightly inferior compared with the Delta-launch orbit.

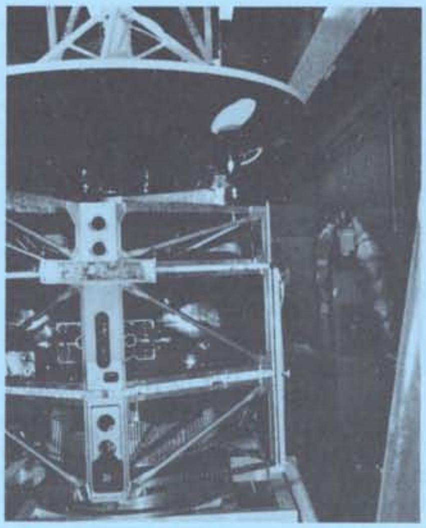
METEOSAT

Space segment
Integration of the Meteosat qualification model is continuing and delivery of the flight model subsystems has started. The satellite engineering model, after successful completion of the system-level tests, is now being used to test compatibility with the ground segment.

Ground segment
Integration of the Data Acquisition Telecommand and Tracking Station (DATTS) has been completed and the acceptance tests were performed in August.

Development of the Secondary Data Users Station has been started and the contract for the development of the Primary Data Users Station (PDUS) has been awarded to the Société Lannionnaise d'Electronique (SLE, France). It is expected that the PDUS prototype will be available in July 1977.

The Meteosat computer has been installed but the manufacturer has announced further delays for completion of the operating software. It is expected that this problem can be solved through increased effort by industry and reorientation of applications software development.



Marots thermal model being assembled at Fokker (Netherlands).

Modèle thermique de Marots en cours d'assemblage chez Fokker (Pays-Bas).

AEROSAT

In early September, the Aerosat Space Segment Board reviewed the results of the evaluation of the satellite proposals submitted by industry. The three proposals (from General Electric, RCA and TRW) were all of a commendably high technical standard, but the tender submitted by General Electric was significantly below the quotations of the other two. The Board therefore resolved that the Space Segment Programme Office be authorised to initiate negotiations with General Electric. Subject to satisfactory completion of such negotiations, it is intended to award a firm fixed-price contract.

MAROTS

Testing of the thermal model of the Marots satellite was completed in July 1976. The static testing of the structural model was successfully completed in August and acoustic noise testing of the same model took place at IABG, Munich during September.

Integration of the Marots payload engineering model is due to start in mid-October and the Payload Development Design Review will be held on 14 and 15 October.

OTS

The OTS qualification model service module and communications module will be integrated at Matra, Toulouse during October, and the first round of special performance and integrated systems testing should be completed by mid-November. The satellite will then be subjected to thermal vacuum testing in December.

Integration of the flight model service and communications modules is under way, with completion of integration at satellite level expected at the end of November, and completion of testing by the end of April 1977.

Work has been started on the power-flux measurement and ranging terminal, which will be located at Villafranca (Spain).

Preparations for the Orbital Test Pro-

EXOSAT

Les réponses de l'industrie à l'appel d'offres ont été reçues à l'ESTEC le 2 août. L'étude des soumissions, effectuée par une commission d'évaluation et dix groupes spécialisés, a occupé les cinq semaines suivantes. Cette première phase d'évaluation avait pour objet de retenir deux propositions au maximum et de préparer une liste des points que l'Agence souhaite négocier avec les contractants potentiels avant de pouvoir arrêter les termes d'un contrat détaillé pour les travaux de phase B et d'un contrat préliminaire pour les travaux de phase C/D.

Parallèlement, des études se sont poursuivies intra-muros sur la possibilité d'utiliser le lanceur Ariane pour la mission Exosat. Un premier examen des implications techniques et financières a eu lieu; il a été résumé dans un document afin de faciliter les négociations aux réunions du SAC, du SPC et du Conseil en septembre et en octobre. Une décision définitive au sujet de l'utilisation du lanceur Delta ou d'Ariane doit être prise en décembre.

Exosat est le premier projet de satellite dans lequel l'Agence assure elle-même le financement et la gestion de la charge utile scientifique. La documentation pour les appels d'offres relatifs au matériel des expériences est en cours de préparation. La date d'envoi de l'appel d'offres est conditionnée dans une certaine mesure par les résultats des essais du modèle scientifique, mais se situera en tout cas au cours du dernier trimestre de cette année.

L'ESOC a continué de contribuer aux études d'analyse de mission et a fourni un soutien à l'évaluation des offres. D'autres études spécifiques ont été consacrées aux arbitrages entre les différentes configurations possibles de suiveurs stellaires. La définition de l'orbite, des fenêtres de tir et de la couverture en cas de lancement par Ariane a été menée à bonne fin; elle autorise une exploitation scientifique un peu moins complète que dans la configuration orbitale qui avait été définie à l'origine.

METEOSAT

Secteur spatial

L'intégration du modèle de qualification de Météosat se poursuit et la livraison des sous-systèmes du modèle de vol a commencé. On utilise actuellement le modèle d'identification du satellite, qui a subi avec succès les essais au niveau système, pour vérifier sa compatibilité avec le secteur terrien.

Secteur terrien

L'intégration de la station de poursuite, de télécommande et d'acquisition des données (DATTS) est achevé et les essais de recette se sont déroulés en août dernier.

Le développement de la station secondaire d'utilisation des données (SDUS) a commencé et le contrat pour le développement de la station primaire d'utilisation des données (PDUS) a été attribué à la Société lannionnaise d'Electronique (SLE, France). On prévoit que le prototype de PDUS sera disponible en juillet 1977.

Le calculateur Météosat est installé mais le fabricant a annoncé que l'achèvement du logiciel d'exploitation serait encore retardé. On pense pouvoir résoudre ce problème en demandant un effort accru à l'industrie et en réorientant le développement du logiciel d'application.

AEROSAT

Début septembre, le Conseil du Secteur spatial Aérosat a examiné les résultats de l'évaluation des propositions soumises par l'industrie pour ce satellite. Les trois propositions reçues (General Electric, RCA et TRW) sont toutes d'un niveau technique remarquablement élevé, le prix cité par General Electric se situant toutefois nettement au-dessous de ceux des deux autres soumissionnaires. Le Conseil du Secteur spatial a en conséquence autorisé le Bureau du Programme à engager des négociations avec General Electric. Sous réserve d'une heureuse conclusion de ces négociations, il est prévu de passer un contrat à prix forfaitaire définitif.

MAROTS

Les essais du modèle thermique du satellite Marots se sont terminés en juillet 1976. Le modèle de structure a subi avec succès les essais statiques en août et les essais de bruit acoustique chez IABG à Munich en septembre.

C'est à la mi-octobre que doit commencer l'intégration du modèle d'identification de la charge utile de Marots tandis que l'examen de conception pour le développement de la charge utile est prévu pour le 14 et le 15 octobre.

OTS

Le module de service et le module de télécommunications du modèle de qualification d'OTS seront intégrés chez Matra (Toulouse) en octobre et la première série des essais spéciaux de performance et du système intégré devrait être terminée pour la mi-novembre. Le satellite sera ensuite

Transportation of Spacelab module (hard mock-up) from Aeritalia to ERNO.
Maquette en dur du module Spacelab pendant son transfert d'Aeritalia à ERNO.

Spacelab cylindrical module, at Aeritalia, showing storage and floor attachments.

Module cylindrique de Spacelab, avec les attaches des consoles et du plancher.

gramme are continuing and include plans to upgrade the 3 m Jungfrau terminal to operate with OTS after the propagation data-collection experiment is complete. The station will be transportable and will be used to transmit and receive beacon signals from both OTS modules as part of the satellite measurements for the Test Programme.

SPACELAB

The main effort in the development programme is currently to ensure a successful Preliminary Design Review, so that the baseline Spacelab design may be frozen.

Hardware manufacture is progressing for selected engineering model subsystems. Integration of the hard mock-up continues on schedule, while the early development model is being modified to reflect the emerging subsystem interface design solutions.

With the signature of two contracts between the prime contractor (VFW-Fokker/ERNO) and Sener and Matra, the contractual network for Spacelab development work is now complete, with all ten co-contractors actively involved, four working on a fixed-price basis and six on a cost-reimbursement basis.

NASA and ESA have agreed to undertake a second joint Airborne Science Shuttle Experiment System Simulation (ASSESS) flight in April 1977. The objectives of this ASSESS-II mission are to study Spacelab experiment operational concepts, and to facilitate development of procedures for Spacelab payload specialist selection and training by performing scientific and applications experiments under simulated spaceflight conditions. On the European side, an agreement has been reached between ESA and DFVLR which defines the latter's participation in the mission.

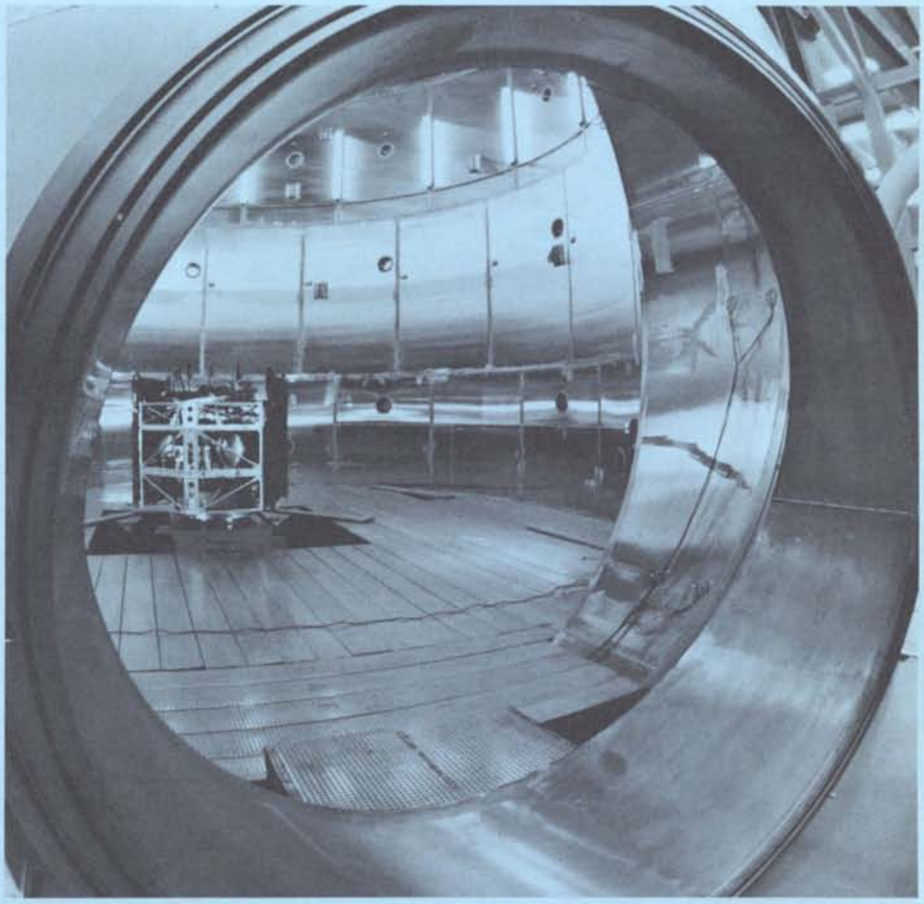
NASA and ESA have also decided on the configuration for the first Spacelab mission, namely a long module plus one pallet. It will be recalled that this first mission will have two primary aims:

(i) Verification of Spacelab's principal design aspects and capabilities.
(ii) Successful achievement of a number of significant scientific, applications and technological objectives.

The composition of the first Spacelab payload, with American and European experiments, is expected to be decided jointly by ESA and NASA in February 1977.

Modèle de structure d'OTS au cours des essais d'équilibrage dynamique à l'ESTEC.

OTS structural model undergoing dynamic balancing at ESTEC.



soumis à des essais sous vide thermique en décembre.

L'intégration des modules de services et de télécommunications du modèle de vol est en cours, l'achèvement de l'intégration au niveau du satellite étant prévu pour fin novembre et celui des essais pour fin avril 1977.

Les travaux du terminal OTS pour la mesure des flux de puissance et la télémétrie, qui sera situé à Villafranca (Espagne), ont été mis en route.

Les préparatifs du programme d'essais orbitaux se poursuivent et on prévoit notamment d'adapter le terminal de 3 m de la Jungfrau de façon à pouvoir l'utiliser avec OTS une fois terminée l'expérience de collecte des données de propagation. Cette station, qui sera transportable, assurera l'émission et la réception des signaux de balise échangés avec les deux modules d'OTS dans le cadre du programme des essais orbitaux.

SPACELAB

Les efforts réalisés dans le cadre du programme de développement sont à l'heure actuelle essentiellement axés sur la réussite de l'examen préliminaire de la conception, qui permettra d'arrêter définitivement la conception de base du Spacelab.

La fabrication des équipements avance en ce qui concerne certains sous-systèmes du modèle d'identification. L'intégration de la maquette en dur se poursuit conformément au calendrier, tandis que le premier modèle de développement est en cours de modification pour tenir compte des solutions conceptuelles qui sont en train de se dégager pour les interfaces des sous-systèmes.

La signature de deux contrats conclus par VFW-Fokker/ERNO, contractant principal, avec Sener, d'une part, et Matra, d'autre part, complète le réseau contractuel pour le développement du Spacelab, avec désormais la participation active des dix cocontractants dont quatre travaillent à prix forfaitaire et six en remboursement de frais.

La NASA et l'ASE sont convenues d'organiser en avril 1977 un deuxième vol conjoint pour la simulation à bord d'un avion d'expériences à embarquer sur la Navette (ASSESS). Cette mission ASSESS-II devra permettre d'étudier les concepts opérationnels des expériences Spacelab, et concourir à la mise au point de procédures de sélection et de formation de spécialistes de la charge utile grâce à l'exécution d'expériences scientifiques et d'applications en conditions de vol simulées. Du côté

européen, un accord est intervenu entre l'ASE et la DFVLR pour définir la participation de cette dernière à la mission.

La NASA et l'ASE ont également décidé de la configuration qui sera celle de la première mission Spacelab: module long plus une plate-forme porte-instruments. On se rappellera que cette première mission aura deux objectifs essentiels:

(i) vérifier les principaux aspects de la conception du Spacelab et ses possibilités;
(ii) mener à bien la réalisation d'un certain nombre d'objectifs importants dans les domaines scientifique et technologique et dans celui des applications.

La composition de la première charge utile du Spacelab, qui doit regrouper des expériences américaines et européennes, devrait être décidé conjointement par l'ASE et la NASA en février 1977.

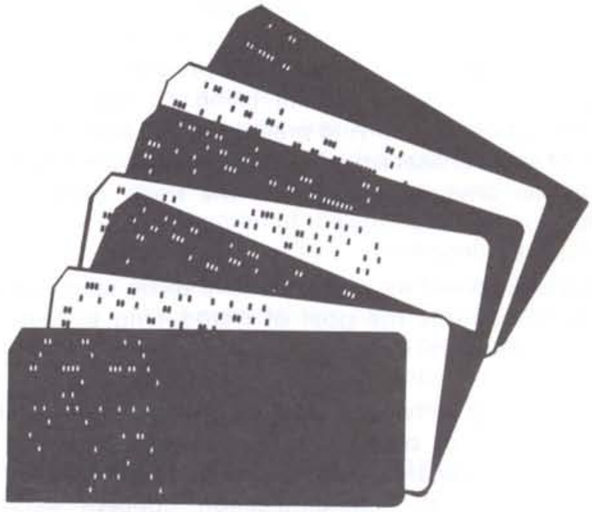
Bâtiment d'intégration de Spacelab (ERNO).

Spacelab integration hall at ERNO.

Some Aspects of Applications Software Development

C. Mazza, Data Processing Division, ESOC

Software production is a creative activity which, although subject to clear and formal logic constraints, can afford a wide degree of freedom to its orchestrators. Some psychologists have already introduced the concept that a computer program can reveal salient features of its writer's personality, rather like a musical score, a painting or a piece of poetry. Unfortunately, there is little room in a technological environment for such artistry and the pressing demands of productivity and of efficiency force the software producers to channel their creative impulses within very constraining boundaries.



One can divide software production quite categorically into a number of phases, based on definition of requirements, design, programming, unit testing, integration, documentation and maintenance, each of which calls for different attitudes and skills on the part of the staff concerned. For some, creativity is a prerequisite without which it is difficult to achieve a good overall product, while for others a bent towards routine production effort is more what is required.

A conflict often arises between ingenious analysts and programmers and those managers who, in the name of effectiveness, insist on adherence to particular programming or documentation standards. Unluckily for the former, until our society accepts companies that sacrifice profit in favour of employee, or more particularly programming inventiveness, software production must be treated like any other production activity and subject to the accepted rules of management. The traditional managerial sciences of planning, organisation and control therefore play a primary role in software production, not forgetting that, as this is an activity relying essentially on human resources, a good working atmosphere is at least as important as a good planning or a good reporting system.

Now, in order to be effective, the creative thinking should be limited to the early phases, like definition of requirements — which are sometimes not clearly specified by the users themselves, who then need to be helped in formulating their initial requirements more exactly — and the conception of the system; subsequently, it should relinquish the stage to a more routine-oriented approach. Whether this is good or bad policy from a human point of view can only be judged, as has been said, on the basis of society's requirements. One might, for example, consider providing alternative means for the routine programmers to achieve job satisfaction, along the lines of the several experiments being conducted with a view to relieving the boredom of production-line staff in industry! For the time being though, we have not yet reached such a stage, and the need to follow precise rules still constrains software production. It is nevertheless encouraging to note that the most advanced software production techniques already envisage some 'team activities' leading to a sense of 'team satisfaction', which it would otherwise be difficult to achieve.

STANDARDISATION OF SOFTWARE

Having examined some aspects of software production in general, one can go on to consider how the concept of standardisation can be applied to software production.

The degree of 'standardisation' adopted when developing software can, as any other 'product-oriented' work, have a very substantial impact on costs incurred during implementation and subsequent maintenance. It can, for example, take ten times as long to implement a system when relying on 'free-style' programming as to implement the same system using an approach with greater rationale, applying predetermined standards. This lack of standardisation can be equally detrimental to the computer time needed to run the freely programmed system.

There are several aspects that have to be considered in working towards the goal of introducing a degree of 'standardisation' into software procurement:

(i) Existing software should be used as far as possible, economics permitting. The benefits to be gained increase sharply as more and more software written applying the standardisation concept becomes available.

(ii) A standard methodology should be used during development to:

   (a) save time and reduce costs
   (b) provide a system that is more easily portable from machine to machine
   (c) ensure that a system is sufficiently documented to be easily understood by those who have not participated in its implementation.

All three aims can be achieved by applying the concepts of 'structured design' and 'structured programming'.

One of the basic features of 'structured design' is adoption of the so-called 'top-down' technique of designing a system, proceeding from the general to the particular in its analysis. This allows integration of the overall system to be conducted in parallel with the programming of any one unit, thereby leading to an overall time saving in implementation. If a particular routine has not been implemented, the system as a whole can still be tested by inserting a dummy routine that has the same interface with the overall system as the routine it is temporarily replacing.

Overall or partial reviews of a formal nature, involving people working on other projects, are to be recommended. A good team spirit must be established, so that progressive suggestions become the constructive advice of a friendly colleague rather than unwelcome criticism. In this context, careful attention must be paid to the structure of the team charged with the software development.

Once the design phase has been completed, the programming activities proper must start and some formal rules have to be added to the general constraints of the programming language adopted. Structured programming provides a set of 'golden rules', ranging from the optimal size for each program module for checking purposes, through logic rules on how to link the various parts of a program, to conventions on how to document it.

Although these concepts may seem natural and straightforward, they have yet to be adopted by the majority of analysts and programmers. Actions to extend their application have been initiated within ESOC's Departments concerned with software production.

SOFTWARE PROCUREMENT POLICY IN ESOC

Within the current structure, ESA's Computer Department (ECD) is charged with the procurement of hardware and basic software for the Agency, and ESOC's Information Handling Department (IHD) is responsible for the development of applications software. In the latter, three basic approaches are followed by IHD:

(a) Complete responsibility (management, design and implementation) is assigned to a commercial software company or consortium, and ESOC monitors progress of the fixed-price or cost-reimbursement contract awarded by ESA.

(b) Responsibility for management and design remains with ESOC, but the implementation team is partially or totally supplied by software companies.

(c) The complete system is developed by ESOC's own staff; in general this happens only for small projects.

The first of these can sometimes result in serious difficulties as the very nature of software makes it difficult to apply the same controlling procedures to its development as to the procurement of hardware. Controls can be applied only at specific stages in its development, but not continuously. Whenever possible, therefore, a

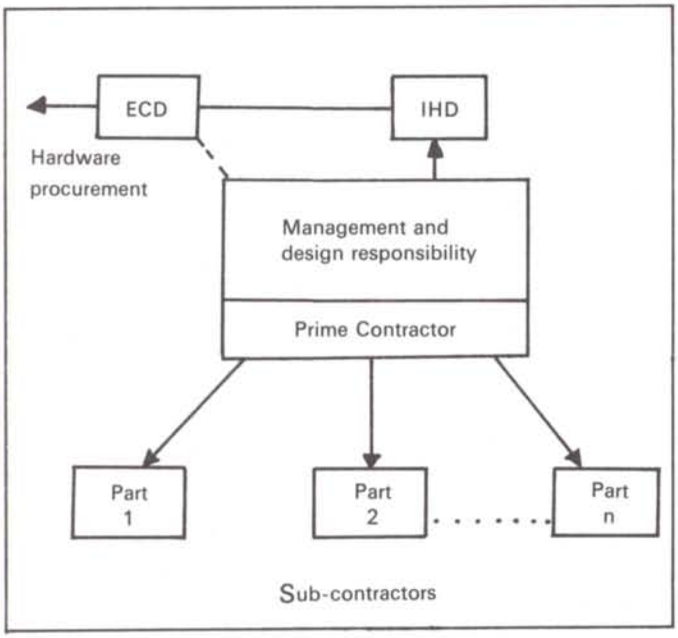


Figure 1 – Division of contracts for software and hardware procurement.

fixed-price contract is established. Unfortunately, there are often too many uncertainties in the definition of requirements or in the hardware and basic software to be used, and contractors feel unable to make a fixed-price proposal and favour a cost-reimbursement undertaking. The result for the Agency can be an unnecessary escalation in costs, recent experiences having shown conclusively that the practice of placing cost-reimbursement contracts should be avoided for large software projects.

Even in cases where it is decided to award a fixed-price contract, a better approach is to split the software contract into at least two parts, so that the prime software contractor can already develop in the design phase a specification that includes hardware requirements (Fig. 1).

These can then be discussed by both IHD and ECD before hardware procurement is started. The prime contractor may be called upon to participate directly or indirectly in the evaluation. Once the hardware has been chosen, management and design responsibility remain with the prime contractor, but selfconsistent parts of the project are subcontracted to other, not necessarily associated, companies. This is possible if clear-cut interfaces are defined in the design phase. Again, if the prime contractor is involved in the selection of the subcontractors, but the subcontracts are placed directly by the Agency, a double-profit situation is avoided. Moreover, the Agency does not then have to make a commitment for the whole project at any one time, and a stage-by-stage procurement and development approach can be followed.

FUTURE DATA-PROCESSING REQUIREMENTS AND TRENDS

Turning now to what can be foreseen as the characteristics of the data-processing systems of the future, in the context of our own space activities, changes in the data-processing requirements themselves and in hardware technology will play a major role. On one hand, there will almost certainly be a constantly increasing rate of data to be processed, satellite imagery data in a variety of spectral bands in particular representing a very heavy load for computer facilities. On the other hand, capacity for data storage will continue to increase at decreasing cost. These factors together lead one to envisage systems based on separate computing elements, communicating with each other via a network, and exchanging data through the medium of large memories accessed in parallel. If forecasted progress in microcircuit technology (e.g. array processors) and newly developed nonrotational mass memories (bubble memories, read/write laser and charge coupled devices, for example) proves realistic, such systems may soon become reality.

Better data compression and extraction techniques and more computing power on board space vehicles will then be needed but, with the improved design and programming techniques already mentioned, the trend should hopefully be towards a reduction in the overall costs of software development. □

Programming under Scrutiny

P.R. Becker, ESA Computer Department, ESOC

During the last five years the computer programming scene has changed considerably, partly as a result of the economic recession and partly due to a suspicion that too much was being paid to make computers do the work they were acquired for. There have been studies on the 'productivity' of programmers, on the error-proneness of large software systems, and on the likely trend of future costs. The community of computer users became alarmed when it was predicted that by the middle of the next decade software would cost four or five times as much as hardware, whereas 10 to 15 years ago the reverse was true. At present, it is asserted, we have already passed the fifty/fifty mark.

The validity of such arguments is dependent on the assumed environment; they may be proved wrong for an installation using a payroll program developed 15 years ago and now running under an emulator because the original machine has long been replaced. But in space research, where each satellite has its own particular requirements, the situation merits close scrutiny.

Such arguments can not be resolved on the basis of the customer's own software development costs alone. To be unbiased they have to include the effort supplied by the manufacturer's programmers. Manufacturer's software costs are not easily estimated. True development costs are not available, the only prices quoted being for purchase or rental of application software. The programs that make up the operating system itself are supplied with the hardware by most manufacturers at no extra cost. Even so, the costs of developing application programs cannot be assessed independently of the manufacturer's support system, because they depend heavily on the facilities provided, the quality of the individual programs supplied and 'human' factors, such as the trust the individual programmers put into the material supplied and the ability of local support staff to uncover or remedy shortcomings.

To quote specific figures from the relevant literature would be inappropriate here, but the general tendency is quite evident. New manufacturing methods and new technology have brought about a drastic fall in hardware prices. At the same time, new fields of application have been and are being developed, requiring more sophisticated and more complex logical support. In the field of space applications in particular the trend is clear: in 1967 a satellite had a data rate of a few hundred bits per second and in most cases the data were serial. For the future satellites, these rates are 1000 times greater, the data representing pictures, which are transmitted serially. This in turn means that neighbouring image points are not necessarily neighbours in the data stream. Processing must then include image manipulation, with rectification, frequency analysis, distorsion removal and so on, all of which are more complex in their demands than the relatively simple problems encountered ten years ago.

Under the terms of its Convention, one of ESA's roles is to promote the development of European industry. This has been reflected in ESOC in the last three years in a considerable program-conversion effort which on the whole has now been successfully concluded. At present implementation of the Meteosat Ground Computer System is the dominant feature of the software scene.

IMPLEMENTING A NEW SYSTEM

Checking out a new computer system is comparable to the early training of a small child when the innermost patterns of behaviour so critical for later life are established. This process has no parallel in the traditional fields of mechanical or electrical engineering, where the proper working of any device can be evaluated without major difficulty, in the laboratory or on the test bench: the abstract nature of software does not allow such testing.

A well-organised software system surrounds the hardware 'nucleus' almost like the layers of an onion (Fig. 1), and each group of computer users sees and uses only the layer appropriate to his work:

- A spacecraft controller operating a visual display sees only the outside of the 'onion', the computer answering to certain input codes by displaying data and possibly graphs.
- The programmer who has written his control

Figure 1 – Model of the relationship between hardware and software in a computer.

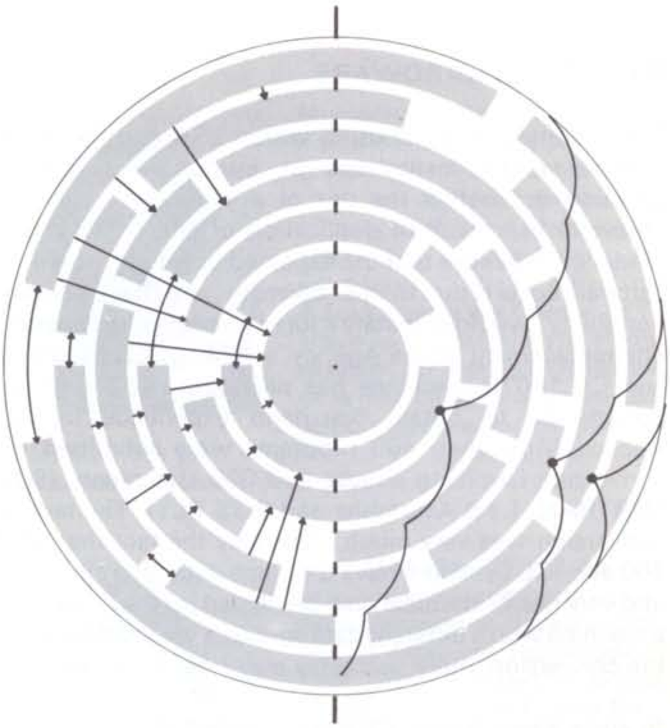


Figure 2 – Communication between program modules (left), and paths of errors spreading through the system (right).

programs is a layer below. The machine reacts in a certain way when presented with input text coded to an agreed convention (FORTRAN or any other high- or low-level language).

- The system programmer who supplies auxiliary software uses assembler programs and invokes 'system macro instructions.'
- The system macro instructions and the operating systems have usually been written by the manufacturer's programmers and such code directly interprets or loads 'visible' hardware registers.
- Inside the onion's 'core', 'micro-code' is used to communicate with those registers that are 'invisible' to the programmer and to drive more elementary instructions which actuate hardware facilities.

In implementing a newly designed computer system, this subdivision works far from perfectly. Errors committed near the core spread to the outer layers and in effect leave — say — the application programmer wondering what went wrong (Fig. 2).

Although new computer systems rarely enter service without considerable teething troubles, a number of precautions can be taken which cushion confrontations and reduce costs for both manufacturer and customer: they include

- clean design, with well-defined interfaces between modules
- scrupulous testing of microprograms and the system nucleus
- strict accounting of all errors located by manufacturer or customer
- an automated and reliable method of updating documentation.

These precautions must be complemented on the customer side by:

- clear definition of system and application programmer duties
- validation of all program and documentation updates
- forbidding of 'patch' solutions for system errors by customer staff
- provision of a competent advisory service.

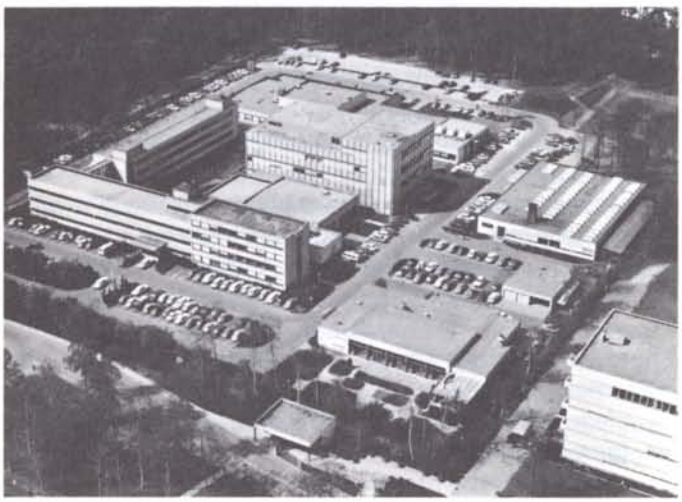
VARIETY OF HARDWARE

In the context of computing within ESA and the other national space institutions in Europe, a justifiable question is whether the use of a variety of computer hardware can result in duplication of effort. There is a tendency to believe that the expected universal growth in software costs is due to this 'diversity' and that 'program portability' would eliminate a lot of unnecessary expense. The replacement of the Agency's IBM by ICL System 4 and CII 10070 machines has provided ESOC with an opportunity to obtain first-hand experience in this respect. More than 400 programs were submitted for conversion involving almost 300 000 statements (90% FORTRAN, 1.7% Assembler and 8.3% PL1). The task of conversion was very much helped by the fact that IBM 360 and ICL System 4 have the same data type structure, and very nearly identical non-privileged instructions. Had a machine with a different data structure been the target of the conversion, more problems may have come to light.

In some cases formal differences between 'dialects' of the same programming language may be transcribed by 'source macro processors', which are programs that accept one type of code string as input and produce a second, 'target' code. Ambitious conversion programs have been constructed transcribing a language of few facilities, such as FORTRAN, COBOL or ALGOL 60 into PL1. The reverse process is, in general, not successful. Even when these language translation programs are applied, they often produce large amounts of inefficient code simply because an automatic conversion process must be based on the most general code possible. The human programmer, on the other hand, recognises 'special cases', an intervention that almost certainly leads to simpler target code.

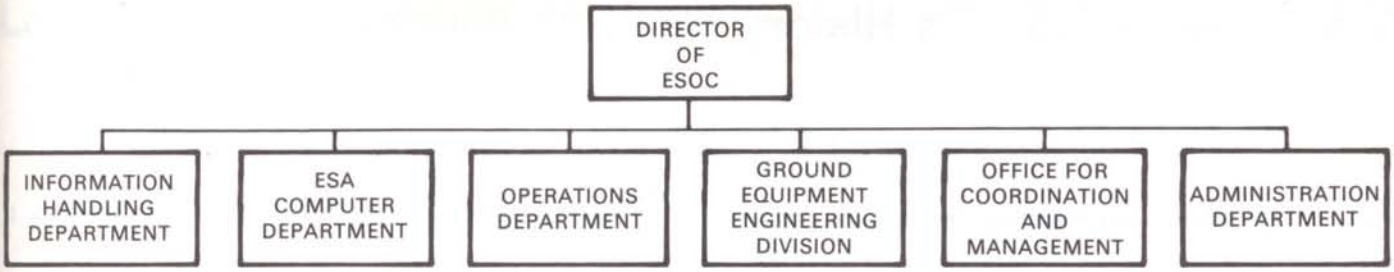
The safest means of achieving simplicity in later conversion to other machines is by proper initial program design. In many cases, apparently complex programs have been converted with remarkably little effort, demonstrating that the programmer who plans and implements programming systems carefully is himself the most able advocate for cost reduction. However, there is no standard solution, and each type of problem has its own optimal approach. □

Division of Responsibilities within ESOC



Aerial view of ESOC

Professor G. Formica (54) is Italian. He is a graduate electrical engineer of the Milan Polytechnic and Libero Docente in Hydraulics. Before joining ESRO in 1973, Professor Formica worked in both the academic and industrial fields. From 1962 to 1973 he held the post of Professor of Hydraulics at the Catholic University of Milan and at the State University of Ancona. After having been active in the field of hydroelectric plants with the Edison Group, from 1959 to 1969 he was a director of CGE – General Electric, Milan, where he was responsible for organisation and management information systems. From 1969 to 1973 he was a director of ITALSIEL, a leading Italian software firm. Professor Formica was appointed Director of ESOC in May 1973.



Mr. J.A. Jensen (47) is Danish. He holds a Masters Degree in electrical engineering from the Technical University of Copenhagen. He has worked with the Royal Danish Air Force and NATO for 13 years, during which period he specialised in planning. Mr. Jensen joined ESRO in 1967 and worked for two years at Headquarters in the fields of planning and budgeting. In 1969 he was appointed Head of the Review and Programme Operations Group at ESOC. At the end of 1970, he became Head of the Programme and Mission Management Department, created at that time. In 1973 he was promoted to Deputy Director of ESOC, and has been Head of the Information Handling Department since 1974.

Mr. K. Debatin (44) is German. He obtained his Diploma in Physics in 1960, at the University of Stuttgart, where he remained until 1963 as a Scientific Assistant in the Department of Aeronautical Engineering. Thereafter he joined IBM, working as an analyst. Mr. Debatin joined ESRO in 1965, and became Head of the ESA Computer Department in July 1972.

Mr. F. Garciá-Castañer (39) is Spanish. He graduated in physics at the University of Madrid, and did post-graduate work at Philips International Institute (Eindhoven, Netherlands), specialising in electronics and automatic control. From 1962 to 1968 he worked first for the Spanish Nuclear Energy Commission and then in private industry (petrochemical process control). In 1968, he joined Instituto Nacional de Tecnica Aerospacial (INTA, Spain). After a period at Goddard Space Flight Center, he subsequently worked at the Canary Islands and Madrid Apollo Tracking Stations of the NASA Manned Space Flight Network. Mr. Garciá-Castañer joined ESRO in March 1975 as Head of the Operations Department.

Monsieur F. Roscian (38) est français. Il a obtenu son diplôme d'Ingénieur Arts et Métiers en 1961 et celui d'Ingénieur de l'Ecole Supérieure d'Electricité en 1963. Il a successivement été employé au Service d'Equipements des Champs de Tir et puis au Centre national d'Etudes spatiales, chargé principalement de la mise en place d'équipement sol pour le soutien des programmes de lanceur. Il a joint l'Agence en 1975 comme Chef de la Division de l'Ingénierie des Equipements au sol (GEED).

Mr. B.M. Walker (38) is British. He completed his studies in mechanical engineering at Battersea College of Advanced Technology in 1961. After a period in private industry, firstly with English Electric Aviation and then with British Aircraft Corporation, he joined ESRO in 1964, taking up a post in the ESRO-II Project Group at ESTEC. Mr. Walker moved to ESOC in 1968 and was appointed Head of the Office for Co-ordination and Management in 1974.

Dr. H. Schramm (54) studied Law and State Economy and Economics at the University of Kiel, Germany. From 1955 to 1963 he worked in the German Ministry of Finance, and until 1972 at the Federal Ministry for Research and Technology, where he was responsible particularly for matters involving ESRO and ELDO. As a German Delegate, he was a member of the ESRO Council and the ESRO Administrative and Finance Committee (AFC). He was Vice-Chairman of the latter from 1968 to 1971, and Chairman of the ELDO Finance Committee from May 1970 until March 1971. He joined ESRO on 1 February 1972 as the Head of Administration at ESOC.

Milestones in ESOC's History

J.A. Jensen, Information Handling Department, ESOC

A Heiner* may not be very talkative, but he observes with curiosity. If he seemed puzzled by ESOC 's beginnings, he has long since ceased to be so, and is now accustomed to the muddle of languages, the odd working hours and the strange antennas that dominante the Centre.

He still recalls how this fenced-off piece of Europe was once just another part of Darmstadt 's forests, before the small groups of men began arriving to unfold their maps, take notes and make measurements.

By then the fate of these peaceful 21 000 square metres was already sealed. In the final report of COPERS** we read: 'The German Authorities had offered the site, situated about 2 km to the West of the Centre of Darmstadt. On 9 April 1963 it was confirmed to the German Government that the site was judged adequate by the Preparatory Commission for Space Research, for the establishment of the Data Centre of the European Space Research Organisation. Provisional accommodation was rented in Darmstadt for the ESDAC*** nucleus, then amounting to three persons.'

The arrival of cars from Darmstadt carrying the familiar local officials for forestry and construction did little to arouse our Heiner 's curiosity but the subsequent arrival of vehicles registered in Bonn told him that here was not going to be just another company or block of apartments!

The first trees came down and tractors began to level the ground and excavate. Then the place seemed abandoned, until one day in November 1965 when the flags of ten nations were hoisted and the foundation stone of ESDAC was laid. Headlines in the local 'Darmstadter Echo' reported that the place was something to do with space research . . . from its size, our Heiner could ascertain, to his relief, that the site was certainly not going to be used as a rocket base.

Furious activity followed and within a year and a half the first buildings, housing modest administration and computer facilities and destined to handle the scientific data of ESRO 's first satellites, had been erected. They soon came to life as the specialists moved in – the Centre was ready to undertake its tasks.

Unknown to our Heiner, by 1968 de-centralisation had become a key word of the organisation and it had been decided that satellite control was to be transferred to Darmstadt, before the first launch in 1968. The Centre had, overnight, had its role changed from a passive to an active one in the European space venture, and ESOC had been born.

No wonder all this passed unnoticed by the outside world; the control room covered only 72 square metres in a corner on the second floor of the administrative building, and the computer 'centre' comprised one IBM 360/50 machine. Nevertheless, ESOC 's people were ready to operate their first spacecraft.

The Centre began to grow, the increasing number of satellites to be controlled gradually requiring more staff and more facilities. To his dismay, the nature-loving Heiner was to see more trees cut down in order to extend the main building first on one side, then on another, and a separate building to rise at the back of the site.

By this time three satellites had been successfully operated, and it had become clear that a more fully equipped control room would be needed for the more sophisticated spacecraft soon to be launched.

Our Heiner 's growing apprehension about his 'expanding' neighbour was soon to be allayed when, after completion of the new control building, the Centre opened its doors to the public for the first time. Influenced by the much-televised Apollo missions, our imaginative neighbour lost little time in nicknaming the Centre 'Kleines Houston am Rhein'.

He could not fail to be impressed by the rows of satellite control consoles, the computers and the battery of electronic equipment. Subsequently, he watched the Centre even more attentively, noting the successful launch of another two satellites under the control of 'Darmstadt'.

May 1972 and there seemed to be something special

(Continued on page 84)

* HEINER: German noun not to be found in a dictionary, although commonly used to describe a native of Darmstadt.

** Preparatory commission to study the possibilities of European collaboration in the field of space research.

*** European Space Data Centre, the former title of ESOC.

La Station de poursuite de Redu

A. Lukasiewicz, Chef de Station ASE, Redu, Belgique

La station ASE de poursuite de satellites de Redu, déclarée opérationnelle depuis le 31 décembre 1967, est à l'heure actuelle bien rodée pour assumer les fonctions de télémesure, de télécommande, de localisation et de synchronisation. Dotée d'une infrastructure d'avant-garde, elle est prête à participer activement aux missions futures de satellites géostationnaires et de télédétection des ressources terrestres.

LES FONCTIONS

La Station de Redu, comme les autres stations du réseau ASE de poursuite de satellites, a pour mission de procurer l'interface entre la Terre et les satellites en orbite terrestre. On peut, d'une façon générale, regrouper les diverses fonctions d'une station de poursuite de satellites sous les quatre rubriques suivantes:

(i) *la télémesure*, ou *collecte de données* issues des satellites, ou provenant des mesures pour le contrôle du satellite lui-même;

(ii) *la télécommande*, ou *envoi d'ordres*, soit pour le changement de configuration électronique (étalonnage d'une expérience ou mise en service d'un sous-ensemble de secours, par exemple), soit pour le changement d'attitude du satellite par rapport à des axes de référence astronomique;

(iii) *la localisation* de la position du satellite dans l'espace à l'aide de mesures angulaires et de mesures de distance;

(iv) *la synchronisation* entre les fonctions de télémesure, de télécommande et de localisation d'une part, et d'autre part, entre ces trois fonctions et le temps universel coordonné (TUC) qui est la référence unique utilisée tant pour les stations terrestres que pour le satellite et pour la communauté scientifique mondiale.

Outre la télémesure et la synchronisation, la Station de Redu assure également les deux fonctions de télécommande et de localisation, bien que ces dernières ne soient pas obligatoires pour une station de poursuite. En effet, il existe des stations sans fonction de télécommande

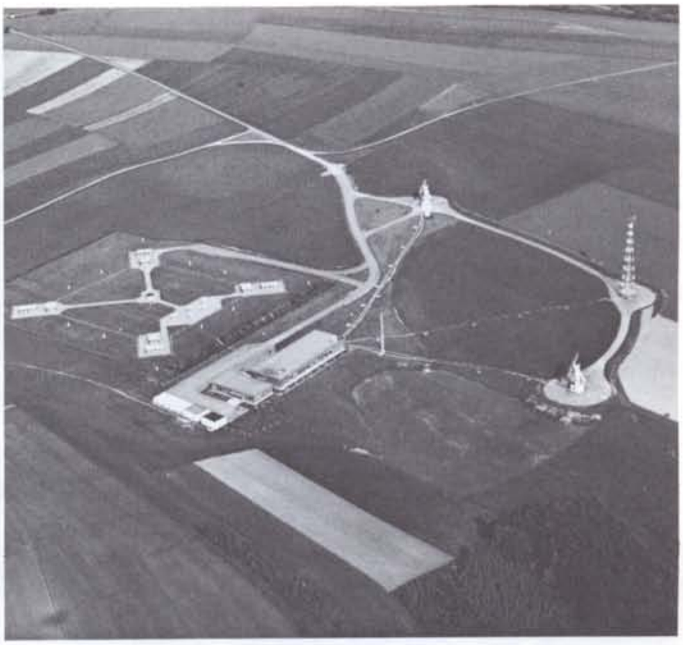


Figure 1 — Vue aérienne du site et de la Station de Redu.

(comme les stations mobiles TD-1), ou bien sans fonction de localisation par mesure de distance (stations du Spitzberg et des îles Falklands maintenant démontées), ou encore sans fonction de localisation angulaire (station de Fairbanks actuellement en activité).

LE SITE

Après une campagne de recherches d'un site qui s'est déroulée en 1965–66, le village de Redu dans la province de Luxembourg (Belgique) a été retenu. Située près d'un carrefour important dénommé 'Barrière de Transinne', la station de Redu (51° de latitude Nord, 5° de longitude Est) est installée sur un terrain presque carré (superficie: 16 ha, périmètre: 2 km, altitude moyenne: 330 m) dans une vallée naturelle bien protégée par l'horizon local contre les émissions radioélectriques qui pourraient gêner la réception des signaux très faibles en provenance des satellites (Fig. 1). Une fois achevés les travaux d'aménagement du site, l'installation et l'intégration des équipements et les tests de recette finale, la station a été déclarée opérationnelle le 31 décembre 1967.

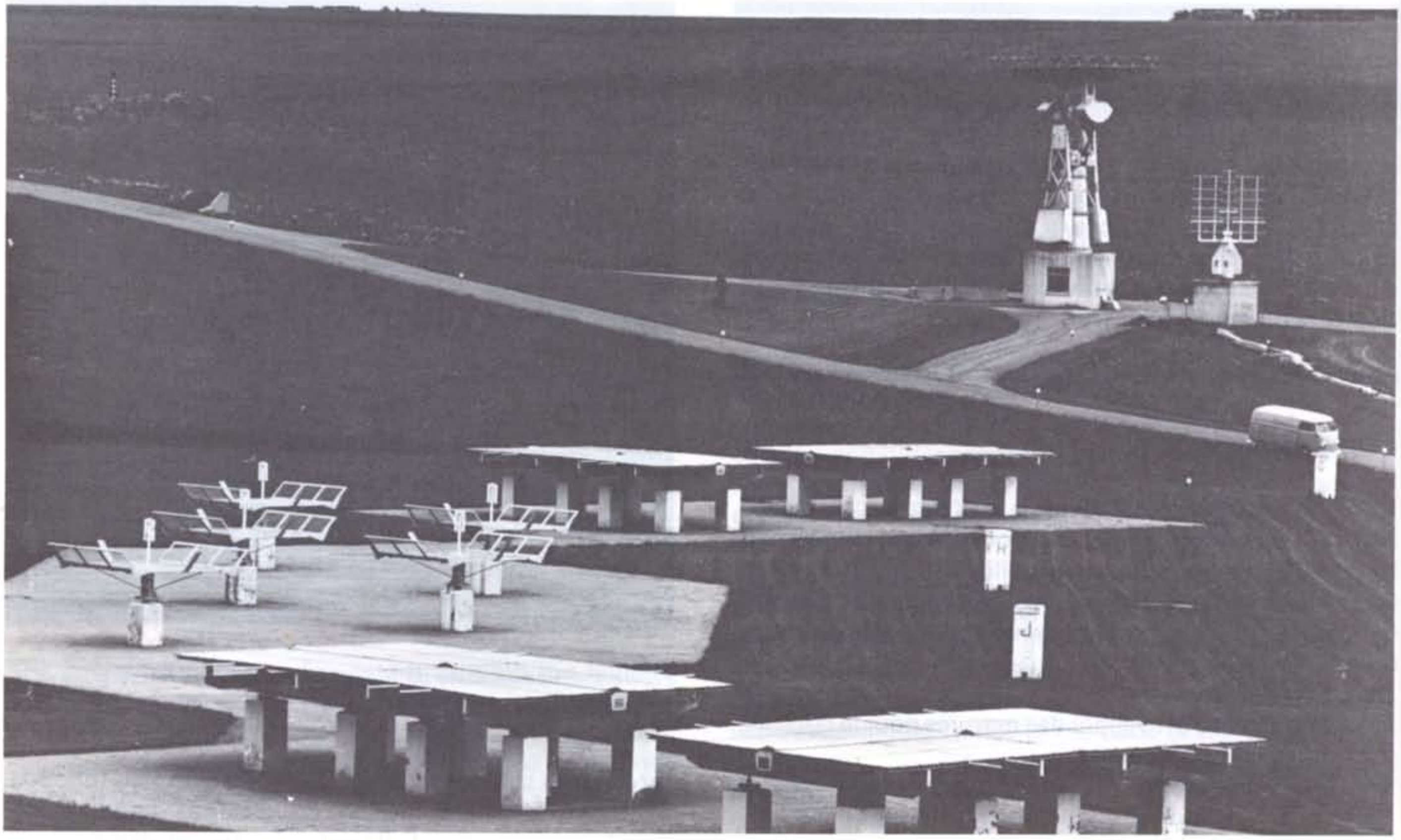


Figure 2 – Réseau d'antennes.

LES ACTIVITES DE 1968 A 1975

A partir du 1er janvier 1968, le personnel de la station a commencé à s'entraîner aux opérations, en collaboration étroite avec le personnel du Centre de Contrôle de l'ESOC à Darmstadt.

Avec les deux premières séries de lancements réussis de satellites du CERS en 1968 (ESRO-II en mai, ESRO-1A en octobre et HEOS-1 en décembre) et en 1972 (HEOS-2 en janvier, TD-1 en mars et ESRO-IV en novembre) – sans oublier le lancement d'ESRO-1B en octobre 1969 –, la station a connu des périodes d'activité intense au cours desquelles les diverses fonctions décrites plus haut ont été parfaitement remplies et les procédures d'opération progressivement affinées. C'est en effet à partir de 1972 que les procédures manuelles ont été peu à peu abandonnées au profit du contrôle par ordinateur.

Avec le lancement, en août 1974, du satellite astronomique néerlandais (ANS) équipé d'un calculateur de bord, la Station de Redu a pu accomplir une performance inédite, puisqu'elle était la seule au monde capable de stocker dans sa mémoire à la fois le programme de travail pour les 12 heures suivantes et les données des 12 heures précédentes.

A l'heure actuelle, après la rentrée d'HEOS-1 dans l'atmosphère et la cessation d'activité d'ANS, COS-B (lancé en août 1975) est le seul satellite encore suivi par la Station de Redu, en coordination avec la Station de Fairbanks.

Figure 3 – Salle d'Opérations.

DESCRIPTION

BATIMENT PRINCIPAL

Le bâtiment principal, qui occupe le centre du terrain, comporte 200 m² de bureaux et 700 m² de partie technique. Cette dernière abrite notamment la salle de climatisation (chaufferie, réfrigération, purification d'eau, ventilation), le magasin, l'atelier de maintenance, etc.

A proximité des bureaux, se trouve un *atelier mécanique* chauffé dans lequel est installé le groupe électrogène de secours de 150 kVA. Ce groupe est à démarrage manuel et subit une coupure de quelques minutes; mais dans un proche avenir, il est envisagé de modifier ce système de manière à obtenir un type totalement 'sans coupure'. En effet, l'utilisation de plus en plus générale de calculateurs numériques d'une part, et l'avènement prochain de satellites géostationnaires (toujours en vue de la station) d'autre part, nécessitent un degré de fiabilité, sinon absolu, du moins très élevé, du système d'alimentation d'énergie.

Dans la *périphérie* du terrain sont situés:

- à l'extrême nord, un bâtiment semi-enterré, qui contient le transformateur haute tension/basse tension (15 000/380 V) de 315 kVA de puissance;
- entre ce dernier et le bâtiment principal, la plate-forme supportant le réseau d'antennes à fentes de l'interféromètre radioélectrique destiné aux mesures de position angulaire (Fig. 2);
- à l'ouest, un bâtiment équipé d'un émetteur de télécommande et d'une antenne associée; le montage mécanique de celle-ci est du type azimut/élévation, et présente donc un point singulier au zénith;
- au sud-ouest, un bâtiment supportant une antenne de télémesure dont le montage est du type *X-Y*, c'est-à-dire qu'il donne des points singuliers à l'horizon, ce qui n'apporte aucune gêne puisque l'horizon naturel est de quelques degrés (2 à 3 selon les antennes);
- au sud, un bâtiment équipé d'un deuxième émetteur de télécommande et d'une deuxième antenne associée du type *X-Y*, et une bâtisse un peu plus petite supportant une antenne auxiliaire du type azimut/élévation, qui peut servir soit pour la télémesure, soit pour la télécommande.

SALLE D'OPERATIONS

La Salle d'Opérations, coeur de la Station (Fig. 3), comporte principalement: la chaîne de télémesure, la chaîne de télécommande, les calculateurs de gestion des données de télémesure et de télécommande ainsi que les calculateurs de pointage d'antenne, les équipements de transmission de données, les équipements électroniques associés aux antennes de mesure angulaire, les équipements électroniques de mesure de distance, l'équipement garde-temps.

Une première salle annexe est destinée aux transmissions par telex (privé et public), la seconde étant prévue pour recevoir prochainement les équipements spécifiques à la mission GEOS.

Les commandes et contrôles importants sont centralisés sur une console située au centre de la Salle.

Chaîne de télémesure

Elle est constituée de trois groupes indépendants de deux récepteurs fonctionnant en diversité de polarisation. Ces récepteurs, très sensibles, sont universels et peuvent démoduler des porteuses soit en amplitude, soit en fréquence, soit en phase. Le signal de sortie (sous-porteuse) est ensuite démodulée une seconde fois si nécessaire par des démodulateurs PSK ou FSK. La sortie de ces derniers est ensuite conduite aux conditionneurs de bits qui sont les organes de décision de la chaîne et qui restituent un signal numérique en modulation d'impulsion codée (PCM). Ce dernier est finalement dirigé vers un système de décommutation qui permet d'afficher en temps réel la valeur numérique de 20 canaux de télémesure d'une part et, d'autre part vers le calculateur de gestion de télémesure qui vérifiera, par exemple, qu'une commande a été bien reçue et exécutée par le satellite et a fait l'objet d'une confirmation.

Par ailleurs, le signal numérique est mis en forme par le calculateur de transmission de données qui, par l'intermédiaire de modems à grande vitesse (9600 bd), et de lignes téléphoniques privées de haute qualité, est relié aux calculateurs du Centre de Contrôle. Ainsi, le Centre de Contrôle est en permanence en position de vérifier le bon fonctionnement du satellite.

Chaîne de télécommande

Suivant ici le processus inverse, les ordres de télécommandes sont générés dans les calculateurs du Centre de Contrôle, puis, par l'intermédiaire des équipements de transmission de données et le calculateur de gestion de la Station, sont codés dans les équipements de télécommande, soit en modulation de durée d'impulsion (PDM), soit en modulation d'impulsion codées (PCM).

Finalement, le signal codé module en amplitude ou en phase des émetteurs dont les puissances s'échelonnent entre 200 W et 3 kW.

Calculateur de pointage d'antenne

Ce calculateur permet le pointage simultané de trois antennes sur deux satellites différents. Les données de pointage sont générées au Centre de Contrôle et transmises par telex. La précision de pointage est de l'ordre du degré.

Equipements de mesure de distance et de mesure angulaire

L'équipement de mesure de distance offre une précision de mesure meilleure que le kilomètre, la précision de la mesure angulaire étant de l'ordre du centième de degré. Les données de ces équipements sont transmises au Centre de Contrôle par telex.

Garde-temps

Il comporte un oscillateur de référence au rubidium dont la dérive de fréquence est de 10^{-11} par mois, et des récepteurs pour signaux de synchronisation du type Loran-C qui autorisent la restitution du temps universel coordonné à quelques microsecondes près.

Il comprend également un système de division et de multiplication de fréquence qui génèrent tous les signaux étalons tant de fréquence que de temps.

Transmission de données

Trois lignes téléphoniques privées de haute qualité sont disponibles, deux étant affectées à la transmission de données, dans les deux sens, entre la Station et le Centre de Contrôle, la troisième étant réservée à la communication orale entre ces deux mêmes points.

Une caractéristique importante est à signaler: équipée à l'origine pour suivre un seul satellite à la fois, la Station de Redu est maintenant capable d'effecteur la télémesure et la télécommande de deux satellites de façon totalement simultanée.

PERSONNEL ET OPERATIONS

Pour la mise en oeuvre de la station, le personnel d'origine, qui relevait entièrement du statut d'agent permanent du CERS, a été remplacé depuis janvier 1971 par du personnel contractuel, le seul représentant de l'ASE étant le Chef de Station. Compte tenu du personnel auxiliaire et de supervision, l'effectif total de la Station a passé de trente personnes au plus fort de l'activité de Redu en novembre 1968 à une vingtaine actuellement.

Le mouvement des satellites dans l'espace relève des lois de Képler et non pas du rythme circadien. Dans ces conditions, la Station doit fonctionner 24 heures sur 24 et 365 jours par an. Pour ce faire, il a été constitué quatre équipes opérationnelles qui couvrent, à tour de rôle, trois périodes de huit heures.

Selon le niveau de la charge de travail, chaque équipe comporte de deux à quatre agents et est responsable uniquement du travail opérationnel, à savoir:

- préparation d'un passage (chargement des enregistreurs, vérification de la configuration, étalonnage, etc.);
- déclenchement en temps voulu des différentes actions planifiées par le Centre de Contrôle pendant le passage;
- activités post-opérationnelles telles que comptes rendus, mise en forme des messages numériques, contrôle de qualité du produit, c'est-à-dire des enregistrements magnétiques de télémesure.

En plus de ces équipes opérationnelles, une équipe de maintenance (3 à 5 agents) est plus particulièrement chargée de l'entretien et de la réparation des équipements en place ainsi que de l'installation de nouveaux équipements. Elle est aussi habilitée à suggérer les améliorations qui, une fois approuvées par le Centre de Contrôle, peuvent être appliquées à tout le réseau de Stations de l'ASE.

ACTIVITES FUTURES

Dans le futur immédiat, la nouvelle grande aventure concerne le satellite scientifique GEOS, dont le lancement doit intervenir au cours du deuxième trimestre de 1977.

En fait, les activités d'une Station en prévision de la poursuite d'un nouveau satellite commencent bien avant le lancement, comprenant notamment:

- l'installation de nouveaux équipements, qui sera terminée d'ici à la fin de janvier 1977;
- la formation du personnel technique (missions chez les fabricants, organisation de cours à Redu ou au Centre de Contrôle);
- la formation du personnel opérationnel (simulation des activités majeures qui se produiront pendant et après le lancement).

Par ailleurs, la Station sera appelée, au cours de l'année 1977, à participer aux projets Météosat et OTS en tant que station VHF de secours tant pour les lancements que pendant les périodes opérationnelles.

CONCLUSION

Bien que les activités à moyen terme ne soient pas encore bien définies, il est certain que les possibilités de développement de la station de Redu ne manquent pas. Une infrastructure considérable existe et la vocation de station VHF pourrait être davantage exploitée, par exemple, en s'orientant vers les missions de télédétection des ressources terrestres ou maritimes.

Les moyens matériels et les compétences sont en place, prêts à servir pour de nouvelles tâches. □

Facilities of the German Space Operations Centre

H. Rister, DFVLR-GSOC, Oberpfaffenhofen, Germany

The Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR) was commissioned in 1967 by the Federal Ministry of Research and Technology to plan, implement and operate a ground operations system consisting of the ground stations, communication facilities, control centre and data-processing facilities necessary to support the German Space Programme. The German Space Operations Centre (GSOC) was established to undertake the planning, preparation and operational aspects of space missions, in co-operation with research institutes, industry and other space agencies.

Since 1968, GSOC has provided support in:

- the planning, preparation and operational phases of scientific and technological space missions and sounding-rocket campaigns;
- the systems analysis and engineering of data-processing systems;
- data processing for space and ground-based research projects (scientific and technological data, image data processing);
- the planning, implementation and operation of ground systems (hardware and software).

Table 1 provides an outline of the major projects so far undertaken by GSOC.

GSOC's GROUND FACILITIES

In the context of the German Space Programme and the requirements of the various projects, a ground system has been developed which is characterised by a high degree of automation, intensive and elaborate data communications between the different elements of the system, and a centralised network monitoring facility.

The ground network itself comprises five stations, the characteristics of which are outlined in Table 2.

S-band antenna at Weilheim.

- *VHF telemetry, telecommand and tracking station at Weilheim*
  Two independent telemetry receiving systems are available with separate antennas, receivers and data-handling equipment. Two independent chains (from encoder to transmitter and antenna) are available for spacecraft command and commands can be generated at and transmitted from the Control Centre in Oberpfaffenhofen or directly at the stations either manually, by means of punched paper tape, or by the station computer (Siemens 305). This computer provides automatic telemetry data handling, telecommand handling, station monitoring, and data communication with the Control Centre and a reduced 'quick-look' capability at the station. The interferometer is characterised by a system of three steerable antennas, which allow high-accuracy tracking over a wide angular range.

TABLE 1

GSOC Spaceflight Operations, 1969 – 1976

Type of Project	Name	Operations	Co-operation
Earth-orbiting satellites	Azur Injun V ext. mission Aeros A Aeros B	Nov. 1969 – Jun 1970 Feb. 1971 – Jun 1971 Dec 1972 – Aug 1973 Jul 1974 – Sep 1975	USA/Germany USA/Germany USA/Germany USA/Germany
Geostationary satellites	Symphonie I Symphonie II	Dec 1974 – 1979 Aug 1975 – 1980	France/Germany France/Germany
Interplanetary space probes	Helios A Helios B	Dec 1974 – 1978 Dec 1975 – 1978	USA/Germany USA/Germany
Remote-sensing missions	FMP meteorological & RS image data preprocessing	Jan 1976 – Jun 1977 1976 – 1979/80	Germany
Sounding-rocket & balloon campaigns		30 sounding-rocket campaigns during 1969 – 1975	NASA/ESA/CNES/ ranges a.o.

– *S-band telemetry and telecommand station at Weilheim*
The 30 m S-band antenna at Weilheim, which both receives telemetry data (2290 – 2300 MHz band) and transmits commands (2110 – 2120 MHz band), and all normal operations like subsystem adjustment, station control, station monitoring and message exchange with the Control Centre, are computer controlled. The command system has been designed to be fully compatible with the stations of NASA's Deep Space Network (DSN) for spacecraft telecommand. Its performance is enhanced by a number of command verification loops and by the computer-operated recording and monitoring of subsystem performance and station parameters. In addition, the station houses an air-conditioned test control room for compatibility tests.

– *VHF stations at Reykjavik (Iceland) and Sodankylä (Finland)*
The VHF station at Reykjavik is a general-purpose telemetry and telecommand station, at which the major station functions are controlled via punched paper tape. A frame decommutator provides a limited 'quick-look' capability. The telemetry data received are recorded on analog tapes. Station monitoring data, some specific spacecraft housekeeping data and command verification data can be transmitted automatically and in real time via a teletype link to the Control Centre. Tone Digital Command System (TDCS) commands can be stored at the station and released by the punched paper tape or manually.

The Sodankylä station is similar to the Reykjavik station, except that it has no telecommand capability.*

– *Mobile VHF station*
This station is housed in two air-conditioned

* Both stations are now administered by their respective national agencies, but are still available for project support on request.

TABLE 2

GSOC Ground-Station Characteristics

Station	Parameter	Telemetry	Command	Tracking	Interfaces local	Interfaces remote
	Frequency	136–138 MHz	147–156 MHz	136–138 MHz	analog recording	
	Ant. gain	22 dB	22 dB	22 dB		
Weilheim	Polarisation	RCP, LCP, LIN	RCP, LCP	RCP, LCP	commanding	HSCL from/to
VHF-station	Mod./demod.	AM, PM, FM	AM	–	digital recording	GSOC
	Output power	–	1,10 kW	–		
	Carrier threshold	–140 dBm		–150 dBm	quick look	
	Resolution	–	–	0,05°		
	Frequency	2290–2300 MHz	2110–2120 MHz		analog recording	
Weilheim	Ant. gain	54 dB	53 dB			
S-band station	Polarisation	RCP, LCP, LIN	RCP, LCP, LIN	–	commanding	HSDL from/to
	Mod./demod.	PCM/PSK/PM	PCM/PSK/PM			GSOC
(30 m antenna)	Output power	–	2–20 kW			
	Carrier threshold	–164 dBm	–			
	Frequency	136–138 MHz	140–156 MHz		analog recording	HSDL/TTY
	Ant. gain	17 dB	11 dB			from/to GSOC
Reykjavik	Polarisation	RCP, LCP, LIN	PCP, LCP	–		(if required)
(Iceland)	Mod./demod.	PM	AM			
	Output power	–	1 kW			
	Carrier threshold	–140 dBm	–			
Sodankylä (Finland)		same as Reykjavik	–	–	same as Reykjavik	same as Reykjavik
	Frequency	136–138 MHz	148–156 MHz		analog recording	HSDL/TTY
	Ant. gain	20,5 dB	16,5 dB			from/to GSOC
Mobile station	Polarisation	RCP, LCP	RCP, LCP	–	commanding	(if required)
	Mod./demod.	PM	AM			
	Output power	–	1 kW (10 kW)			
	Carrier threshold	–140 dBm	–			

containers, which can be transported by land, sea or air and can be operated from any 50 or 60 Hz power supply. The receiving, data-handling (bit synchroniser, PSK demodulator and frame decommutator) and command systems are similar to those at Reykjavik and provide the same facilities for station operation and spacecraft control, except that higher gain antennas are available.

GSOC COMMUNICATIONS AND OPERATIONS CONTROL SYSTEM

The communication system is centred around a communications processor (Fig. 1) which handles all data and information exchanges between outside facilities (control centres, stations) and GSOC's computers.

Spacecraft and network control and monitoring functions are performed in the control area, which consists of two spacecraft control rooms and one network operations control room. The available facilities are listed in Table 3.

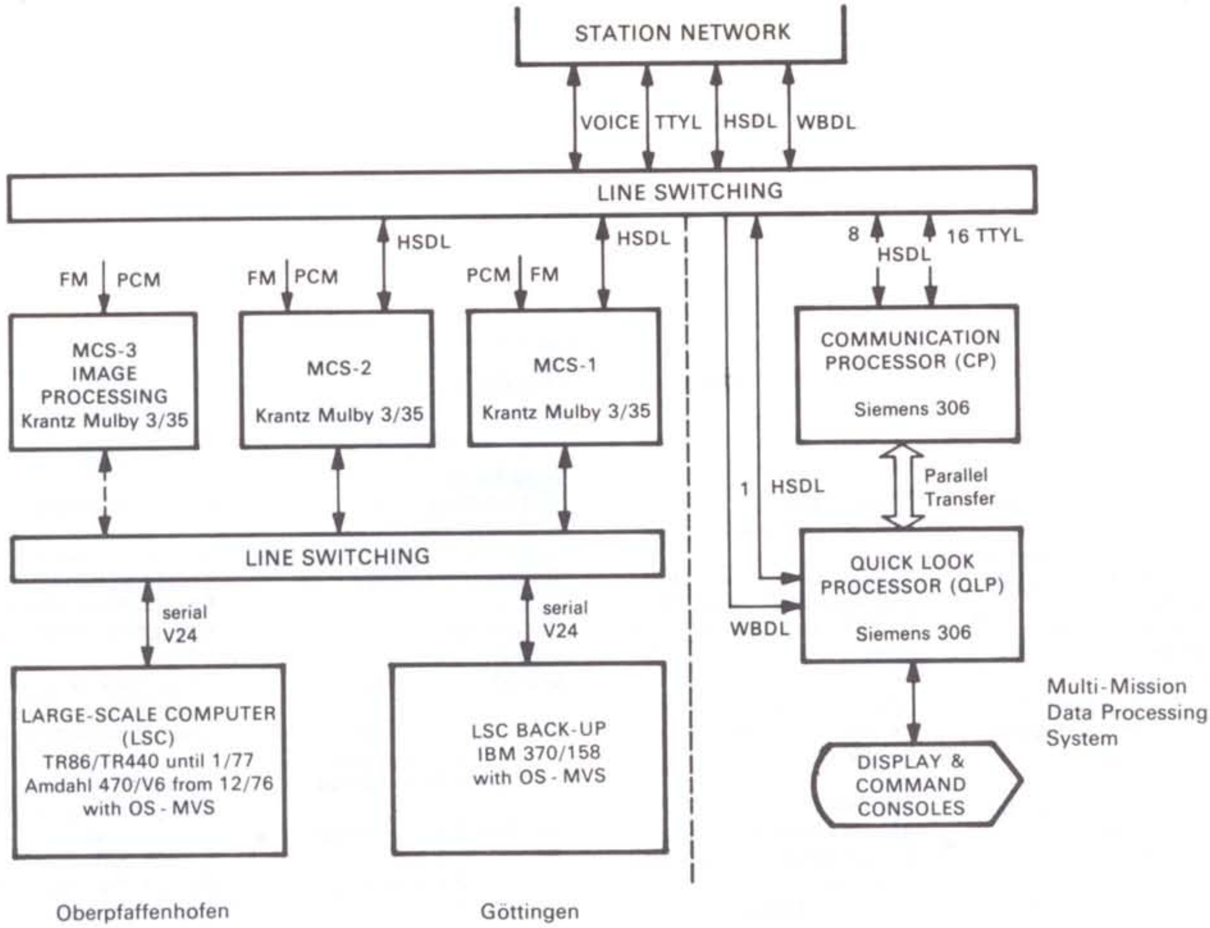
DATA-PROCESSING FACILITIES

The role of the GSOC computer complex in DFVLR's computer network is illustrated in Figure 1. It consists of three major subsystems which perform all the on- and off-line functions needed for spacecraft mission preparations and operation.

The *Multi-Mission Data Processing System* (MMDPS) is designed to support several projects simultaneously. It is capable of handling spacecraft telemetry/command data and station monitor data on-line for mission operation as well as spacecraft telemetry/tracking data off-line for data processing. The system is currently supporting four missions (Helios 1/2 and Symphonie I/II) and relies on two general-purpose computers, used on-line:

- Communication Processor (Siemens 306)
- Quick Look Processor (Siemens 306).

The *Modular Computer System* (MCS) has been designed by GSOC/DFVLR as a flexible tool to support on-line and off-line data-processing requirements for space projects. The basic system, which can easily be



TTYL = Teletype Link
HSDL = High-Speed Data Links (serial, V24)
WBDL = Wideband Data Link (serial, 48 kHz)

Figure 1 – DFVLR-GSOC computer configuration.

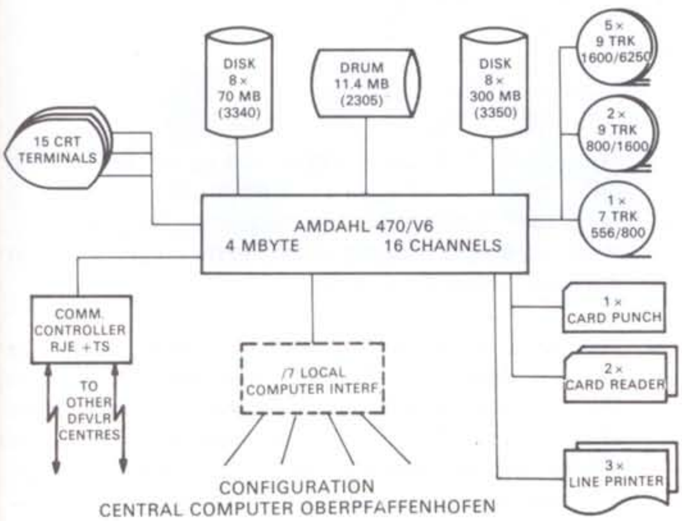


Figure 2 – DFVLR's computing centre.

adapted to cope with increasing requirements by renting additional modules, consists of a set of three minicomputers (Krantz Mulby 3/35), two of which have identical hardware configurations. They will be dedicated to tasks or projects using highly standardised and modular software packages.

Two of the MCS systems can back each other up; the third is used primarily for the GSOC Image Data Processing System.

The *Large Scale Computer* (LSC) provides on- as well as off-line mission support and is part of DFVLR's Large Scale Computer Network. By the end of 1976, the present installation in Oberpfaffenhofen, a TR 86/TR 440 combination, will be replaced by a new and much more powerful AMDAHL 470/V6 system (Fig. 2). The existing IBM 370/158 will serve as a back-up, but located in Göttingen.

Via the Modular Computer System, the LSC is used on-line to support orbit/attitude manoeuvres for geostationary satellites (Symphonie I/II) and to perform off-line tasks such as orbit/attitude determination and telemetry data processing.

TABLE 3
Control Centre Facilities

Display Devices for Spacecraft Control	Display Devices for Network Operations	Data Recording, – Handling and – Transmission	Communications
Driven by real-time computer (Siemens 306): 3 CRT with keyboard, 21 DTV-channels, 2 line printers, hard copy, 1 plotter, 3 GMT- and timing displays, 3 project displays *Driven by MCS (Mulby 3/35):* 11 CRT with keyboard, 2 line printers	*Driven by communications processor (Siemens 306):* 4 CRT, line printer, hard copy *Driven by real-time computer (Siemens 306):* 5 DTV-channels *Hardware:* 3 GMT-Displays 2 countdown clocks, wall display, 3 project displays	*Timing: 2EECO 911 TCG* *Recording:* digital rec. 9 9-track analog rec. 3 7-track *Decom:* 2 bit cond., 2 frame sync., 1 PSK-demod. *Modem:* 2 Racal Milgo 4,8 kb/s, 2 Racal Milgo 9,6 kb/s, 1 ITT 40,8 kb/s, 2 Siemens 4,8 kb/s *Line equalisation:* automatic for Racal Milgo modems, manual for ITT and Siemens	*Voice/data circuits* Oberpfaffenhofen-Robledo Oberpfaffenhofen-Weilheim *Voice-only circuits* Oberpfaffenhofen-Toulouse Oberpfaffenhofen-Weilheim *Data-only circuits* Oberpfaffenhofen-Weilheim *TTY-circuits* Oberpfaffenhofen-Robledo Oberpfaffenhofen-Toulouse Oberpfaffenhofen-Weilheim *Intercom* 10 conference circuits

THE GSOC IMAGE DATA PROCESSING SYSTEM

An increasing amount of remote-sensing data, originating mainly from a Bendix Modular Multiband Scanner, is being processed at GSOC, the processing system consisting of an image conversion system, a software system for digital image processing, a photographic laboratory, and a data-management system.

Together, these systems permit routine preprocessing operations, analog to digital conversion of tapes, image generation, photographic processing, dissemination and archiving. Certain digital preprocessing operations (e.g. radiometric and geometric corrections, image enhancement) can be applied to selected data.

The central processor is a fast, byte-oriented minicomputer and the software that has been developed consists primarily of:

- The *'quick-look' program*, which reads the scanner data through the scan synchroniser into the computer. It checks data quality and generates a film strip of a single channel, which is then used to select data for further processing.

- The *tape conversion program*, which reads the scanner data from the High Density Digital Tape (HDDT) and correlated auxiliary information from the analog tape unit. It then calibrates the data radiometrically, extracts and prints auxiliary data, reformats the video data and writes it on computer-compatible tape (CCT).

- The *image-generation program* reads the video data from tape, reformats and adapts it to the characteristics of the image-generation system, and then writes video, grey scale and annotation data on film.

Universal (MAN) launcher and Skylark sounding rocket.

TABLE 4

Major Facilities of the Mobile Rocket and Balloon Base

Facilities	Description
Launchers	– Universal (MAN) single-rail 14 m beam launcher; two versions (MK I and MK II) each with launch capability to 4 tons. Installed weights, 17 and 15 tons, respectively. Both are remote controlled. – Nike launcher; zero length type with launch capability of up to 1 ton, e.g. Nike-Tomahawk. – BAJ tube launcher; for launching Skua and Petrel rockets. – Arcas short-rail launcher; for launching small-diameter (Arcas, etc.) rockets.
Radars	– Radar MPS 19 – S Band, power 0.5 MW, range 320 km (using transponder). – Radar MPS 36 – C Band, power 1.0 MW, range 64.000 km (using transponder).
Telemetry Station	– TM receiving station (2 versions) operating in 210-265 MHz band. – PCM data station, for TM data recording and evaluation. – PCM 'quick-look' station, for check-out and data handling. – FM station, giving analog data (experimenter's real-time data). The TM and PCM stations use high-gain, multi-array, fully steerable antennas. – L/S band telemetry station (to be operational at the end of 1977).

THE MOBILE ROCKET AND BALLOON BASE (MRB)

Last but not least, GSOC provides support to extraterrestrial research by conducting sounding-rocket and balloon campaigns in co-operation with other ranges. The MRB is equipped with mobile launchers, radars, telemetry-telecommand, and data-processing stations, and has so far carried out about 50 campaigns with varying degrees of external support and 7 solo campaigns along with the recovery of payloads (see Table 4). Other MRB activities include the testing and integration of rocket payloads, in particular the check-out and mission simulation of payload attitude control systems, and the development of payload recovery systems. The base's future efforts will concentrate on the implementation and operation of a mobile L/S-band telemetry station and a mobile balloon-launching facility. □

Les moyens sol de poursuite des satellites et de traitement des données du CNES

J. Blachon, Chef de la Division Opérations
J.D. Delpont, Chef Adjoint de la Division Mathématiques et Traitement, CNES, Centre spatial de Toulouse, France

Le Centre National d'Etudes Spatiales (CNES) a développé, dans le cadre du programme national français et de programmes en coopération, un ensemble de moyens de poursuite des satellites et de traitement des données de télémesure qui réalise une intégration complète des différentes fonctions. Son originalité est caractérisée par:

- **l'automatisation complète du réseau permettant d'assurer une très grande sécurité des opérations, les stations pouvant intervenir comme des équipements périphériques connectés directement au Centre d'Opérations;**
- **la mise à la disposition des utilisateurs des données de télémesure et des moyens de traitement par l'intermédiaire d'un ensemble de terminaux comportant des équipements de sortie spécialisés (alphanumériques, graphiques, images). Ce réseau de télétraitement permet aux utilisateurs, sans quitter leurs lieux de travail, d'accéder aux données qui les intéressent et d'utiliser de puissants moyens de traitement.**

Cet ensemble peut effecteur pour le compte d'autres pays toutes opérations de localisation, télémesure, télécommande et traitement. Le CNES peut soit assurer l'entière responsabilité de ces opérations, soit permettre de compléter l'action d'un autre réseau.

CONTROLE ET OPERATIONS DES SATELLITES EN ORBITE

Pour assurer la réception des signaux de télémesure, l'envoi des signaux de télécommande, la localisation en orbite des satellites, le CNES s'est doté d'un ensemble de stations de poursuite connectées à un Centre d'Opérations unique.

RESEAU DE STATIONS

Il compte actuellement quatre stations. Chacune possède un équipement Iris capable d'assurer les fonctions TM/TC (télémesure et télécommande) dans une bande VHF 136-138 MHz pour TM et 148-149 MHz pour TC. Deux d'entre elles possèdent en outre un équipement de localisation interférométrique Diane opérant dans la bande 136-138 MHz, donnant la direction du satellite en site et gisement. Celle de Toulouse possède en outre des équipements SHF dans la bande 4-6 GHz lui permettant d'assurer la localisation angulaire précise, la réception des télémesures et l'émission de télécommandes (Fig. 1). Ces équipements ont été mis en place dans le cadre du programme des satellites franco-allemands de télécommunication Symphonie.

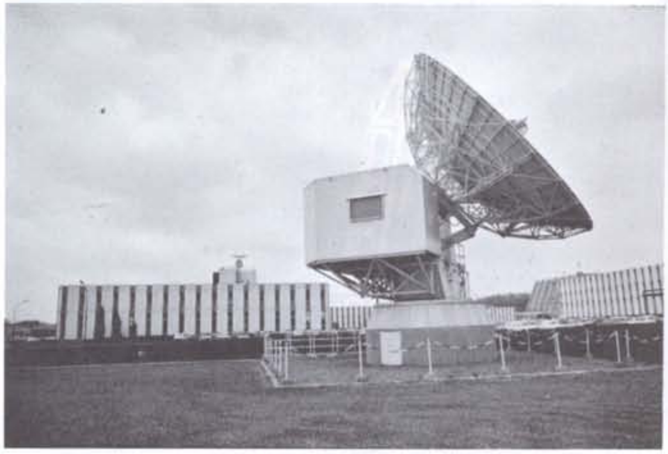


Figure 1 — Le bâtiment de la station Jean-Bernard Dementhon (JBD) à Toulouse. Au premier plan: l'antenne SHF.

Une cinquième station dite 'mobile' a été constituée avec des équipements VHF retirés de deux stations supprimées récemment; elle peut donner à ce réseau une souplesse supplémentaire.

SYSTEME DE TRANSMISSION RESEDA

Un système de transmission spécialisé permettant l'échange de données et de messages entre les stations et le Centre d'Opérations a été mis en place au milieu de l'année 1974. Construit autour de calculateurs de moyenne capacité, il a été conçu de façon à être

Les stations françaises

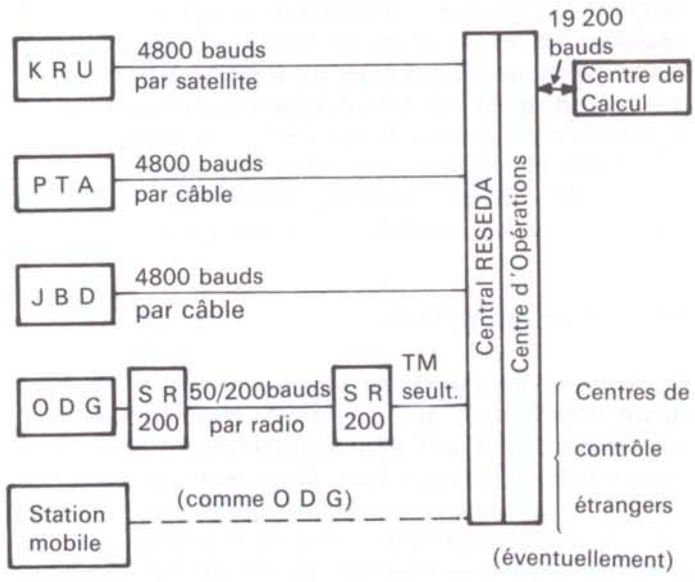
Indicatif	JBD	KRU	PTA	ODG
Implantation	Toulouse (France)	Kourou (Guyane Française)	Prétoria (Rép. Sud-Afric.)	Ouagadougou (Haute-Volta)
TM/TC VHF	×	×	×	×
Doppler VHF	×	×	×	×
Localisation VHF		×	×	
TM/TC SHF	×			
Localisation SHF	×			
Photographie sur fond d'étoiles		×		×

indépendant des supports de transmission utilisés (liaisons téléphoniques par câbles, par satellites, liaisons radio); seuls des équipements d'interface et des modules de programmation de liaison peuvent éventuellement être mis en cause.

Les codeurs de télémesure initiaux situés dans les stations ont été remplacés par des codeurs asservis à un calculateur central afin d'assurer un contrôle automatique à tous les niveaux des ordres envoyés aux satellites; ils permettent d'élaborer des séquences de télécommande selon des différents standards internationaux.

Le système RESEDA peut être utilisé en temps différé (transmission des données à partir d'un enregistrement magnétique effectué dans la station) ou en temps réel. Dans ce dernier cas, il permet d'établir une boucle TM/TC en temps réel qui peut être caractérisée ainsi:

- acquisition de la TM par la station
- transmission immédiate de cette TM aux Centres d'Opérations et de Calcul
- traitement de la TM par le Centre de Calcul
- élaboration de la TC au vu de la TM
- envoi de la TC au codeur puis au satellite
- exécution de la TC par le satellite
- retour de la TM vers le Centre de Calcul.



Réseau de stations et système de transmission

Durant toutes ces opérations, la TM est recueillie et traitée en permanence. Ceci permet d'effectuer en temps réel des opérations délicates comme la mise à poste d'un satellite géostationnaire qui nécessite une sécurité parfaite.

Figure 2 – La salle d'opérations de Toulouse.

CENTRE D'OPERATIONS

Le Centre d'Opérations, transféré de Brétigny-sur-Orge à Toulouse en 1974, dirige les opérations du réseau et assure les transmissions (Fig. 2). Il offre aux utilisateurs des salles d'opérations bien équipées leur donnant accès à tous les contrôles qu'ils jugent nécessaires durant les opérations de satellites en orbite. La proximité d'un Centre de Calcul puissant donne à ce Centre d'Opérations des possibilités considérables.

EVOLUTION DU RÉSEAU

Les moyens du réseau de stations françaises doivent suivre l'évolution des satellites. Des études sont actuellement en cours pour assurer dans l'avenir une compatibilité technique avec les projets de l'Agence spatiale européenne et les satellites qui seront lancés par la fusée européenne Ariane. Ces études concernent en particulier le passage éventuel des TM/TC dans la bande S et l'adjonction de mesures de distance en VHF et en bande S.

MOYENS D'ACQUISITION ET DE TRAITEMENT DES DONNEES DE TELEMESURE

Le Centre spatial de Toulouse est équipé de moyens

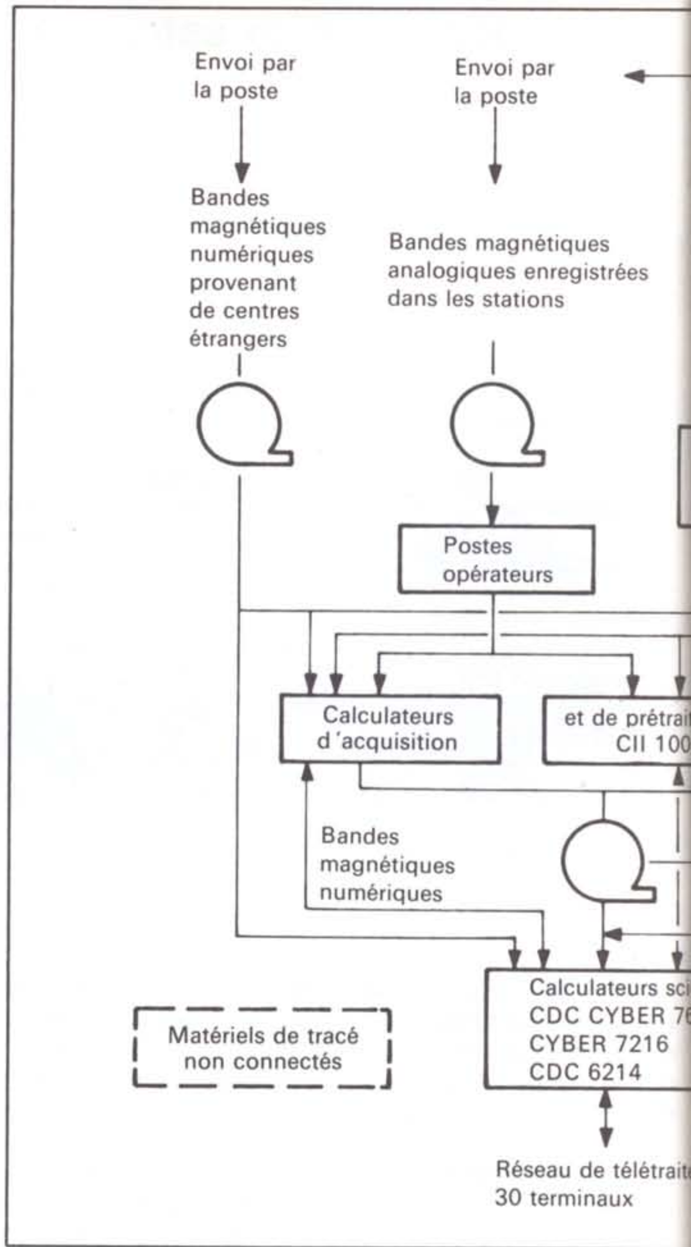
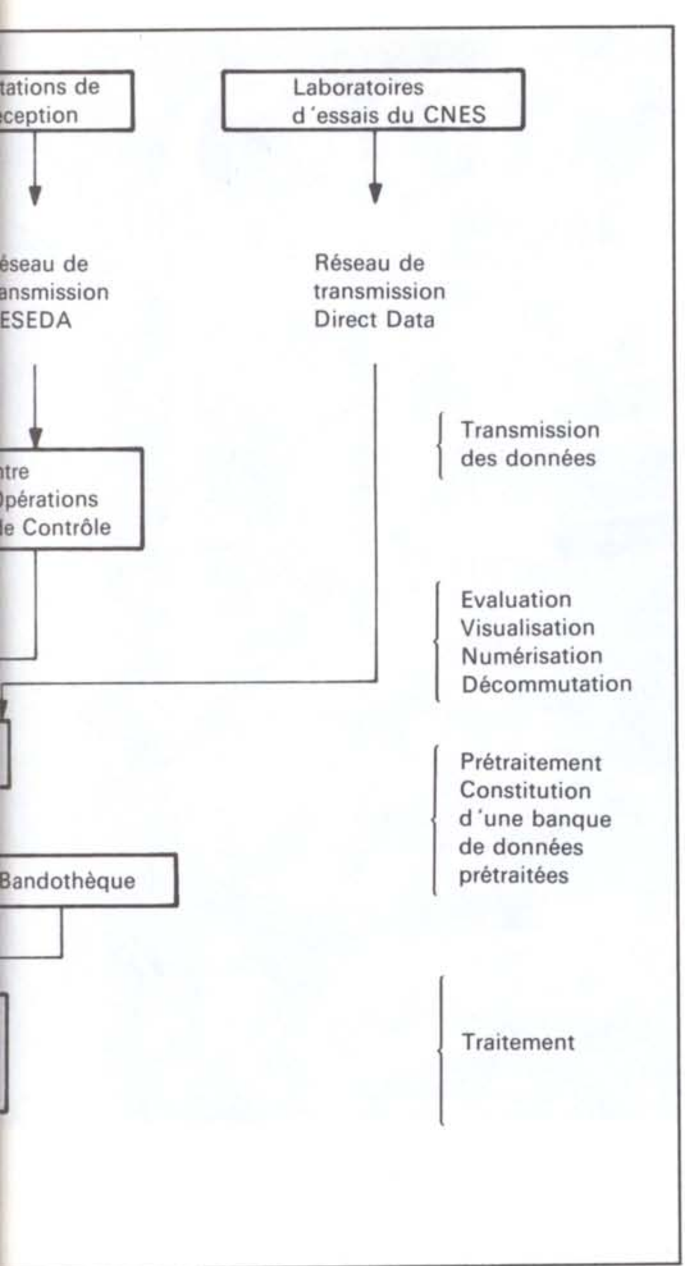


Figure 3 – Schéma d'organisation des moyens du Centre de Calcul.

puissants d'acquisition et de traitement des données de télémesure, situés à proximité immédiate du Centre d'Opérations. Les données de télémesure arrivent par quatre voies différentes (Fig. 3):

– des données transmises directement par le réseau de transmission RESEDA et le Centre d'Opérations de Toulouse (voir ci-dessus);
– des données enregistrées sous forme analogique dans les stations de réception, les stations des champs de tir, des avions dans le cas de données de télédétection des ressources terrestres;
– des données enregistrées sous forme numérique sur bandes compatibles ordinateurs dans des stations ou des centres de traitement étrangers;
– des données générées dans les laboratoires d'essais



du CNES à Toulouse lors d'essais d'intégration ou de réception d'équipements ou de charges utiles; elles sont transmises sous forme numérique par le réseau de transmission Direct Data qui permet au laboratoire de commander directement à distance leur acquisition par le calculateur, leur traitement et le retour de résultats.

POSTES OPERATEURS

Les enregistrements analogiques effectués dans les stations sont pris en compte par des matériels appelés *postes opérateurs* spécialement conçus par le CNES qui permettent de les relire, d'évaluer leur qualité, de les visualiser sur des enregistreurs graphiques, de démoduler,

Figure 4 – Poste opérateur PCM.

de numériser, de transcoder les signaux de temps, de synchroniser bits et formats, de définir le prétraitement à effectuer au niveau du calculateur et de commander directement l'acquisition des données par celui-ci. Ces appareils permettent de traiter tous les enregistrements qui peuvent leur être soumis (Fig. 4).

CALCULATEURS D'ACQUISITION ET DE PRÉTRAITEMENT

Du type CII 10070, ils assurent:

- l'acquisition des données de télémesure quelle que soit leur provenance;
- leur prétraitement ou traitement en temps différé lorsque la nature des opérations effectuées le permet;
- leur traitement en temps réel et la préparation d'ordres de télécommande lors des opérations en temps réel des charges utiles.

Ces deux calculateurs (Fig. 5) ont des configurations très proches qui leur permettent d'intervenir en redondance lors des opérations en temps réel. Le contrôle des opérations peut être effectué au moyen de six consoles visuelles alphanumériques CII Iriscope 300 (16×80 caractères) et deux consoles visuelles graphiques SINTRA VU 2000 (2048×2048 points).

Ces calculateurs sont dotés chacun d'une mémoire

Figure 5 – Calculateur d'acquisition CII 10070.

centrale à tores de ferrites de 112 Kmots de 32 bits organisée par groupes de 8, 16, 32 et 64 bits. Ils comprennent par ailleurs des mémoires à disques (300 Moctets en ligne au total) et des dérouleurs de bandes magnétiques (9 pistes, 1600 bpi.) Ils sont orientés calcul scientifique et temps réel et utilisent le moniteur de multiprogrammation SIRIS 7.

Le prétraitement en temps différé des données de télémesure fournit des données reconnues, validées, mises sous une forme permettant leur traitement ultérieur (reformatage, application de calibrations et de fonctions de transfert, etc.) A ces informations peuvent être ajoutées des informations sur la trajectoire et l'attitude de la charge utile, permettant de constituer une 'banque de données prétraitées' qui peuvent être stockées sur bandes magnétiques en prévision de traitements ultérieurs. Près de 20 000 bandes magnétiques sont actuellement stockées et gérées à ce titre par la bandothèque du CNES à Toulouse. (Fig. 6).

Les calculateurs d'acquisition et de prétraitement sont cependant connectées aux calculateurs scientifiques afin de permettre le transfert direct de données lorsque cela est nécessaire.

CALCULATEURS SCIENTIFIQUES

Trois calculateurs CDC CYBER 7614, CYBER 7216 et

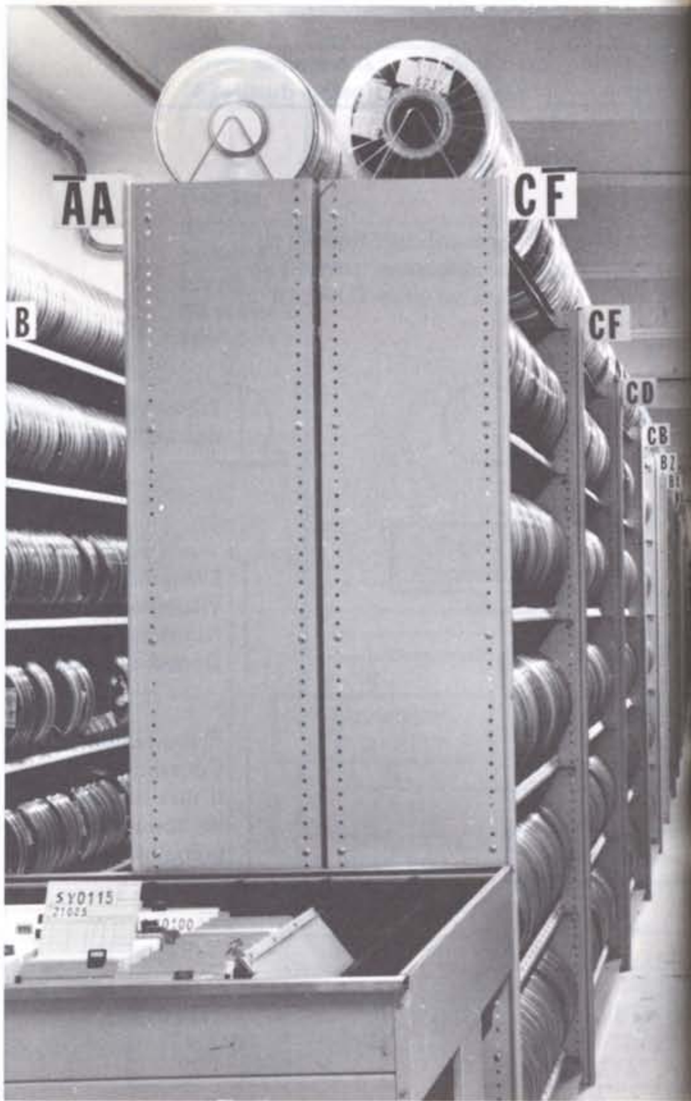


Figure 6 – La bandothèque du CNES.

CDC 6214 assurent le calcul scientifique, c'est-à-dire:

- au niveau du prétraitement des données, certains calculs nécessitant une puissance de calcul élevée (orbitographie, détermination d'attitudes, certains prétraitements d'images);
- au niveau des traitements proprement dits, la plupart de ceux-ci, généralement à partir de données situées sur des bandes magnétiques issues du prétraitement.

Ces calculateurs sont mis à la disposition d'un certain nombre d'utilisateurs et de laboratoires scientifiques au moyen de terminaux de chargement et d'édition à distance situés dans la région parisienne, à Toulouse, Marseille et Nice. Ces utilisateurs peuvent ainsi accéder aux données prétraitées stockées à Toulouse et effectuer les traitements qui leur conviennent.

Ils peuvent écrire et mettre au point eux-mêmes les logiciels de traitement dont ils ont besoin ou demander au

Figure 7 – Consoles de commande des calculateurs de traitement scientifique CDC.

CNES de le faire suivant leurs spécifications dans le cadre d'une convention ou d'un marché. Cette formule originale réalise un excellent compromis efficacité/coût: les utilisateurs accèdent ainsi à un ensemble de matériels importants servis par des équipes compétentes tout en demeurant dans leurs milieux de travail respectifs.

Le calculateur CYBER 7614 est un processeur extrêment rapide. Il est servi par deux calculateurs frontaux (CYBER 7216 et CDC 6214) qui assurent les échanges de l'ensemble avec l'extérieur. La mémoire dont il dispose est constituée de 64 Kmots en SCM, 256 Kmots en LCM, et deux disques 819 de 2 × 400 Mcaractères. Le mot utilisé comporte 60 bits, il est particulièrement bien adapté au calcul scientifique. Les calculateurs frontaux supportent par ailleurs des mémoires à disques (11 800 Mcaractères en ligne au total) et des dérouleurs de bandes magnétiques (10 dérouleurs, 9 pistes 800/1600 bpi, 2 dérouleurs 7 pistes 200/556/800 bpi). Le moniteur de multiprogrammation Scope gère l'ensemble des calculateurs en assurant les transferts et en utilisant avec la meilleure efficacité les différents types de mémoires. Le système de télétransmission Intercom orienté temps partagé assure les communications des calculateurs frontaux avec les terminaux lents, y compris les terminaux interactifs (Fig. 7).

Des matériels de tracés, actuellement non connectés, permettent aux utilisateurs de recevoir les résultats sous forme de courbes, de schémas ou d'images plutôt que de listes de chiffres difficiles à interpréter Ils comprennent des traceurs sur papier et sur film.

Des terminaux spécialisés assurent l'aide au traitement et à l'interprétation des images au moyen de logiciels interactifs de présentation des données images. Ils sont utilisés principalement pour la mise au point de programmes de télédétection des ressources terrestres.

Les calculateurs scientifiques ne servent pas qu'à effectuer le traitement des données de télémesure. Dans le cadre de sa mission nationale de promotion de l'industrie et des applications spatiales, le CNES effectue également des tâches d'analyse de missions et d'études de systèmes spatiaux, conception et faisabilité de charges utiles, recherche et développement technologiques, évaluation et recettes de systèmes et équipements. Des logiciels de haut niveau ont été développés dans ce cadre; ils sont soutenus par des équipes compétentes et peuvent être utilisés pour le compte de sociétées ou d'organismes extérieurs au CNES. □

Esrange - A High-Latitude Rocket and Balloon Range managed by the Swedish Space Corporation

L.H. Larsson, Swedish Space Corporation, Esrange, Kiruna, Sweden

The Esrange sounding-rocket range, situated in northern Sweden inside the Arctic Circle (67°53'), is used mainly for auroral studies. From its inauguration in 1966, it has been used primarily for co-operative international projects. Until 1972 the range was owned and operated by ESRO. Since then it has been managed by the Swedish Space Corporation, which is also responsible for most of the executive functions of the Swedish space programme.

Although Esrange is as far north as Alaska or Siberia, its climate is very similar to that elsewhere in northern Europe or North America. It has been designed exclusively for launching sounding rockets and balloons for scientific research, and no other activities such as military tests, satellite countdowns or the presence of ships or aircraft in the impact area interfere with launches. The range is supported financially through the Esrange Special Project by seven ESA Member States, including Sweden, who can also use it on a marginal cost basis. It is open, on a non-profit basis, to all scientists utilising sounding rockets or balloons for scientific research, and for ground-based scientific experiments in any way connected with such activities.

There is a co-operative agreement between Esrange and the Norwegian sounding-rocket range at Andøya, on the Atlantic coast.

The commonest scientific experiments flown from Esrange are designed to study electric and magnetic fields and auroral particles and are usually conducted during the auroral season, from October to March. Another class of phenomena that can be studied only at high latitudes is noctilucent clouds. Several experiments using sampling techniques as well as photometers are conducted during July and August most years. A third class of experiments is formed by those designed to investigate the structure of the Arctic mesosphere, and these are conducted mainly in the spring.

TECHNICAL FACILITIES

The main building at the range houses the control centre, scientific centre, telemetry station, timing centre, computer room, offices, conference room, workshop, stores and recreation areas. In the launch area (1 km east of the main building) there is a block-house, a payload-preparation hall, two rocket-preparation halls, six launchers, and rocket-storage buildings. The radar station is situated south of the main building and also houses transmitters, receivers and instruments for scientific ground measurements.

LAUNCH CAPABILITIES

There are six permanent launchers at the range for sounding rockets of different sizes (Table 1). Skylark vehicles are launched from a 30 m rail housed in a metal tower. Two Centaure launchers can be moved on rails from the preparation hall to the launch platform. These launchers can also be used to fire Nike combinations, Skuas and Petrels. The Nike launchers are used for Nike, Black Brant III, Skua and Petrel launchings. Heating for these launchers is provided by warm-air blowers. The Aries building contains the simple 'stool' launcher needed for this vehicle and the necessary heating and handling equipment. The building itself is rolled away on rails prior to launch. Installation of additional launchers by users is encouraged and the range has provided support for such work in the past.

Balloons are launched from the helicopter platform close to the main building.

ESOC-RELATED FACILITIES

Two facilities at Esrange are of special interest for this ESOC edition of the Bulletin, the telemetry data-handling system and the real-time satellite data link with ESOC.

The telemetry data-handling system (Fig. 1) is a continuation of the ESOC Data Conversion Line, which was operated until 1973. The Esrange system is designed to provide scientists with their experiment data in a form compatible with their own computers. During a rocket or

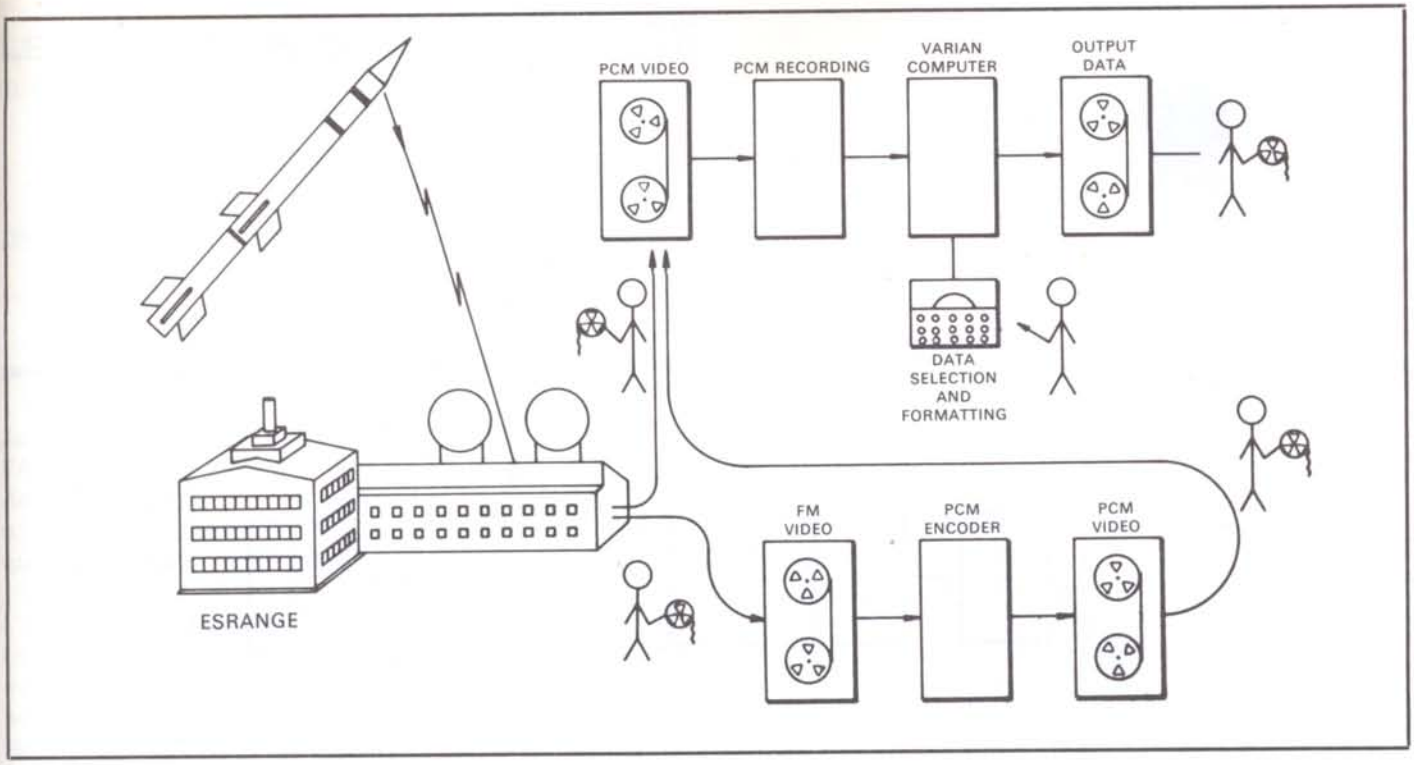


Figure 1 – Esrange telemetry data-handling system.

balloon flight, the video output from the telemetry receivers is recorded on magnetic tape together with time information, etc.

Normally, the signals are either pulse-code (PCM) or frequency (FM) modulated. In the first case, the 'analog' video tape is played back to the PCM decoding equipment in the telemetry station, resulting in an output of binary data words and synchronisation pulses. The output is fed, together with timing information, to Esrange's Varian computer (Fig. 2), which sorts and formats the data words, and writes the output on magnetic tape (ECMA standard form). In the FM case, the

Figure 2 – The Varian V73 computer.

TABLE 1

Rocket Types Launched from Esrange

Name	Manufacturer	Number of Stages	Total Length (m)	Diameter of Second Stage (cm)	Total Weight at Start (kg)	Normal Weight of Payload (kg)	Weight at Impact (kg)	Peak Altitude (km)
Centaure	France	2	5.9	30	536	60	147	150
Skylark	United Kingdom	2	9.2	44	1477	150	385	200
Nike-Apache	USA	2	8.6	17	724	25	69	200
Nike-Cajun	USA	2	8.1	17	719	30	66	120
Nike-Tomahawk	USA	2	10.0	23	960	100	150	240
Black Brant III	Canada	1	5.5	26	320	40	116	185
Petrel	United Kingdom	2	3.8	17	169	20	49	140
Skua II	United Kingdom	2	2.9	13	57	5	14	70
Aries	USA	1	7.9	112	6280	530	1228	500

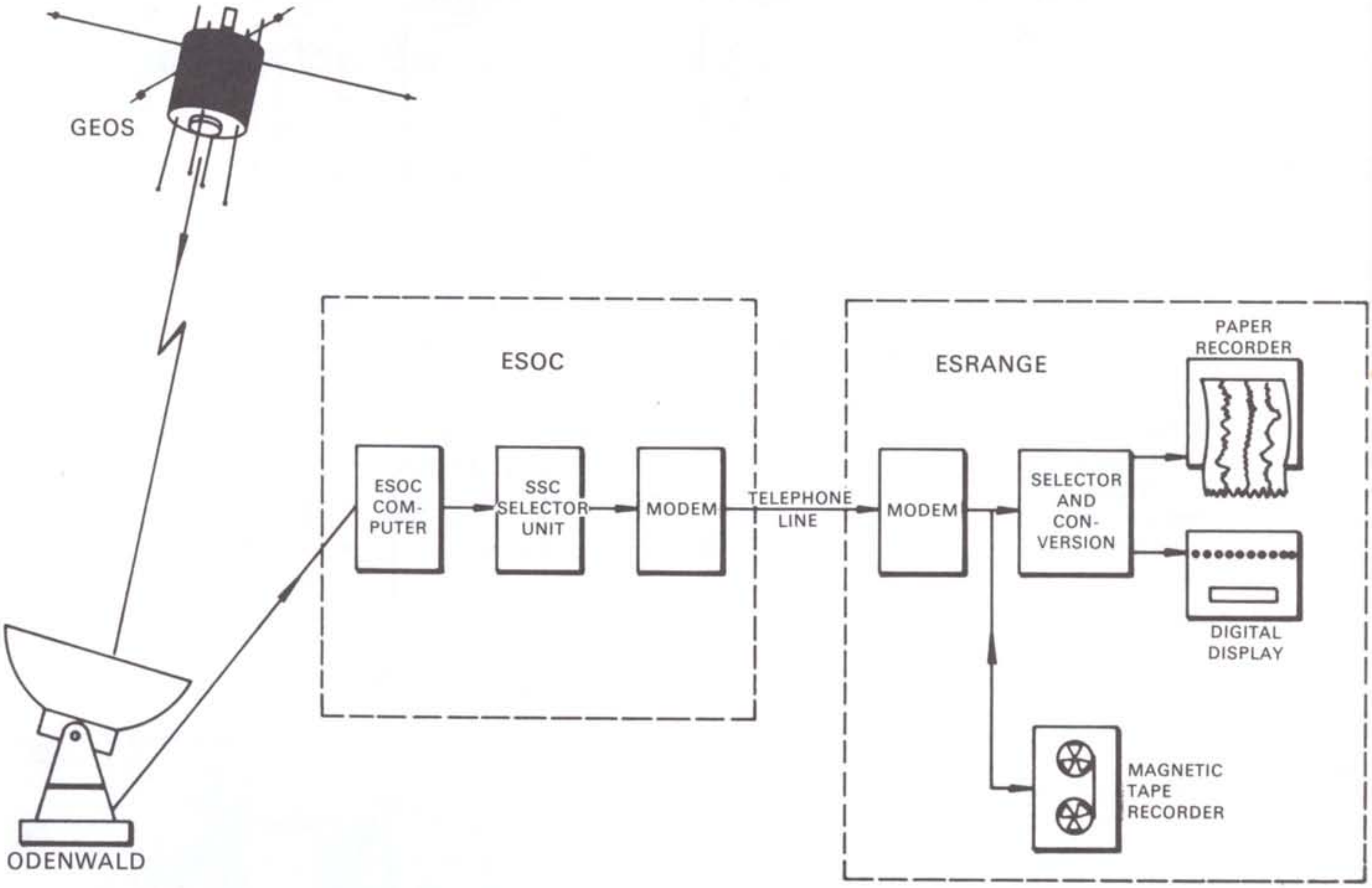


Figure 3 – Real-time satellite data link between Esrange and ESOC.

video signal is demodulated using standard equipment in the telemetry station. The demodulated signals are fed to a PCM encoder, and the resulting output is recorded on magnetic tape, which is later processed as in the PCM case.

The equipment can handle analog tapes recorded other than at Esrange, in most standard formats. Tapes from Wallops Island (USA), Søndre Strømfjord (Greenland) and Andøya (Norway) have been processed in the past with good results.

A real-time satellite data link (Fig. 3) currently being installed between ESOC and Esrange gives sounding-rocket experimenters at Esrange an opportunity to monitor the outputs of satellite experiments and to select the most appropriate moment for launching sounding rockets as part of a co-ordinated programme of satellite and rocket measurements. The system will be used with ESA's GEOS satellite, the reference spacecraft for the International Magnetospheric Study in the years 1976–78. GEOS low-speed telemetry data (see ESA Bulletin No. 4) will be supplied to Esrange via a selector unit constructed by the Swedish Space Corporation but sited at ESOC. This unit can be remotely controlled from Esrange to select about 100 of the 2048 data words in the 'GEOS low-speed telemetry format' for reception over a standard telephone line. The data can then be monitored by the range staff on paper recorders or digital displays.

FUTURE PLANS

Future plans for Esrange include the launching of Nike/Black Brant VC rockets with an SSC-developed guidance system to apogees of up to 500 km. To make these launches possible, a new launcher and other equipment will be installed. In addition to the routine types of scientific experiments conducted at the range, a number of launches for conducting zero-gravity experiments are planned in the coming years.

A Landsat receiving station is to be installed and will be operational by the end of 1977. Discussions regarding the integration of the Esrange station into the ESA Earthnet are currently in progress.

Les nouvelles stations de l'ASE

Division Moyens d'Equipements Sol, ESOC

Jusqu'à ce jour, les opérations sur les satellites de l'Agence étaient conduites à partir du réseau VHF de l'ESOC (Estrack). Il s'agissait alors de satellites à défilement et qui ne transmettaient qu'une quantité d'informations limitée vers le sol.

L'avènement prochain des satellites géostationnaires (GEOS, Météosat, OTS, Marots, Aérosat), qui doivent utiliser des gammes de fréquences nouvelles et transmettre une quantité d'informations considérablement accrue, va nécessiter un réseau de stations terriennes entièrement nouvelles (y compris pour IUE qui n'est pas un satellite géostationnaire).

INTRODUCTION

Le premier facteur déterminant dans la définition de ce nouveau segment sol est le fait que les satellites sont géostationnaires. Cela impose qu'une station doit être affectée à un satellite particulier pendant toute la durée de sa mission (deux ans pour GEOS, sept ans pour Marots). Un deuxième facteur tout aussi important est la disponibilité des fréquences utilisées pour les échanges satellite-sol. Ce problème, qui met en cause les divers utilisateurs du spectre de fréquence, constitue la contrainte déterminante pour la localisation géographique des stations. En effet la sensibilité des systèmes de réception et les puissances nécessaires à la transmission des informations vers le satellite exigent une coordination des fréquences sur une zone d'une centaine de kilomètres. La troisième contrainte à prendre en compte est le concept opérationnel adopté pour ce type de projet. En effet, il a été jugé plus économique de regrouper tout le contrôle des satellites à l'ESOC et de mettre en place un système de calcul permettant le traitement des données transmises dans les deux sens en temps réel. Pour ce faire, il est indispensable de disposer de moyens de transmission fiables et de très grosse capacité, en particulier pour les satellites tels que GEOS et Météosat.

Enfin, un dernier facteur dont il faut tenir compte est la volonté de certains Etats membres de mettre à la disposition de l'Agence les terrains nécessaires pour l'installation de telles stations.

A partir de ces données, trois sites ont été choisis:

1. *Michelstadt (Allemagne)* pour les projets GEOS et Météosat. Le choix de ce site (à environ 40 km de l'ESOC) a surtout été guidé par la masse considérable de données à échanger entre la station et le Centre de Contrôle (liaison à 2048 Mbits/s).
2. *Fucino (Italie)* pour le projet OTS. Le choix de ce site (à 120 km de Rome) a été dicté par les contraintes techniques (utilisation des fréquences de la bande X et Ku) et par la procédure de mise en place du système (contrat conjoint avec Telespazio).
3. *Villafranca del Castillo (Espagne)* pour les projets IUE et Marots. Situé à 30 km de Madrid, ce site est pour l'Agence, au point de vue des fréquences disponibles, le meilleur. Son extension est déjà prévue pour le soutien d'Aérosat.

FONCTIONS ASSUREES ET CRITERES FONDAMENTAUX

Indépendamment du type de mission qui lui est assignée, la fonction primordiale d'une station est d'assurer la transmission d'information entre le sol et l'espace. Cette fonction de *télécommunication* peut être définie en termes de densité de flux de puissance, de dégradation acceptable du signal (taux d'erreur sur les bits), de type de modulation choisi, de contraintes sur le spectre du signal. Elle se traduit par le dimensionnement de l'élément d'interface avec l'espace, l'antenne, et des deux facteurs principaux: le rapport gain/température (G/T) et la puissance isotrope rayonnée équivalente (PIRE).

L'équipement de la station doit par ailleurs permettre d'assurer des *fonctions spécifiques* à la mission considérée. Dans tous les cas, elles sont de deux ordres:

(i) La surveillance et le contrôle du satellite par la télémesure des paramètres des divers sous-systèmes à bord, l'envoi des ordres de télécommande et la mesure des paramètres permettant sa localisation précise.

(ii) L'acquisition des données élaborées à bord du

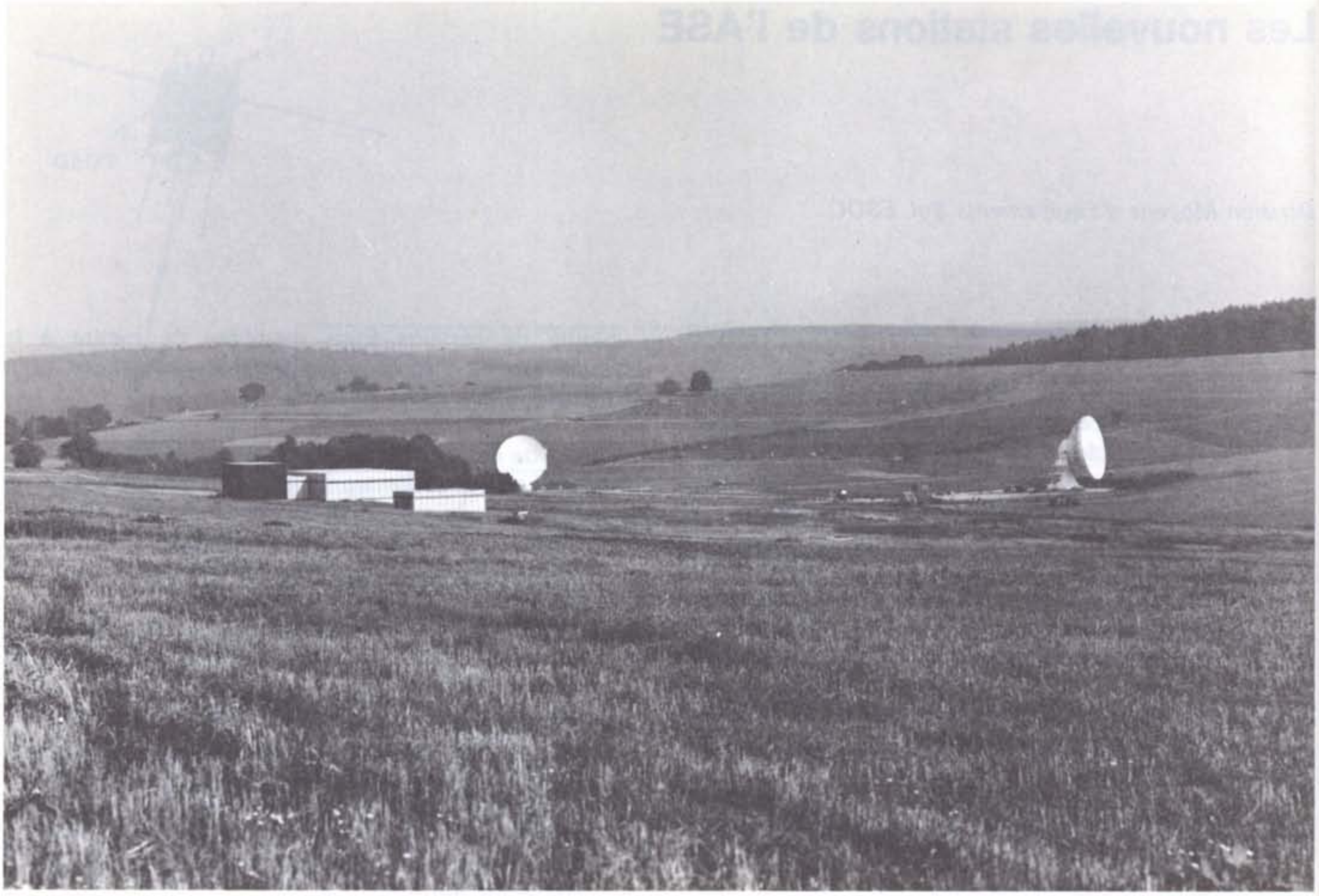


Figure 1 – Antennes GEOS et Météosat de la station de Michelstadt.

satellite (cas de GEOS, Météosat, IUE) ou la capacité de télécommunication nécessaire à un programme expérimental de satellite de télécommunication comme OTS.

La troisième fonction est la *transmission de données* permettant la liaison avec le Centre de Contrôle de l'ESOC.

Les critères pris en compte pour le dimensionnement des stations sont fonction du type de satellite et du concept opérationnel adopté.

Le premier critère est qu'à un satellite correspond une station qui doit assurer sans interruption pendant toute la durée de la mission les fonctions requises. Compte tenu de cet impératif, le système sol doit offrir toute garantie de fiabilité, ce qui suppose une redondance au niveau des sous-systèmes, permettant ainsi d'assurer le service et la maintenance nécessaires. Le second critère vient du fait que tous les satellites doivent être contrôlés à partir de Darmstadt. Pour ce faire, la station doit être transparente aux signaux et d'autre part ne doit pas (ou peu) demander d'intervention manuelle locale.

STATION DE MICHELSTADT (ODENWALD)

Cette station regroupe les moyens nécessaires au soutien des satellites GEOS et Météosat (Fig. 1). Tout en remplissant les fonctions et critères définis ci-dessus, elle a été conçue pour être entièrement mise en oeuvre sans opérateur, en dehors de la présence occasionnelle de techniciens de maintenance.

EQUIPEMENTS PRINCIPAUX

Antennes

Les facteurs de mérite imposés par les missions GEOS ($G/T \geqslant 27$ dB/K) et Météosat ($G/T \geqslant 23$ dB/K) sont obtenus par l'utilisation de deux antennes identiques de 15 m de diamètre suivies d'amplificateurs paramétriques non refroidis de 55 K à 2,3 GHz: la PIRE nécessaire à la mission Météosat (3 porteuses simultanées: 2 de 64 dBW et une de 57 dBW) par un ensemble d'amplificateurs redondant à klystron de 1 kW.

Ces antennes utilisent des supports du type azimut/élévation à couverture hémisphérique complete; les systèmes d'asservissement utilisent des moteurs à courant alternatif et à effet de contre-couple.

Le pointage vers le satellite utilise en mode principal des récepteurs de poursuite et peut être aussi commandé par programme ou manuellement.

Le choix d'antennes identiques a été dicté par des considérations économiques. En effet les dimensions des antennes nécessaires pour les projets GEOS, Météosat et IUE étant voisines, l'ensemble a fait l'objet d'un contrat unique attribué à la Société Siemens (Allemagne) qui avait comme cocontractants principaux MAN (Allemagne), LCT (France) et Continental Microwave (Royaume-Uni).

C'est ainsi que le dimensionnement des antennes n'a pas été basé sur les caractéristiques de transmission (G/T et PIRE), mais plutôt obéi à la règlementation imposée par les PTT allemandes concernant la limitation du rayonnement parasite et la coordination des fréquences avec les autres utilisateurs.

Ensemble de réception

Les sous-systèmes de convertisseur de fréquence des antennes transforment les fréquences reçues en bande S en une fréquence intermédiaire unique de 70,2 MHz, facilitant la transmission au système de réception et de démodulation installé dans le bâtiment d'exploitation situé à une centaine de mètres des antennes.

Ce système de réception et de démodulation est d'un concept original. En effet l'étude des récepteurs classiques existant sur le marché a montré que les impératifs du système ne pouvaient pas être satisfaits. Une approche modulaire fonction par fonction a donc été définie: en particulier la partie démodulation PSK et synchronisateur de bits a été optimisée pour un fonctionnement à un rythme de bits fixé permettant une meilleure optimisation de la chaîne.

Synchronisateur de format et composition de message

Cet équipement est de type classique mais a été programmé pour fonctionner avec des formats fixes et définis. Pour la transmission des informations au centre de traitement de l'ESOC, on utilise la procédure de messages standard qui, en plus des données, comportent les entêtes nécessaires à leur aiguillage en fonction des besoins. En outre chaque message comporte les informations précises de temps nécessaires aux corrélations demandées.

Ensemble d'émission

L'ensemble d'émission destiné à la mission Météosat est regroupé dans la même salle d'exploitation que l'ensemble de réception. Cet ensemble est ensuite relié à l'antenne par une transmission à la fréquence intermédiaire de 90 MHz, suivie d'une transposition en bande S et de l'amplification nécessaire à cette fréquence pour obtenir la PIRE requise.

L'équipement situé dans la salle d'exploitation reçoit depuis le Centre de Contrôle les informations à transmettre sous forme de messages. Avant transmission, ces derniers sont vérifiés puis mémorisés dans une mémoire-tampon avant d'être mis en série pour moduler la porteuse correspondante. Pour éviter toute transmission erronée ou l'accumulation de messages à la station, les calculateurs de l'ESOC reçoivent en permanence les messages de compte rendu d'exécution depuis la station.

La partie à fréquence intermédiaire est constituée de synthétiseurs de fréquence modulés en fréquence ou en phase suivant les cas. Ces synthétiseurs sont asservis à la fréquence du standard de fréquence. Les divers modulateurs utilisés sont identiques. Leurs sorties sont combinées sur le câble coaxial assurant la liaison vers l'antenne.

Mesure de distance Météosat

Compte tenu des impératifs sur la localisation de ce satellite, un système particulier a été mis en place. La détermination d'un point dans l'espace requiert la connaissance soit d'une direction et d'une distance, soit de deux distances. Une de ces mesures est donnée par la détermination de la distance de la station au satellite et retour et l'autre par celle de la station à une station auxiliaire via le satellite et retour.

Cette station auxiliaire comprend une antenne de 3 m de diamètre, un ensemble de réception et un ensemble d'émission d'une puissance de 100 W. La particularité de cette station est d'être automatique. Le système de réception est en veille permanente. Dès la réception d'un message provenant de la station principale, le système d'émission est mis en route et le message de mesure de distance (porteuse à 160 kHz multiplexé avec un code pseudo-aléatoire de 20 Kbit/s) pourra être transmis de la station principale au satellite, à la station auxiliaire et retour, la mesure de distance étant effectuée par la mesure du temps de transit.

Standard de temps et fréquence

L'ensemble des fréquences ainsi que les informations de temps (jour, heure, seconde) sont fournis par un équipement unique qui utilise des étalons primaires au césium.

Surveillance et commande

L'ensemble de la station est surveillé et commandé depuis le Centre de Contrôle de l'ESOC, grâce à l'utilisation de deux minicalculateurs. Chaque paramètre nécessaire à la surveillance est codé sous forme numérique, puis l'ensemble est transmis à l'ESOC sous forme de message pour être comparé dans deux minicalculateurs à des limites préétablies. En cas de défaillance, la commutation d'une chaîne à une chaîne redondante est faite automatiquement.

En outre chaque minicalculateur donne sous forme d'affichage l'état du système (console alpha-numérique et présentation synoptique). Les informations détaillées peuvent être demandées par un opérateur sous forme de listes grâce à un clavier de dialogue et à une imprimante connectée à la machine. Par ailleurs ce système permet la poursuite en mode programmé des antennes en cas de panne du système d'autopoursuite.

Transmission des données

Compte tenu du volume de données à transmettre entre la station et le Centre de Contrôle, un système de transmission adapté a été développé, qui utilise une liaison coaxiale à haute capacité redondante et des modems à 2048 Mbit/s.

Ce système a été étendu à l'acheminement des messages d'une part entre les différents calculateurs du Centre de Contrôle, d'autre part entre ces derniers et toutes les stations de l'ESOC.

Il constitue aujourd'hui le centre du système temps réel de l'ESOC et permet l'aiguillage de tous les échanges d'informations nécessaire à la conduite des opérations. Il comprend un terminal unique à la station de Michelstadt et un terminal redondant à l'ESOC. Il est articulé sur un calculateur PDP 11/45 d'une mémoire de 80 Kmots par terminal à laquelle une mémoire de 16 Kmots de type MOS a été ajoutée pour la mémorisation du logiciel d'application. Tous les canaux d'entrée-sortie se font par une interface standard série de 16 bits par mot. L'ensemble du logiciel d'application comprend 70 modules qui sont mis en oeuvre par un logiciel spécial.

STATION DE FUCINO

Cette station (Fig. 2) remplit les deux fonctions nécessaires au soutien du satellite OTS:

(i) Télémesure, télécommande et localisation
(ii) Transmissions pour le programme expérimental de télécommunication (cf. *Bulletin ESA* No. 5, mai 1976).

Les équipements liés à la fonction de surveillance et contrôle du satellite sont plus particulièrement décrits ci-après.

CONCEPTION

A la différence de la station de Michelstadt, le principe de base de celle de Fucino a été de séparer la fonction de surveillance et contrôle du satellite de celle de l'expérimentation des techniques de transmission afin d'éviter l'interférence opération/expérimentation, compte tenu de la nature de ces expériences. Ce principe se traduit par la mise en place des divers équipements suivants:

- une antenne principale commune avec ses équipements associés et une antenne auxiliaire utilisée pour les essais de transmission;
- une salle d'équipement principale regroupant les sous-systèmes TTC et les consoles de surveillance

Figure 2 – Station de Fucino.

des équipements communs (antenne et équipements associés);
- une salle de télécommunication regroupant les équipements d'essais de transmission.

Comme toutes les stations de cette nouvelle génération, celle de Fucino est reliée directement au Centre de Contrôle et permet sans intervention manuelle l'exécution des fonctions qui lui sont demandées. Mais à la différence de la station de Michelstadt, celle de Fucino n'est pas télésurveillée et télécommandée et requiert la présence permanente d'un personnel pour la surveillance des divers équipements.

DESCRIPTION

La station est équipée d'une antenne Cassegrain de 17 m de diamètre à monture carrousel. Elle présente un gain d'environ 63 dB dans les bandes de réception 10,95–11,2 GHz et 11,45–11,7 GHz et est suivie par trois amplificateurs paramétriques à large bande non refroidis (un pour chaque polarisation et un en redondance). La PIRE, qui varie de 92,5 dBW pour la transmission du train de données à 180 Mbits/s utilisé par le programme expérimental de télécommunication à 84 dBW pour la porteuse télécommande, est assuré par un ensemble de trois amplificateurs de puissance de 2,5 kW dans la bande de fréquence de 14 à 14,5 GHz.

L'ensemble de ces derniers équipements est installé dans une vaste cabine d'antenne et la liaison avec la salle d'équipement s'effectue à une fréquence intermédiaire de 750 MHz.

L'équipement de réception-démodulation-synchronisation de bit utilise des techniques classiques ainsi que les équipements de transmission en fréquence intermédiaire.

Par contre, toute la partie numérique des fonctions fait appel à une technique modulaire CAMAC permettant une interface série identique pour tous les sous-systèmes.

Le système base de temps utilise des étalons primaires au rubidium et distribue l'ensemble des signaux temps et fréquence nécessaires à la station.

La transmission des messages au Centre de Contrôle se fait par l'intermédiaire d'un système redondant de lignes de transmission. L'échange de messages utilise la procédure de duplex intégral.

MISE EN PLACE

L'ensemble des équipements a été mis en place aux termes d'un contrat conjoint ESA-Telespazio attribué à la Société AEG-Telefunken (Allemagne), les sous-contractants principaux étant BTA/Stork (Hollande) pour la mécanique de l'antenne, SIT et GTE (Italie) pour les amplificateurs de puissance et à faible bruit, Dornier (Allemagne) pour le sous-système TTC et Oscilloquartz (Suisse) pour l'ensemble temps-fréquence.

STATION DE VILLAFRANCA

Cette station comprend les équipements destinés au soutien des deux projets Marots et IUE (Fig. 3). Si les installations affectées à la mission Marots sont similaires à celles prévues pour OTS à Fucino, la station IUE, par contre, obéit à un concept unique dans son genre.

STATION MAROTS

On y retrouve le même concept que celui de la station OTS de Fucino, à savoir:

(i) la fonction télémesure, télécommande et localisation

(ii) la partie nécessaire à la conduite d'expériences de télécommunications.

Equipements de localisation, télémesure et télécommande

Ces équipements sont en cours de réalisation au titre d'un contrat passé avec Siemens (Allemagne). Ils comprennent:

(i) Une antenne Cassegrain de 12 m de diamètre capable de recevoir les signaux transmis par le satellite dans la bande 10,69–10,70 GHz et d'émettre des signaux vers le satellite dans la bande 14,49–14,50 GHz et dont la conception particulière peut permettre l'adaptation dans une très large plage de fréquences. Elle est équipée d'un système d'autopoursuite performant qui permet la localisation angulaire du satellite avec une précision de 0,02°. Une cabine lui est associée qui renferme le système de réception à faible bruit composé principalement de deux amplificateurs paramétriques (température de bruit: 200 K), le système de servomécanismes et de poursuite, l'amplificateur d'émission utilisant un TOP dont la puissance à saturation est de 2,4 kW.

(ii) Un ensemble video-fréquence installé dans la salle principale d'équipements et qui comprend:

- une chaîne de réception de télémesure effectuant la démodulation du signal à fréquence intermédiaire en provenance de l'antenne et délivrant le signal de télémesure PCM, après conditionnement et décommutation, à l'interface de communications avec le Centre de Contrôle;

Figure 3 – Antenne de la station de Villafranca.

- une chaîne de transmission de télécommande qui reçoit les ordres de télécommande par l'interface de communications avec le Centre de Contrôle, effectue les opérations de modulation, transmet les signaux de télécommande à fréquence intermédiaire à l'émetteur et assure la bonne transmission des ordres de télécommande par l'antenne;
- un système de mesure de distance station-satellite utilisant la mesure du déphasage d'un signal sinusoïdal à 100 kHz modulant sur le trajet montant la porteuse de télécommande et sur le trajet descendant la porteuse de télémesure;

- une interface de communications avec le Centre de Contrôle permettant la connexion, sous forme de messages, du Centre de Contrôle avec les sous-systèmes télémesure, télécommande, mesure de distance, surveillance et contrôle de la station par l'intermédiaire de deux lignes téléphoniques louées. La conception normalisée de l'interface avec les sous-systèmes (CAMAC) peut permettre de connecter au Centre de Contrôle des sous-systèmes supplémentaires pouvant être affectés à d'autres projets. Le terminal utilisé à l'ESOC est le même que celui utilisé pour la liaison avec la station de Fucino;
- les signaux de temps et de fréquence sont distribués à partir du système général temps-fréquence réalisé au titre du contrat d'intégration IUE.

Equipements de mesure de la charge utile

Ces équipements, en cours de définition dans le cadre du projet Marots, comporteront un terminal dont l'antenne parabolique en bande L d'environ 3 m de diamètre serait installée sur le toit du bâtiment principal; des équipements de modulation et démodulation nécessaires à la transmission et à la réception de voies téléphoniques et de données reliées au réseau de terminaux-navires et de stations côtières du système Marots; les équipements d'enregistrement et de traitement des mesures de la charge utile; des équipements permettant le contrôle préopérationnel du réseau Marots, notamment du niveau de puissance à l'accès réception du transpondeur de bord des signaux en provenance des stations côtières.

STATION IUE

Au titre de sa participation à ce projet réalisé en commun avec la NASA, l'Agence a entrepris la mise en place d'une station sol et de l'observatoire associé, qui doivent permettre de contrôler la charge utile pendant le tiers du temps de visibilité du satellite.

Le segment sol comprend trois éléments: l'observatoire, le centre de traitement et les équipements d'acquisition des données et de télécommande du satellite.

Observatoire

L'observatoire permet à l'utilisateur d'effectuer les fonctions demandées, au travers du système de traitement. Des consoles de visualisation présentent d'une manière aisée les informations. Reliée à l'observatoire, la console de l'ingénieur système lui permet de maintenir le satellite en condition opérationnelle.

Système de traitement

La station est équipée d'un ensemble de calcul destiné au traitement des données acquises et la transmission des ordres de télécommande pour la modification de la configuration du satellite. Le système de calcul travaille en deux temps:
- temps réel lors de l'acquisition des données pendant la période de visibilité définie du satellite (8h/jour);
- temps différé pour le traitement des données enregistrées pendant le reste du temps.

Ensemble télémesure et télécommande

Cet ensemble correspond davantage à ce que l'on a l'habitude de définir comme station sol. Il s'agit en effet des équipements qui permettent d'assurer les fonctions télémesure et télécommande nécessaires pour la conduite des opérations sur le satellite. La liaison descendante est effectué en bande S tandis que liaison montante se fait en VHF.

L'ensemble réception-démodulation est directement connecté au calculateur de la station ainsi que l'ensemble de transmission des ordres de télécommande. Cet ensemble utilise une antenne de 15 m de diamètre identique à celles installées à Michelstadt. Situé dans la salle d'équipements à une centaine de mètres de l'antenne, il est caractérisé par l'utilisation des synchronisateurs de bits et de formats sous contrôle du calculateur et d'un décodeur convolutionnel de Viterbi permettant un gain net de 5 dB sur le bilan de liaison.

Le système de télécommande utilise une méthode de modulation en fréquence. Il est relié en fréquence intermédiaire à l'antenne VHF située à 200 m de la salle, où, après une conversion en fréquence suivie d'une amplification, il est émis à une PIRE de 89 dBW en utilisant une antenne de 20 dB de gain.

Un sous-système de temps-fréquence, commun à Marots et IUE, permet la distribution des signaux nécessaires à la corrélation des divers sous-systèmes.

L'ensemble d'équipements mis en place pour IUE est complété par un système de transmission de données avec le Centre spatial Goddard, permettant ainsi l'échange d'informations entre ce dernier et l'ESOC pendant toute la durée de la mission.

A l'exclusion de l'ensemble de traitement, la mise en place des équipements a été confiée à Plessey Radar (R-U) à titre de contractant principal, avec MBB (Allemagne), Oscilloguartz (Suisse) et CASA (Espagne) comme cocontractants. L'antenne a été fournie par Siemens (Allemagne) et l'ensemble de réception par Intertechnique (France).

En outre la Station abrite une station de mesure de distance nécessaire pour la localisation du satellite OTS.

CONCLUSION

La station de Michelstadt, maintenant terminée, a été inaugurée officiellement le 14 septembre 1976 par le Ministre allemand de la Technologie et de la Science, M. Matthöfer, et par M. Roy Gibson, Directeur général de l'Agence. Depuis lors, les essais de compatibilité avec le modèle du satellite GEOS se sont déroulés d'une manière satisfaisante. Des essais similaires avec le modèle du satellite Météosat sont prévus pour janvier 1977.

La station de Fucino sera recettée au mois de janvier 1977. La première phase des travaux pour la station de Fucino sera terminée vers fin août 1977. □

(Continued from page 56)

happening! Another launch? Unlikely, as only two months had passed since TD-1 had been sent into orbit. But what then was this hectic activity throughout the night? The TD mission, which had started so promisingly, was now endangered by failure of the satellite's tape recorders and a concentrated effort to salvage the mission, relying on a combination of knowhow and improvisation, was under way.

In less than two months ESOC installed a network of supplementary stations around the world to collect the data that could no longer be recorded for retransmission when the satellite was in contact with Darmstadt.

Switchboard and telex were liaising day and night with such far away places as Chile, Hawaii and Tahiti and agreements and contracts had to be negotiated with a host of governments and institutions. Seven caravan-like huts were delivered to ESOC to be equipped with antennas and receiver facilities, before being airfreighted to Fiji, Tahiti, Hawaii, Singapore, Easter Island, the Antarctic and the banana boat 'Candide' operating in the South Pacific.

Perhaps our Heiner could hear the sigh of relief when the first data began to arrive, confirming that the salvage mission had been accomplished.

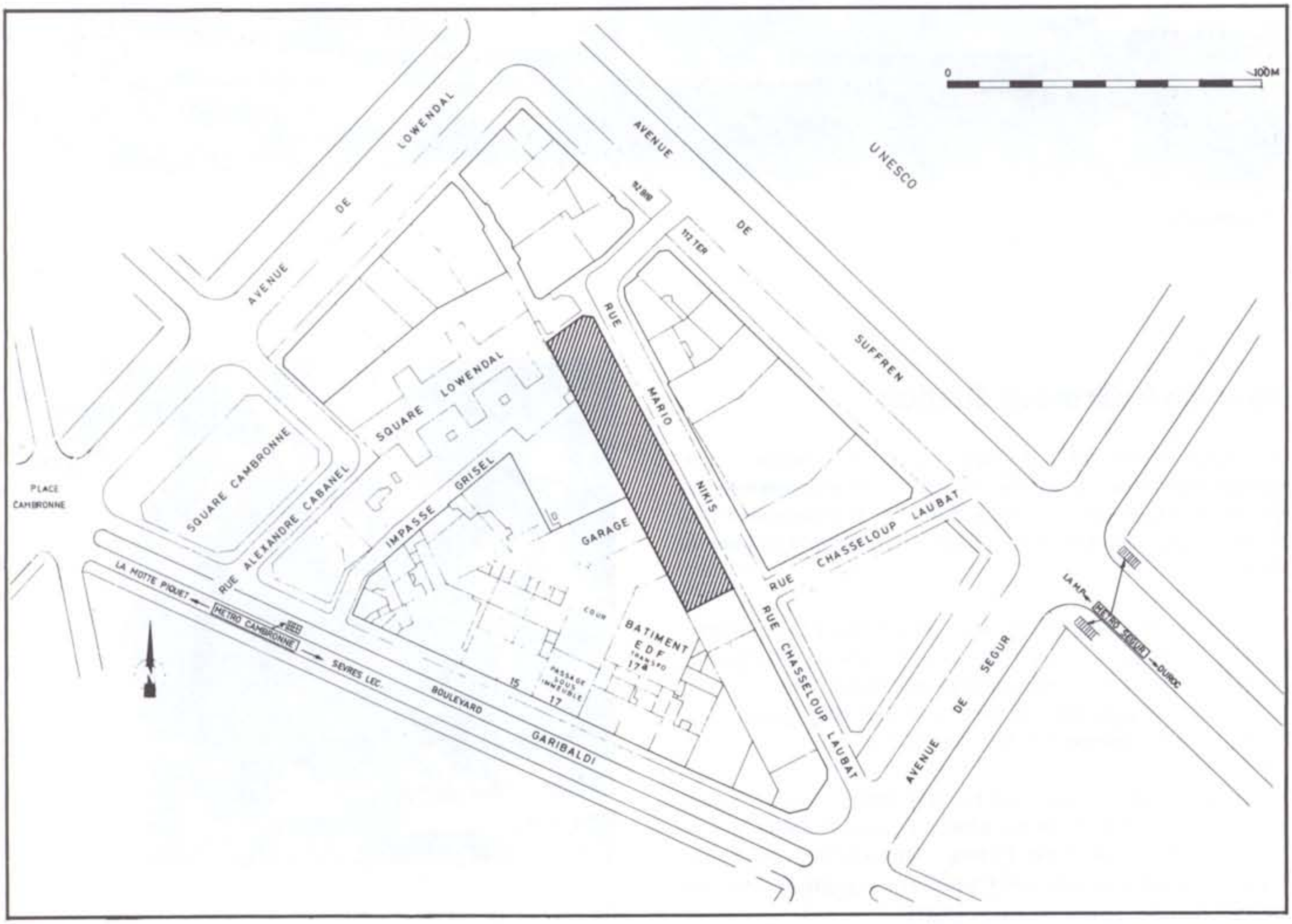
The end of that same eventful year (1972) was to be marked by the launch of ESRO-IV, the last polar-orbiting satellite to require use of the ESOC tracking stations at Spitzbergen and in the Falklands. For the new generation of geostationary satellites that was to follow, Fairbanks and Redu were to be maintained, but new sites were needed for three further ground stations and Fucino (Rome), Villafranca (Madrid) and Michelstadt (south-east of Darmstadt) were eventually chosen. At this same time, ESOC itself underwent a further transformation. For the future programmes, extension of the existing computer capacity was urgently needed and additional ground facilities were required for the Meteosat project, the data handling for which was to be entrusted to ESOC. To the Darmstadt skyline was added a tall, silver building, with 'roots' reaching out to control the two big parabolic antennas at the Michelstadt station, inaugurated last September.

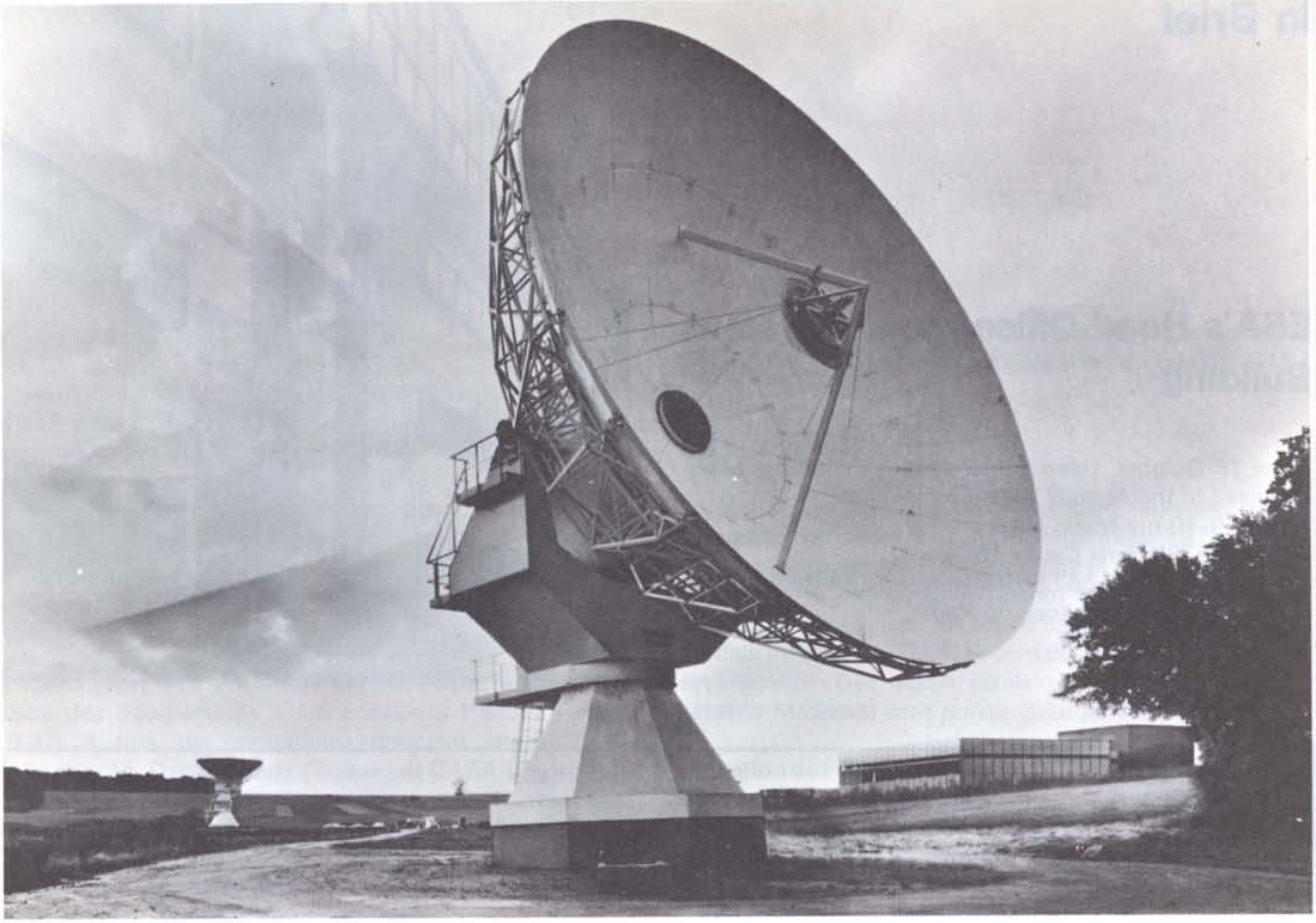
By now, our Heiner has come to appreciate that ESOC and his home town of Darmstadt have become a focal point for European satellite operations. □

ESA's Head Office moves to New Building

As of 18 October, Head Office staff in Paris have been rehoused in the Agency's new building at:

8-10 rue Mario Nikis
75738 Paris Cedex 15
Tel. (33.1) 567.55.78 – Telex ESA 202746
Telegrams Spaceurop Paris.





Michelstadt ground station.

New ESA Ground Station

On September 14, a new ground station, near Michelstadt/Odenwald (Germany), was inaugurated by Mr. Hans Matthöfer, German Minister for Research and Technology and Mr. Roy Gibson, Director General of ESA.

The Odenwald station forms part of the ESA ground-station network – the others being Redu (Belgium), Fairbanks (USA), Fucino (Italy) and Villafranca (Spain) – and will be operational for the launch of the Agency's GEOS and Meteosat satellites in 1977.

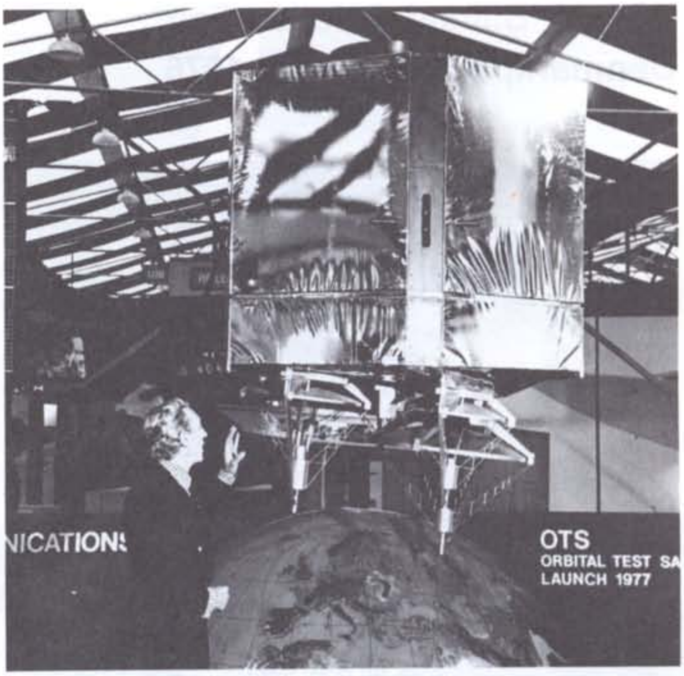
The satellite data received by the station will be sent directly to ESOC via a broadband coaxial cable leased from the German Post Office. The station itself will function automatically and both the satellites and the station will be operated from ESOC.

Opening by Mr. Hans Matthöfer.

ESA at 'Farnborough International 76'

A full-scale Spacelab model was shown in Britain for the first time at the Farnborough International Aerospace Exhibition and Flying Display, 5-12 September. A walkway flanking Spacelab's instrument-carrying pallet allowed visitors to enter the pressurised laboratory in which scientists and engineers will work in orbit. Among other items displayed were full-size models of the Agency's Meteosat and OTS satellites, and a one-tenth scale model of the Ariane launcher. A continuous demonstration of the RECON system and its ESANET network was provided by ESA's Space Documentation Service, in liaison with the UK Department of Industry.

Many journalists from specialised magazines visited the ESA stand, which was also featured in a BBC TV programme on space communications. Other visitors to the stand included Mr. Malow, from the US Congress House Appropriations Committee, and Dr. Lovelace, Deputy Administrator of NASA.



Mr. Raymond Baxter recording for BBC television's Tomorrow's World programme.

Two New Scientific Projects for European Space Agency

Two new scientific projects were unanimously approved by the European Space Agency's Science Programme Committee at its sixth meeting, in Paris, on 4 and 5 October.

ESA participation in the Space Telescope which NASA plans to develop for launch in 1983 was approved, subject to the favourable outcome of negotiations with NASA and to approval of the project by US authorities in 1977. The Agency will also finance a project called GEOSARI (at a cost of 8-9 MAU*).

The European contribution of 15% (approximately 80 MAU*) to the Space Telescope programme would include a faint object camera and its associated detector (image photon counting system), the solar array and part of the associated activities of the Space Telescope Science Institute. It may also cover additional items. European astronomers would in return be allocated not less than 15% of the total space telescope observing time. ESA will start Phase-B studies on this project while continuing negotiations with NASA.

The GEOSARI project consists of launching the GEOS qualification spacecraft, with the same complement of experiments as the flight model but in a different orbit, on the second qualification flight of the Ariane launcher, scheduled for December 1979. The geosynchronous, elliptic orbit of this second GEOS satellite will provide an entirely different programme of scientific investigation to that of the first GEOS spacecraft to be launched in April 1977.

* Million Accounting Units, at mid-1976 price levels (1 AU = 1.3 US $).

ESA at 'Billund Aviation Fair', Denmark, 12-15 August 1976

President of the Billund Aviation Fair, Mr. Nielsen (right) with the American Military Attaché to Denmark (left) and Mr. J.A. Jensen (ESOC).

Mr. J.A. Jensen (ESOC) meeting the Danish press.

ESA appoints New Director of Spacelab Programme

The Council of the European Space Agency, at a meeting in Paris on 7 October, appointed Mr. Michel Bignier as Director of the Spacelab programme.

He is expected to take up this five-year appointment at the beginning of November.

Mr. Michel Bignier.

Mr. Bignier (50) is a graduate of the Ecole Polytechnique, Ecole nationale supérieure d'Aéronautique and Ecole nationale supérieure de Télécommunications. He was Director General of the French Centre national d'Etudes spatiales (CNES) from January 1972 to June 1976 and held various other positions at CNES between 1961 and 1971.

In addition to being responsible for the direction and control of the Spacelab programme, as a member of ESA's nine-man Directorate Mr. Bignier will take part in the collective consideration of the major managerial problems relating to the Agency's activities.

ESA representatives at the Shuttle 'roll-out'. From left to right: Prof. M. Trella, Mr. R. Gibson, Prof. L. Broglio, Mr. H. Stoewer and Mr. W.J. Mellors.

Shuttle Roll-Out on 17 September

The first of the space vehicles that will carry Spacelab into earth orbit in the 1980's was unveiled at Palmdale, California, on 17 September 1976, when Orbiter 101, the first reusable Space Shuttle vehicle, was put on public display by the National Aeronautics and Space Administration.

Although Orbiter 101 is the first vehicle off the assembly line, it will not fly into space until the early 1980's. Its first job in 1977 will be as a test vehicle. It will be launched from the top of a modified Boeing 747 aircraft in a series of manned flights (Approach and Landing Tests – ALT) to verify its aerodynamic and flight control characteristics. Extensive ground vibration tests will subsequently be conducted in 1978 at Marshall Space Flight Center (MSFC), Huntsville, Alabama. When these tests are concluded, Orbiter 101 will be returned to Palmdale for modifications to prepare it for space flight. The second Orbiter (OV-102) will be used in the initial earth orbital flights from Kennedy Space Center, Florida, in 1979.

Royal Visitors to ESTEC

In the course of a three-day state visit to the Netherlands, the King and Queen of Sweden visited ESTEC on 27 October in the company of Princess Beatrix of the Netherlands. After being introduced to the Agency's Swedish staff, they attended a presentation of the work of the Agency and made a tour of ESTEC facilities.

Availability of ESA and NASA Publications
Liste des publications ESA et NASA disponibles

PUBLICATION	Availability Note	DISTRIBUTION OFFICE
REPORTS		
ESA Scientific Reports etc. (ESA SR, SN, SM)	(1) and (2)	
ESA Technical Reports etc. (ESA TR, TN, TM)	(1) and (2)	
ESA Special Publications (ESA SP)	(1) and (2)	
ESA Contractor Reports (ESA CR)	(1) and (2)	ESA Space Documentation Service 8-10 rue Mario Nikis 75738 PARIS 15 France (Telex ESA 202746)
ESA Contractor Reports (ESA CR(P))	(2)	
ESA Contractor Reports (ESA CR(P)*)	(3)	
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ESA Electronic Component Databank Catalogues (ESA ECDB)	(1)	
NASA Scientific & Technical Publications	(2)	
JOURNALS		
ESA Bulletin (quarterly)	(4)	
ESA Scientific and Technical Review (quarterly)	(4)	
PROCEDURES, STANDARDS & SPECIFICATIONS (ESA PSS)	(1)	The ESA Division or Department named as author of the publication
PUBLIC RELATIONS MATERIAL General literature, brochures, posters, photographs, films, etc.	-	ESA Public Relations Service 8-10 rue Mario Nikis 75738 PARIS 15 France

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(2) - Available in microfiche or photocopy against a charge to meet reproduction costs.

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

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RAPPORTS & DOCUMENTS SPECIAUX		
Rapports scientifiques (SR, SN, SM)	(1) et (2)	
Rapports techniques (TR, TN, TM)	(1) et (2)	
Publications spéciales (SP)	(1) et (2)	Service de Documentation spatiale de l'ASE 8-10 rue Mario Nikis 75738 PARIS 15 France (telex ESA 202746)
Rapports de contractants (CR)	(1) et (2)	
Rapports de contractants (CR(P))	(2)	
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Traductions techniques (TT)	(2)	
Catalogues ESA des composants électroniques établis par ordinateur (ECDB)	(1)	
Publications NASA (scientifiques et techniques)	(2)	
PERIODIQUES		
Bulletin ESA (trimestriel)	(4)	
Revue scientifique et technique ESA (trimestriel)	(4)	
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On trouvera dans les pages suivants la liste des documents qui ont été publiés depuis la dernière annonce de publications parue dans le Bulletin. Les demandes sont à formuler en tenant compte des conditions d'obtention précisées ci-dessus et en utilisant le formulaire au dos de la couverture.

SPECIAL PUBLICATIONS

SP-112 Papers presented at the Second International Heat-Pipe Conference sponsored by CNR, co-sponsored by AIAA, ESA and Euratom, Bologna, Italy, 31 March-2 April 1976 (Volume 2).

SP-114 Material Sciences in Space, *Proceedings of the Second European Symposium, held in Frascati, Italy, 6-8 April 1976.*

SP-115 European programmes on sounding-rocket and balloon research in the auroral zone, *Proceedings of a Symposium held at Schloss Elmau, Germany, 3–7 May 1976.*

SP-116 Product Assurance, *Proceedings of a Symposium held in Frascati, Italy, 4-6 May 1976.*

SP-117 Dynamics and control of non-rigid spacecraft, *Proceedings of a Symposium held in Frascati, Italy, 24–26 May 1976.*

SP-118 Photoemission from surfaces, *Extended abstracts of papers presented at an International Meeting on Photoemission from Surfaces, Noordwijk, Netherlands, 13–16 September 1976.*

SP-1001 Spacelab Users Guide, November 1976.

TECHNICAL MEMORANDA

TM-156 An instrument-pointing system for Spacelab, *by H. Heusmann et al.*

TM-161 The Bruceton test method and analysis with an APL programme for electro-explosive devices, *by J.P. Yribarren & G. Benedetti.*

TM-167 Atmospheric attenuation and noise in satellite systems at 11/14 GHz, *by S.E. Dinwiddy*

TECHNICAL NOTES

TN-126 Comparative analysis of INTELSAT IV and ECS replenishment policies, *by G.P. Cantarella*

TN-128 Testing materials for space applications, *by J. Dauphin*

TN-132 Sounding-rocket payloads C 111/1 and C 111/2, *by T.R. Sanderson & J. Henrion*

TN-134 A digital solar aspect sensor for spinning spacecraft, *by B. Morgenstern & B. Söderholm*

TN-135 Continuous time models for PWM switched convertors in heavy and light modes, *by H.A. Owen, J.G. Ferrante & A. Capel*

PROCEDURES, STANDARDS AND SPECIFICATIONS

PSS-09/ QRM-02T A screening test method employing a thermal vacuum for the selection of materials to be used in space (Issue 2), *by Product Assurance Division, ESTEC*

PSS-23 ESTEC standard for surface roughness, *by Engineering Section, ESTEC*

PSS-24/ QRM-18P Specification for the application of Hughson T 1960-71 black conductive coating, *by Product Assurance Division, ESTEC*

CONTRACTOR REPORTS

CR-764 Molybdenum-disulphide lubrication – A continuous survey 1973–74, *by A.R. Lansdown, Swansea Tribology Centre, UK*

CR-770 Study on the compression of image data on-board an applications or scientific spacecraft, Vol. 1: Description of the simulator and summary of results, *by Messerschmitt-Bölkow-Blohm, Germany*

CR-771 *idem*, Vol. 2: Mathematical derivations of compression methods.

CR-772 *idem*, Vol. 3: User's manual.

CR(P)-820* Study of the lifetime of NiCd cells for space use and of the battery charge retention capability, *by Swedish National Defence, Sweden*

CR(P)-821* Mesures radiométriques à deux polarisations à 11 GHz, *par Université Catholique de Louvain, Belgique*

CR(P)-822* Mesures de dépolarisation à 12 GHz sur un site court, *par Université Catholique de Louvain, Belgique*

CR(P)-823* Expérience de propagation de la Jungfrau, *par Direction générale des PTT, Berne, Suisse.*

CR(P)-824* Final report of Magnola Mount depolarization experiments (period 1.11.73 to 30.11.74), *by Telespazio SpA, Italy*

CR(P)-825 Utilisation du dispositif pendulaire pour l'étude de la lubrification au plomb, *par DERTS (ONERA), France*

CR(P)-826 European Space Tribology Laboratory Progress Report 1975 (ESTL 21), *by European Space Tribology Laboratory, UK*

CR(P)-827 Study of beam forming systems for phased array antennas. Final Report, *by L.M. Ericsson, Sweden*

CR(P)-828* Final report of Magnola Mount depolarization experiments (period 1.12.74 to 31.5.75), *by Telespazio SpA, Italy*

CR(P)829* Shipborne DCP stabilisation system study. Final Report, *by Hawker Siddeley Dynamics, UK*

CR(P)-830 Progress report on the lubrication of bearings in vacuum, *by Marconi, UK*

CR(P)-831* European Space Tribology Laboratory Progress Report 1974 (ESTL 18), *by European Space Tribology Laboratory, UK*

CR(P)-832 Testing of NiCd cells over geostationary orbit type cycling period, *by CGE-FIAR, Italy*

CR(P)-833 Large infrared telescope for Spacelab Phase A study, *by MATRA, France*

CR(P)-834* Definition study OTS performance capability for ECS and other missions, *by Hawker Siddeley Dynamics, UK*

CR(P)-835* Meteosat ground segment availability, *by Messerschmitt-Bölkow-Blohm, Germany*

CR(P)-836 Phase A study of Spacelab-borne atmosphere passive experiments, *by Appleton Laboratories, UK*

CR(P)-837 Phase A of an out-of-ecliptic solar stereoscopy mission, *by British Aircraft Corporation, UK*

CR(P)-838 Fault-tolerant computing for on board spacecraft applications, *by SAAB-Scania, Sweden*

CR(P)-839* PAMIRASAT study – Final Report, *by British Aircraft Corporation, UK*

CR(P)-840 Application of the multirevolution orbit prediction method, *by Analytical & Computational Mathematics (ACM), Switzerland*

CR(P)-841 Etude de four pour fusée sonde, *par Centre d'Energie Nucléaire de Grenoble, France*

CR(P)-842 Simulation software of digital data detection methods, *by Istituto Politecnico, Turin, Italy*

CR(P)-843 Etude de méthode et d'écriture de programme pour l'établissement d'un plan de radiodiffusion par satellite, *par SAI, France*

CR(P)-844* Procurement and exploratory life testing of low thrust catalytic hydrazine engines, *by ERNO, Germany*

CR(P)-845* Design, manufacture and test of positive expulsion propellant tank. Phase 2. Report of life test, *by British Aircraft Corporation, UK*

CR(P)-846 Thermal vacuum qualification tests on a Dornier medium speed despin mechanism (ESTL 20), *by European Space Tribology Laboratory, UK*

CR(P)-847* Degradation of the Meteosat radiometer primary mirror by contamination and radiation – Final Report, *by AERE Harwell, UK*

TECHNICAL TRANSLATIONS

TT-213 Report on the meeting of the DGLR chemical-propulsion systems committee 12-13 February 1974, Stuttgart: Payload transfer systems based on chemical rocket propulsion including attitude control & orbit correction: application, analysis, concepts, *by DGLR, Germany*

TT-223 Synthesis of partially fluorinated phosphoric di-aryl esters-akyl esters and potential application as additives and/or base oils, *by H. Linkinger & L. Fanghänel, DFVLR*

TT-232 Experimental and theoretical analysis of three-dimensional turbulent boundary layers in a supersonic curved nozzle, *by J. Cousteix & R. Michel, ONERA*

TT-271 Visualisation of the subsonic flow around two space glider configurations (DLR-FB 75-49), *by H. Bippes & P. Colak-Antić, DFVLR*

TT-272 Unsteady pressures on a harmonically oscillating staggered cascade. Part 1: Incompressible flow (DLR-FB 75-57), *by H. Triebstein, V. Carstens & J. Wagener, DFVLR*

TT-273 Unsteady pressures on a harmonically oscillating staggered cascade. Part 2: Compressible flow (DLR-FB 75-58), *by H. Triebstein, V. Carstens & J. Wagener, DFVLR*

TT-276 A compact velocimeter for measurements in highly turbulent flows, *by A. Boutier, ONERA*

TT-277 Deformation at high temperature of copper-silica dispersion-strengthened alloys, *by R. Ramboarina, ONERA*

TT-284 Parametric study of the gain in CO_2 lasers, *by J. Bonnet, ONERA*

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TT-288 Free jet test set-up for aeroacoustic experiments, *by W. Dobrzynski, DFVLR*

TT-289 Ignition behaviour of aviation fuels and some hydrocarbons, *by F. Körber, DFVLR*

TT-290 Minimisation of functions with discontinuous derivatives and non-linear constraints, *by E.-D. Dickmanns, N. Engersbach & R. Schwertassek, DFVLR*

TT-291 Modelling of the positioning procedure starting from primary orbit for the geostationary satellite Symphonie, *by E.-D. Dickmanns, N. Engersbach & R. Schwertassek, DFVLR*

TT-292 On the amplification of broad-band jet noise by a pure tone excitation, *by D. Bechert & E. Pfizenmaier, DFVLR*

TT-294 Development of the combustion zone in a stabilised turbulent flame, *by V.P. Singh, ONERA*

TT-295 Calculated restitution of structural modes from non-appropriated excitation, *by Xan Thanh Nguyen, ONERA*

TT-296 La Recherche Aérospatiale – Bimonthly Bulletin, 1975–4, *by ONERA*

TT-297 Estimation of the flow conductance of shrouds in space simulation chambers, *by H. Hamacher, DFVLR*

TT-298 La Recherche Aérospatiale – Bimonthly Bulletin, 1975–5, *by ONERA*

TT-301 Design for fatigue conditions, *by R. Somoza Soler, Esuela Tec. Sup. de Ingos. Industriales, Madrid.*

TT-305 Dynamics of chemical reactions at a stagnation point illustrated for the combustion of carbon, *by W. Haase, Technische Universität Berlin*

TT-306 La Recherche Aérospatiale – Bimonthly Bulletin, 1975–6, *by ONERA*

TT-307 La Recherche Aérospatiale – Bimonthly Bulletin, 1975–3, *by ONERA*

TT-308 La Recherche Aérospatiale – Bimonthly Bulletin 1973–6, *by ONERA*

TT-309 The hypersonic flow along a slender body with rounded nose for small Reynolds numbers, *by D. Vennemann, DFVLR*

TT-310 An analytical mass model of chemical rocket stages for space flight missions. Part 2: Long duration missions, *by J. Broschk, M. Bunn & D. Manski, DFVLR*

TT-311 Experiments on the feasibility of aeroacoustic measurements in the 3-m low speed wind tunnel of the DFVLR-AVA, *by F.-R. Grosche, H. Holst & R. Wulf, DFVLR*

TT-312 Theoretical and experimental investigations on landing gear spring blades out of fiber reinforced plastic for small aircraft, *by R. Schuetze, DFVLR*

TT-313 Experimental investigation of the behaviour of ablating bodies of different shape and material composition, *by K. Kindler, DFVLR*

TT-314 Evaluation of force measurements of free flying models in a gun tunnel, *by W. Wyborny, DFVLR*

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TT-319 Investigation of mass loss rate and internal temperature development of simple cylindrical ablating bodies, *by K. Kindler, DFVLR*

TT-320 Convection and refraction effects of an acoustic wave in a flow, *by J. Randon, ONERA*

TT-321 Real time Mach number control in a transonic blow-down wind tunnel, *by J.-L. Gobert, ONERA*

ELECTRONIC COMPONENTS DATABANK CATALOGUE

ECDB-2 Passive component reference book, *by Electronic Components Databank Section, ESA Space Documentation Service*

OTHER PUBLICATIONS

Atmospheric Physics from Spacelab – Proceedings of the 11th ESLAB Symposium, Frascati, Italy, 11-14 May 1976, *Reidel, Dordrecht and Boston, Edited by J.J. Burger, A. Pedersen & B. Battrick.*

ESA Scientific and Technical Review

Revue scientifique et technique ESA

Copies of the Review are available free of charge. Requests to be placed on the distribution list should be made by completing the Order Form inside the back cover of this Bulletin and mailing to ESA Space Documentation Service, 8-10 rue Mario Nikis, 75738 Paris 15.

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

Review of important problems in physics of the auroral zone, *G. Pfotzer*

Auroral phenomena are discussed in terms of magnetospheric topology and dynamics. Features of the diffuse aurora are related to the precipitation patterns of protons and electrons below 10 keV. Its general appearance is interpreted as a consequence of a complex turbulence which causes strong pitch-angle scattering and precipitation of these particles during injection. Electric fields orthogonal to the the magnetic lines of force, the evidence for parallel fields and their role in the magnetosphere and in the auroral zone are described and commented upon. These fields are seen as due to an external driving mechanism and being modified by plasma motions and magnetospheric instabilities. Recent results for equivalent current systems in the ionosphere, i.e. the high-latitude sunlit currents (HLS) and the electrojets and their connection with magnetic field-aligned Birkeland currents are stressed. Finally, the partition and effects of energy input to the auroral atmosphere are briefly summarised.

On examine les phénomènes auroraux sous l'angle de la toplogie et de la dynamique de la magnétosphère. Les caractéristiques de l'aurore diffuse sont mises en rapport avec les formes de précipitation des protons et des électrons d'énergie inférieure à 10 keV. On interprète leur aspect général comme la conséquence d'une turbulence complexe qui est à l'origine de la forte dispersion des angles d'attaque et de la précipitation de ces particules au cours de la phase d'injection. On donne une description commentée des champs électriques normaux aux lignes de force magnétiques, des éléments attestant la présence de champs parallèles ainsi que du rôle joué par ces derniers dans la magnétosphère et dans la zone aurorale. Ces champs, attribuées à un mécanisme d'entraînement extérieur, seraient modifiés par les mouvements du plasma et les instabilités au sein de la magnétosphère. L'accent est mis sur les résultats récents concernant d'une part les systèmes de courants équivalents dans l'ionosphère, à savoir les courants existant aux hautes latitudes du côté diurne (HLS), d'autre part les électrojets et leur raccordement aux courants magnétiques de Birkeland le long des lignes de force. On présente enfin brièvement la séparation et les effets des apports d'énergie dans l'atmosphère aurorale.

Continuous matched filter design: an application to the ESA silicon star mapper, *by D. Sciacovelli*

An analysis of two different filter configurations that approximate to an optimal matched filter for a silicon star-mapper sensor is presented. The received signal is corrupted by additive coloured noise. The first configuration consists of a simple bandpass filter, with an RC high-pass filter and an RC low-pass filter in cascade. The second consists of an RC high-pass filter followed by a filter matched to the deterministic component of its input signal. The signal-to-noise amplitude ratio at the filter output is presented as a function of various system parameters and compared with that arising from an optimal matched filter. A time-domain synthesis of the matched filter in the second configuration has been used. Simulation plots included in the paper confirm qualitatively the expected behaviour of the filters.

Cet article analyse deux configurations de filtre offrant des caractéristiques proches de celles d'un filtre adapté optimal et destinées à un localiseur d'étoiles au silicium. Le signal reçu est déformé par le bruit additif coloré. La première version consiste en un simple filtre passe-bande formé de deux éléments RC en cascade, l'un passe-haut, l'autre passe-bas. La seconde version est constituée d'un filtre passe-haut suivi d'un filtre adapté à la composante déterministe du signal d'entrée. Le rapport signal sur bruit à la sortie de ces filtres est donné en fonction de différents paramètres du système et comparé à celui d'un filtre adapté optimal. Pour la seconde version, on a fait appel à la synthèse dans le domaine temporel. Les courbes de simulation présentées confirment qualitativement le comportement prévu des filtres.

Evaluation régionale de l'évapotranspiration avec le radiomètre à infrarouge du satellite Nimbus 5, *par R. Bossard & Y. Vuillaume*

Cette étude examine l'évaluation de l'évapotranspiration par télédétection.

Les données utilisées concernent la zone semi-aride du Sénégal; elles ont été fournies par le satellite Nimbus 5 de la NASA. Par ciel clair et pour un certain nombre de points de la région considérée, on calcule par une méthode de bilan, l'énergie utilisable dans le processus d'évapotranspiration. A cette fin on développe un 'modèle' du globe terrestre faisant appel à des éléments de la théorie du rayonnement électromagnétique, et à l'étude des bilans énergétiques de la surface du globe. L'un de ces bilans (atmosphère espace) rend compte de la mesure thermique effectuée par le satellite, l'autre (sol atmosphère) est associé au processus d'évapotranspiration. Moyennant certaines hypothèses simplificatrices concernant les propriétés de l'atmosphère, ces deux bilans sont combinés afin d'atteindre l'évapotranspiration à partir des données de satellites.

Les résultats ainsi obtenus sont en accord avec ceux produits par la méthode classique de Brunt faisant appel aux données météorologiques locales.

This article examines the evaluation of evapotranspiration by remote-sensing techniques. The data used were provided by NASA's Nimbus 5 satellite for the semi-arid zone of Senegal. For clear weather and a certain number of points in the area considered, the energy involved in the evapotranspiration process is calculated by a balance method. For this purpose, a 'model' of the globe has been developed using electromagnetic radiation theory as well as the energy balances of the Earth's surface. One of the latter (atmosphere/space) takes account of the thermal measurements carried out on board the satellite, the other (ground/atmosphere) is associated with the evapotranspiration process. With certain simplifying assumptions concerning the atmosphere's properties, the two balances are combined to extrapolate the evapotranspiration from the satellite data.

The results thus obtained are in agreement with those given by Brunt's 'conventional' method based on the local meteorological data.

Modèle linéaire d'un régulateur shunt PWM dissipatif, *par M. Clique & A.J. Fossard*

Cet article présente une analyse du comportement dynamique d'un régulateur shunt PWM dissipatif aux *petit signaux. Deux méthodes sont utilisées pour établir les fonctions de transfert qui lient la tension à réguler au rapport cyclique du PWM et au courant délivré par le générateur solaire; la première est basée sur des techniques de moyennage, la seconde sur l'utilisation d'une modèle linéarisé obtenu à partir des équations d'état traduisant la structure du système á l'intérieur de chaque phase.*

This paper presents an analysis of the small-signal dynamic behaviour of a dissipative PWM shunt regulator. Two methods are proposed for establishing the transfer functions between the regulated output voltage, the duty cycle of the PWM and the current of the solar generator. The first is based on averaging techniques, and the second uses a linearised model obtained from the state equations of the system for each phase.

Essais en vibrations sinusoïdales: tolérance et distorsion, *par G. Bodereau*

Cette étude passe en revue les causes probables des difficultés rencontrées pour asservir un excitateur de vibration à bas niveau, en présence de structures fragiles pesant plus de 500 kg; elle tente notamment d'expliquer la distorsion enregistrée sur les signaux d'entrée. A travers la description d'un schéma classique (chaîne d'asservissement analogique), on expose les limitations du moyen d'essai. On examine les conséquences de la distorsion des signaux d'entrée sur les marges de tolérance applicables aux spécifications et on suggère des mesures de sécurité pour éviter de dépasser les niveaux spécifiés.

Possible causes of difficulties in controlling a vibrator at low level when testing fragile and heavy spacecraft ($>$500 kg) are described, with special emphasis on the input signal distorsion. A (conventional) analog-control system is described and vibrator performance limitations are pointed out. Effects of input-signal distorsion on the specified input level tolerance are deduced and safety precautions are suggested in order to avoid over-testing.

A note on the poles of a spherical harmonic, *by G.L. Webb*

The use of spherical harmonics to describe particle distributions has led to interest in the problems of determining the poles of a known spherical harmonic and of finding the coefficients of a spherical harmonic when the poles are known. It is the purpose of this note to clarify the computation of solutions of the first problem, and to give a method of solving the second. The solutions of the second problem for the first three harmonics are given.

L'utilisation des harmoniques sphériques dans la description des populations de particules a conduit l'auteur à s'intéresser d'une part à la détermination des pôles d'un harmonique sphérique lorsque celui-ci est connu, d'autre part à la recherche des coefficients d'un harmonique sphérique dont on connait les pôles. L'objet de cet article est de préciser les méthodes de calcul pour le premier problème et de fournir une méthode pour résoudre le second. On présente également les solutions du second problème pour les trois premiers harmoniques.

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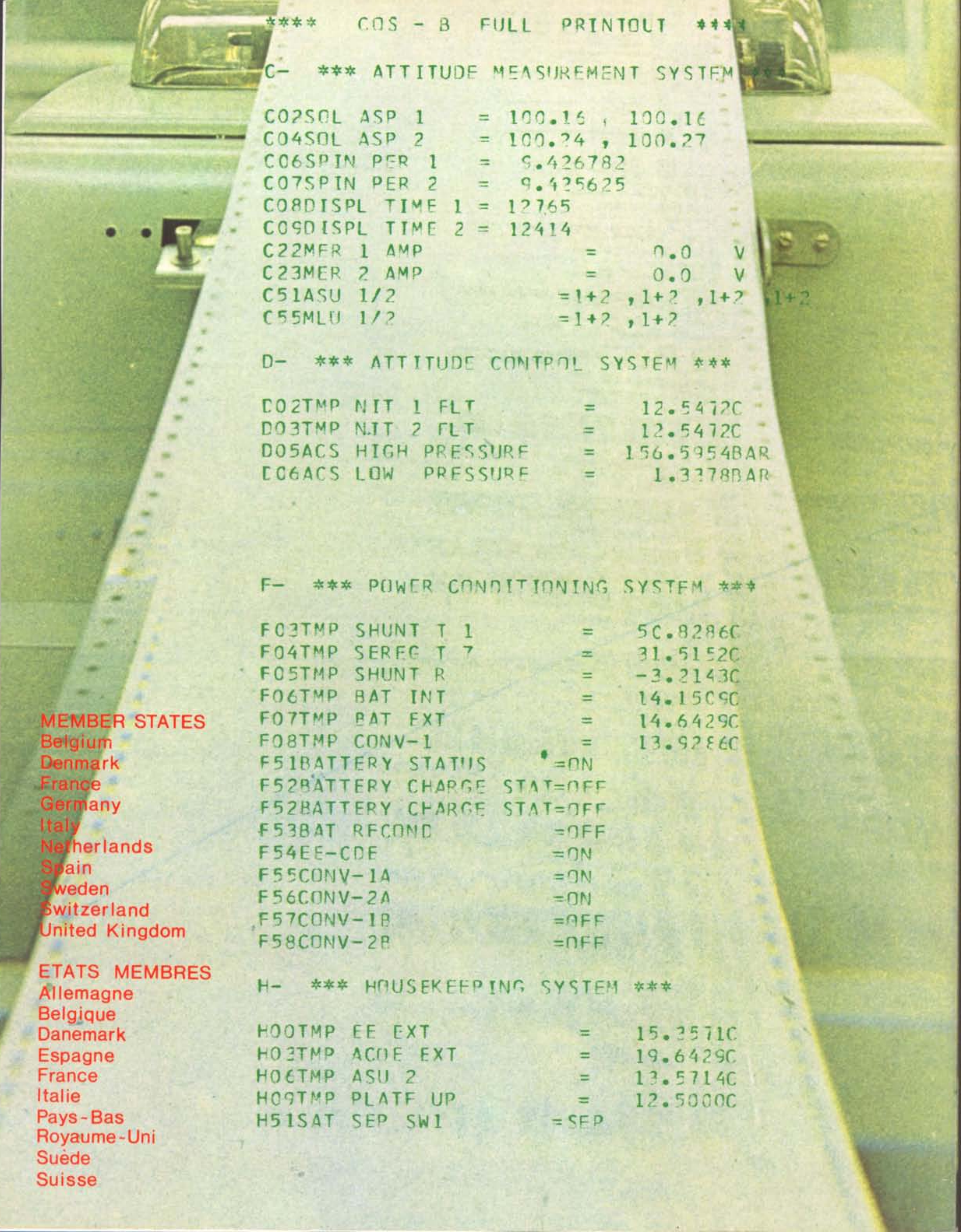

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