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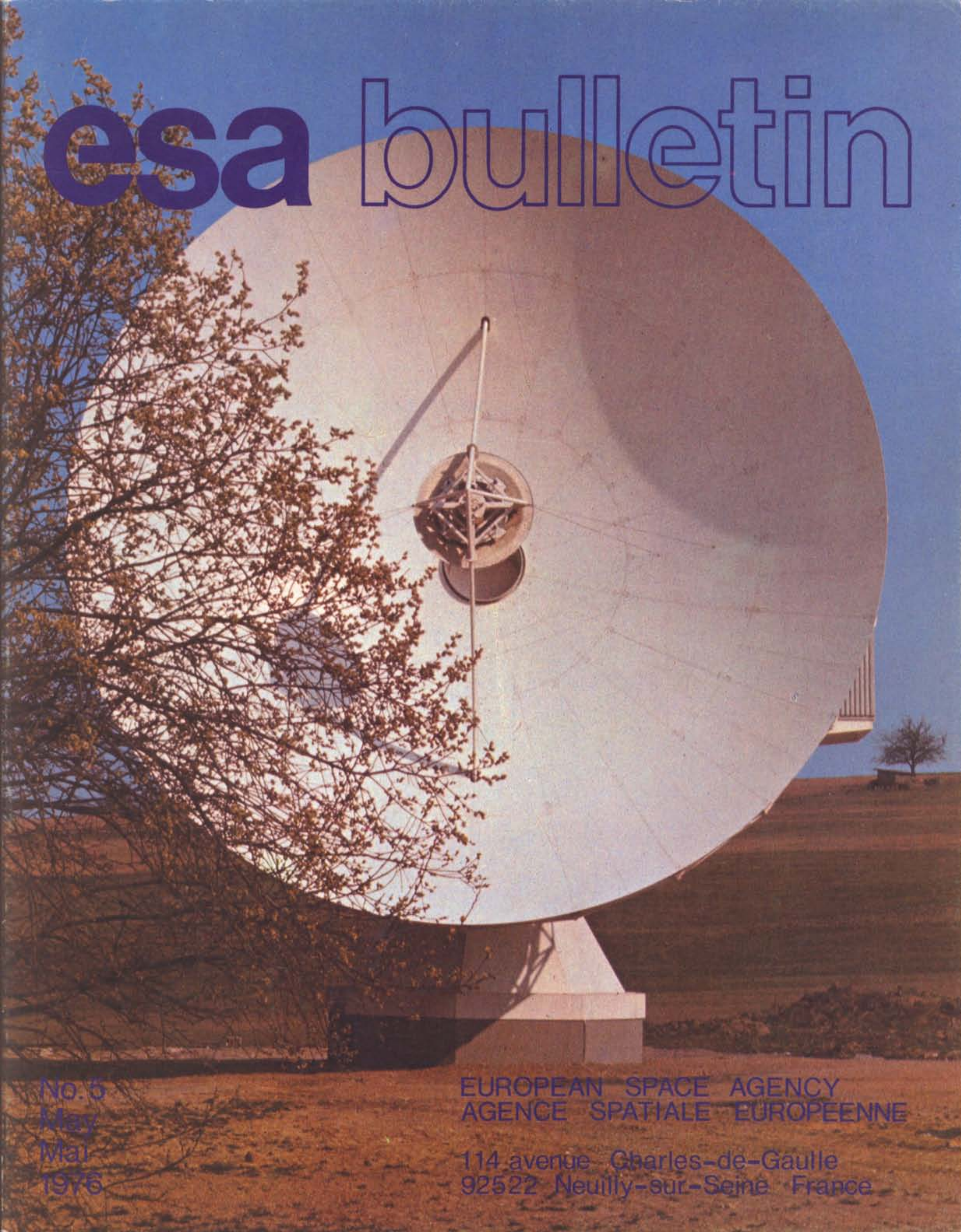

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EUROPEAN SPACE AGENCY
AGENCE SPATIALE EUROPEENNE

114 avenue Charles-de-Gaulle
92522 Neuilly-sur-Seine 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.

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

(a) by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;

(b) by elaborating and implementing activities and programmes in the space field;

(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;

(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

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

The Directorate of the Agency consists of the Director General; the Director of Planning and Future Programmes; the Director of Administration; the Director of Scientific 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 (Neuilly-sur-Seine).

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.

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 (Neuilly-sur-Seine).

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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Introduction

By way of introduction to this special edition of the ESA Bulletin, devoted to communication satellites, it may be of interest to review briefly the extraordinarily rapid development of satellite communications and to give an idea of the promising future that is open to this sector. Technological progress has not been the only marked feature of the evolution of satellite communications; it has also been accompanied by remarkable developments both from the geographical point of view and also in the diversification of applications. We may cite, for instance, their introduction into the fields of maritime and aeronautical communications and of television broadcasting.

PROGRESS OF INTELSAT NETWORK

Let us cast a glance over the last ten years, noting the tremendous progress made since the launch on 6 April 1965 of Early Bird, the first commercial geostationary communications satellite, which followed a series of experimental spacecraft such as Score, the first communications satellite, Echo I and II, Courrier, Telstar, and finally Syncom, the first of the geostationary satellites.

Early Bird represented the first generation of Intelsat satellites and now, only a few years later, we are witnessing preparations for their fifth generation. Early Bird's 66 telephone circuits between North America and Europe developed successively, in 1966, to 240 circuits on Intelsat II and 1200 on Intelsat III with world-wide coverage, and finally to Intelsat IV's 5000 circuits, whilst the ground network expanded to more than a hundred stations providing round-the-clock service with near-100% reliability. Continuing under its own impetus, the INTELSAT network is already preparing its next generation, the Intelsat V satellites, which are due to take over in about 1980 and will provide the users with yet another considerable increase in capacity. In the meantime, in order to preclude network saturation before then, it is planned to place in orbit a number of Intelsat IV-A satellites of an improved design and with doubled capacity, the first model of which was launched in 1974.

The evolution we have witnessed from 1965 to 1975 has been marked by impressive technological progress in satellite design and, to a lesser extent, in the sector of ground stations. From an operational viewpoint, this progress has resulted in increased capacity and in the service being extended to more participants, as well as in greater circuit reliability. From an economic point of view, the technical improvement has led to a steady lowering of tariffs. Everything suggests that this evolution will continue in the coming years and that there will

Comme introduction à cette édition spéciale du Bulletin ESA consacré aux satellites de télécommunications, il est intéressant de retracer très brièvement l'évolution extraordinairement rapide des télécommunications par satellites, et ceci pour montrer à quel point ce secteur est plein d'avenir. L'évolution de ces systèmes n'est pas uniquement caractérisée par le progrès technologique mais également pas un développement remarquable tant sur le plan géographique que sur celui de la diversification de leurs applications. Citons par exemple leur entrée dans le domaine des communications maritimes et aéronautiques et dans celui de la diffusion de la télévision.

PROGRES DU RESEAU INTELSAT

Jetons un rapide coup d'oeil sur les dix dernières années. Que de progrès réalisés depuis le 6 avril 1965, jour du lancement d'Early Bird, premier satellite stationnaire de télécommunications à usage commercial, lui-même précédé par une série de véhicules expérimentaux comme Score, premier satellite de télécommunications, Echo I et II, Courrier, Telstar et enfin Syncom qui fut le premier des satellites géostationnaires.

Early Bird constitua la première génération des satellites Intelsat, et aujourd'hui, quelques années plus tard, nous en sommes déjà au démarrage de la 5ème génération. Des 66 circuits téléphoniques d'Early Bird entre l'Amérique du Nord et l'Europe, on est successivement passé en 1966 à 240 circuits sur Intelsat II et à 1200 circuits sur Intelsat III avec une couverture mondiale pour arriver aux 5000 circuits d'Intelsat IV avec un tel développement du réseau que le nombre des stations au sol a dépassé la centaine permettant des liaisons 24 heures sur 24 avec un fiabilité proche de 100%. Continuant sur sa lancée, le réseau INTELSAT prépare déjà la prochaine génération de satellites, les Intelsat V, qui doivent normalement prendre la relève vers 1980 et mettre à la disposition des utilisateurs une capacité de trafic encore considérablement accrue. D'ici là, et pour parer à l'éventualité d'une saturation du réseau se produisant avant cette date, il sera mis en place un certain nombre d'Intelsat IV-A de conception améliorée et de capacité doublée, dont le premier modèle a été lancé en 1974.

L'évolution à laquelle nous avons assisté au cours de cette période, 1965–1975, a été marquée par un progrès technologique impressionnant dans le domaine de la conception des satellites et, dans une moindre mesure, dans celui des stations terriennes. Sur le plan opérationnel, ce progrès s'est traduit par une augmentation de la capacité et l'extension du service à un plus grand nombre de participants, ainsi que par une amélioration de la fiabilité des liaisons. Sur le plan économique, cette be a further leap forward with the introduction of Intelsat V.

ADVANTAGES OF SPACE LINKS

With the constant increase in available traffic capacity, a new tendency is taking shape for the utilisation of Intelsat satellites. Whereas hithero the network has been used for intercontinental links only, several countries are now preparing to call on INTELSAT to improve their internal telecommunications. Algeria, Brazil, Norway, Chile and others will be among the first to set up links of this type. A particularly interesting example is provided by Norway, which has concluded an agreement for the renting of half a repeater aboard Intelsat IV. In this case it was not a matter of making up for a deficiency in the conventional telecommunications network, but of establishing a new service to link the mainland with the prospecting and drilling platforms operating in the North Sea. In view of the geographical location of the rigs, their distance from the mainland, and the fact that some of them are mobile, this problem cannot be solved easily by traditional means: submarine cables are relatively vulnerable and moreover lack the flexibility required for this type of mission; the range of over-the-horizon microwave links is limited to some three or four hundred kilometres and they are subject to constraints because of the need to avoid interference between the different systems; and, finally, short-wave links do not offer sufficient capacity. In these conditions space links appear to offer the most attractive solution, since they do not possess any of the inherent drawbacks of the conventional solutions. They are eminently flexible and allow changes in configuration to be made without difficulty; they are unaffected by changes in distance and at the same time provide high quality and reliability of service for both fixed and mobile terminals.

These remarks in connection with INTELSAT reflect a trend which will probably continue in the coming years, with satellite communication systems developing at an increasing rate and being used more and more for specific applications to meet particular requirements. This expansion will be helped by uninterrupted technical progress and by longer lives for satellites in orbit. Moreover, as the design of the space segment becomes more and more sophisticated, that of the ground stations can in some cases be simplified and this should have a further stimulating effect on system economy.

GROWTH OF REGIONAL AND DOMESTIC SYSTEMS

After this brief review of the world-wide system, let us now —

amélioration technique a eu pour résultat une baisse continue des tarifs. Cette évolution, tout semble l'indiquer, se poursuivra dans les années qui viennent et connaîtra un nouveau bond avec la mise en service des Intelsat V.

AVANTAGES DES LIAISONS SPATIALES

Avec la mise à disposition d'une capacité de trafic de plus en plus importante, une nouvelle orientation se dessine dans l'utilisation des satellites Intelsat. Alors que, jusqu'à maintenant, les services du réseau n'étaient utilisés que pour des liaisons intercontinentales, plusieurs pays s'apprêtent à recourir aux services de l'INTELSAT pour améliorer leurs télécommunications internes. L'Algérie, le Brésil, la Norvège, le Chili et d'autres sont parmi les premiers à établir ce genre de liaisons.

Un exemple intéressant est celui de la Norvège qui a conclu un accord pour la location d'un demi-répéteur à bord d'un Intelsat IV. Dans ce cas, le problème à résoudre n'est pas de pallier l'insuffisance du réseau de télécommunications traditionnel mais de mettre en place un nouveau service destiné à relier avec le continent les stations de prospection et de forage établies par des compagnies pétrolières en Mer du Nord. Etant donné la position géographique des points terminaux, la distance qui les sépare du continent et le fait que certains d'entre eux sont mobiles, ce problème ne peut être aisément résolu par des moyens classiques. Les câbles sous-marins sont relativement vulnérables et, de plus, n'ont pas la souplesse requise par ce type de mission, les liaisons hertziennes transhorizon ont une portée limitée à 300–400 km et sont soumises à des contraintes imposées par la nécessité d'éviter des interférences entre différents systèmes, et les liaisons en ondes courtes enfin n'offrent pas une capacité suffisante. Dans ces conditions, les liaisons spatiales apparaissent comme la solution la plus attrayante en raison du fait qu'elles ne présentent aucun des inconvénients des solutions classiques. Elles sont éminemment souples et permettent toute modification de configuration sans difficulté; elles sont insensibles aux changements de distance et procurent simultanément qualité et fiabilité de service avec des terminaux fixes aussi bien que mobiles.

Ces remarques à propos de l'exemple d'INTELSAT soulignent une tendance qui se poursuivra vraisemblablement au cours des prochaines années et verra les systèmes de communications par satellites se développer à un rythme accéléré et être de plus en plus utilisés pour des applications spécifiques répondant à des problèmes particuliers. Cette expansion sera favorisée par un still in the area of conventional public telecommunications – consider national and regional systems. Here again, in less than five years, progress has been enormous. The first domestic systems in Canada and the United States have been operating for some time, others are about to become operational, and the list of countries that have already decided to follow suit, or are about to do so, grows daily. The same goes for the regional systems now being considered. Expansion in this area is necessarily less rapid than in the case of national systems in view of the slowness of international decision-making. Two groups, however, are about to set up such systems, namely the Arab countries and the European countries belonging to the CEPT, the latter group doing so within the European Space Agency's communications satellite programme, referred to in this Bulletin.

In the case of the trans-oceanic links of the INTELSAT system, the basic objective is an economic one and involves on the one hand the procurement of cheaper telephone circuits, and on the other the establishment of intercontinental television relays. But in areas where distances are shorter, where there is no major obstacle such as an ocean to be overcome, and where terrestrial networks are already highly developed, what reasons are there in favour of a satellite system? In the specific case of Europe, for instance, even though the cost may finally turn out to be lower than that of terrestrial links – which is certainly the case with television traffic – the economic factor does not play a dominant part. In any event, when the European Space Agency's communications satellite programme was initiated in 1971, the European Ministers of Posts and Telecommunications declared that, economically speaking, it would be sufficient if the space circuits cost approximately the same as their equivalent terrestrial counterparts. What the CEPT is essentially seeking in the setting up of a regional satellite system is diversification of facilities, redundancy of routes, and hence greater reliability and greater operational flexibility. Indeed, in addition to duplication of routes for point-to-point circuits, the satellite offers – within the framework, for example, of a time-division multiple access system – very considerable flexibility of operation, since the capacity of the space segment can in principle be allocated in different ways to the various stations, according to requirements.

In fact, the use of satellites will not only lead to improved operations in conventional transmissions (telephone, telex, telegraphy, television), it will also – and this will later turn out to be the most important aspect – open the way for new services for which space links will prove to be particularly well suited, such as wideband data exchanges (especially between computers and data banks), distribution of information to a

progrès technique ininterrompu et l'accroissement de la durée de vie des satellites en orbite. Par ailleurs, la conception du secteur spatial devenant de plus en plus sophistiquée, celle des stations terriennes pourra, dans certains cas, aller en se simplifiant, ce qui devrait avoir un autre effet stimulant sur l'économie des systèmes.

EXPANSION DES SYSTEMES DOMESTIQUES ET REGIONAUX

Après ce coup d'oeil sur le système mondial, passons ensuite, toujours dans le domaine des télécommunications publiques traditionnelles, aux systèmes nationaux et régionaux. Là aussi, en moins de cinq ans, un long chemin a été parcouru. Les premiers systèmes domestiques du Canada, des Etats-Unis sont opérationnels depuis un certain temps déjà, d'autres sont sur le point de le devenir et la liste des pays qui ont pris, ou sont sur le point de prendre la décision d'aller de l'avant, s'allonge sans cesse. Il en est de même des systèmes régionaux considérés en ce moment. L'expansion dans ce domaine est forcément moins rapide que pour les systèmes purement nationaux étant donné la lenteur du processus des décisions internationales. Deux groupes sont toutefois sur le point d'établir ce type de système: les nations arabes et les Etats européens de la CEPT, ces derniers dans le cadre du programme de satellites de télécommunications de l'Agence spatiale européenne traité ci-après dans ce Bulletin.

Dans le cas des liaisons transocéaniques du système INTELSAT, l'objectif fondamental était économique, à savoir d'une part l'obtention de liaisons téléphoniques moins coûteuses et, d'autre part, l'établissement des transmissions télévisuelles intercontinentales. Mais dans le cas de plus courtes distances et là où il n'y a pas d'obstacle naturel majeur à franchir, tel un océan, et où les réseaux terrestres sont déjà très développés, quelles sont les raisons qui militent en faveur d'un système par satellite? Dans le cas précis de l'Europe par exemple, même si le coût des transmissions via satellite s'avère finalement être moins cher que celui des liaisons terrestres, ce qui est certainement le cas pour le trafic de télévision, le facteur économique ne joue pas un rôle dominant. D'ailleurs en 1971, lors du démarrage du programme de télécommunications de l'Agence spatiale européenne, les ministres européens des PTT ont déclaré à ce sujet qu'en ce qui concerne l'aspect économique, il suffirait que les coûts des liaisons terrestres ou spatiales soient sensiblement équivalents. Ce que la CEPT recherche essentiellement dans la mise sur pied d'un système régional par satellite, c'est la diversification des moyens, la redondance des liaisons et, partant, une plus haute fiabilité et une plus grande large number of users, and teleconference circuits. This type of service could then soon undergo considerable development in view of its usefulness in the world of commerce, banking and industry.

TELEVISION BROADCASTING BY SATELLITE

It is therefore also because of these prospects of evolution towards new systems and services that a number of telecommunication administrations, both in the highly industrialised countries and in the developing countries, are already setting up satellite communications systems around the world, providing, of course, for conventional services to begin with. Still, in the matter of fixed telecommunications, it should also be noted that in the medium term an important feature will be television broadcasting by satellite. This is a case where the satellite is an extraordinarily useful tool. In countries that do not yet have a complete ground-distribution network the space system provides the obvious means of rapidly setting up a system to serve the whole population.

In the case of Europe, where the VHF and UHF ground networks are near saturation, the introduction of additional television programmes is hardly conceivable except with the assistance of satellites broadcasting in the 12 GHz range. Further to this technical consideration, the introduction of a television broadcasting channel covering an average-size country through a space system will in future cost less than setting up an equivalent network of ground transmitters and radio relays.

This type of service, which at present is still only at the experimental stage — under the Canadian and Japanese programmes, for example — will be called upon to play an important role as from the next decade. There will be a number of variants, making use of the 2.5 GHz or 12 GHz frequency bands and providing a service in which television broadcasting will range from distribution to urban or regional collective receiving antennas (semi-direct broadcasting) to individual reception on domestic antennas (direct broadcasting).

AERONAUTICAL AND MARITIME MISSIONS

Turning now to more specialised fields of application, particular attention should be paid to maritime and aeronautical missions.

souplesse des opérations. En effet, en plus du dédoublement des routes pour les connexions de point à point, le satellite offre en plus, dans le cadre par exemple d'un système d'accès multiple dans le temps, une très grande souplesse d'exploitation, la capacité du secteur spatial pouvant en principe être répartie différemment entre les diverses stations en fonction des besoins.

En fait, le satellite permettra non seulement une amélioration des opérations dans le domaine des transmissions de type classique (téléphone — télex — télégraphe — télévision), mais également, et ceci se révèlera ultérieurement être l'aspect le plus important, il ouvrira la voie aux services nouveaux pour lesquels les liaisons spatiales s'avèreront être particulièrement bien adaptées tels les échanges de données à large bande, en particulier dans le domaine des calculateurs ou des banques de données, la distribution d'information vers un grand nombre d'utilisateurs, les circuits de téléconférence, etc. Ce genre de service pourrait alors prendre rapidement un essor considérable en fonction de son utilité dans le monde commercial, bancaire et industriel.

DIFFUSION DE TELEVISION PAR SATELLITE

C'est donc également en raison de cette ouverture et de cette évolution vers des systèmes et des services nouveaux que bon nombre d'administrations des télécommunications, tant des pays fortement industrialisés que des nations en voie de développement, établissent dès à présent et un peu partout dans le monde des systèmes de télécommunications par satellite, en commençant bien entendu par des transmissions traditionnelles. Toujours dans le domaine des télécommunications fixes, il importe également de noter l'importance à moyen terme de la diffusion de télévision par satellite. Il s'agit là d'un exemple où le satellite se révèle être un outil extraordinairement utile. Dans le cas de pays non encore équipés d'un réseau complet de distribution au sol, le système spatial est la solution évidente à la mise sur pied rapide d'un service couvrant l'ensemble de la nation.

Dans le cas de l'Europe, où les réseaux VHF et UHF au sol sont proches de la saturation, l'introduction de programmes de télévision additionnels ne peut guère se concevoir qu'à l'aide de satellites diffusant à la fréquence de 12 GHz. En plus de cette considération technique, le coût d'installation d'une chaîne de diffusion de télévision à l'échelle d'un pays de dimensions moyennes est désormais inférieur dans le cas d'un système spatial à celui du réseau équivalent de relais hertziens et d'émetteurs au sol.

Aeronautical satellites have been the subject of great controversy over the last few years, although their future usefulness has never been in doubt. The discussions have concerned essentially the date of introduction and the precise definition of an operational network, and whether or not to set up a preparatory system in the meantime. The problem is that, whereas there do not appear to be any urgent requirements as regards navigation proper, aeronautical communications over long ocean routes or sparsely equipped continental areas are far from giving full satisfaction. In some places HF radio communications can be either impossible or extremely bad. Moreover, at least in the long term, air traffic controllers obviously ought to have access to an independent control system providing reliability of the same order as is now available over the continents. The successive delays encountered in this area have been due to the serious economic difficulties which civil aviation has had to face for some time.

However, a great step forward has now been taken with the setting up of Aerosat, an international experimental programme involving three partners – the Federal Aviation Administration (FAA) of the United States, the Canadian Government and the European Space Agency – who recently agreed to go ahead with the industrial stage of the work.

In the maritime sector, progress has been much more rapid, COMSAT general having just provided the United States Navy with their first satellite communications system, the MARISAT network, which can later be used by the merchant navy.

The European Space Agency has been following the same path and intends, within the next two years or so, to launch the Marots satellite, which is specially designed to meet the future requirements of maritime communications. This type of system will undoubtedly open up fresh prospects, since shore-to-ship communications will then become practically instantaneous and can be conducted in wider bands, whereas at present we still have fairly elementary radiotelephony and radio-telegraphy systems of relatively low reliability. The advent of satellite systems in this area will obviously make a notable contribution to the improvement of operational techniques in the maritime world.

INDUSTRIAL POLICY

Finally, this brief review of space communications calls for a few remarks about the manufacturing prospects open to industry. Even though the total number of circuits made available to users will become quite impressive, the fact

Ce type de service, qui n'en est encore aujourd'hui qu'au stade de la phase expérimentale, dans le cadre des programmes canadien et japonais par exemple, est appelé à jouer un rôle important dès la prochaine décennie. Un certain nombre de variantes verront le jour utilisant les bandes de fréquences de 2,5 ou de 12 GHz et fournissant un service allant d'une part de la distribution de télévision vers des antennes réceptrices au niveau des villes ou des régions (réception semi-directe) et, d'autre part, à la réception individuelle chez l'habitant (diffusion directe).

MISSIONS MARITIMES ET AERONAUTIQUES

Passant maintenant à des domaines d'application plus particuliers, il est opportun d'insister sur les missions maritimes et aéronautiques.

Les satellites aéronautiques ont été l'objet d'importantes controverses durant ces dernières années. Leur utilité future n'a toutefois jamais été mise en doute et les discussions ont essentiellement porté, d'une part, sur la date d'introduction et la définition précise d'un réseau opérationnel et, d'autre part, sur l'intérêt entre-temps de mettre sur pied un système préparatoire. En effet, si du point de vue de la navigation proprement dite, il ne semble pas y avoir de besoins pressants, par contre les services de communications aéronautiques sur les grands trajets océaniques ou dans des zones continentales peu équipées ne donnent pas, à l'heure actuelle, pleine satisfaction, loin de là. Les liaisons HF en certains endroits peuvent être soit impossibles, soit de très mauvaise qualité. D'autre part, à long terme en tout cas, il est évident qu'il y aura intérêt à ce que les services de contrôle du trafic aérien puissent disposer d'un instrument de surveillance indépendant et d'une sécurité comparable à ce qui existe aujourd'hui au-dessus des continents. Ce sont en fait les difficultés économiques sérieuses dans lesquelles l'aviation commerciale s'est vue plongée depuis un certain temps qui ont provoqué les retards successifs dans ce domaine.

Aujourd'hui, toutefois, un grand pas a finalement été franchi: Aérosat, un programme international à caractère expérimental, a été mis sur pied. Les trois partenaires, à savoir l'Administration de l'Aviation civile américaine (FAA), le gouvernement canadien et l'Agence spatiale européenne, se sont récemment mis d'accord pour aller de l'avant et aborder le stade des travaux industriels.

En ce qui concerne le secteur maritime, les progrès auront été beaucoup plus rapides puisque COMSAT General vient de

remains that the number of satellites to be supplied will initially not be high (and will not need to be, in view of the increase in the unit capacity of each spacecraft). The number of manufacturers will therefore necessarily have to remain small. Consequently, industrial procurement policy will need to ensure that each manufacturer of space equipment can receive a sufficient portion of the relevant development and production contracts, otherwise the industries concerned cannot hope to maintain the desired degree of quality nor keep their prices down to a sufficiently attractive level. These two factors — competence and competitiveness — will be fundamental to the full growth of this highly promising industrial and operational sector.

CONCLUSION

In conclusion it can be said, after observing the progress made in the capacity carried in orbit by all geostationary systems, that satellite communications, by extrapolation, can look

mettre à la disposition des forces navales des Etats-Unis un premier système de communications via satellite. Par la suite, ce réseau MARISAT pourra être utilisé par la marine marchande.

L'Agence spatiale européenne s'est également engagée dans la même voie et, d'ici deux ans environ, mettra en orbite le satellite Marots spécifiquement conçu pour répondre aux besoins futurs des communications maritimes. Ce type de système ouvrira sans aucun doute de nouveaux horizons puisqu'à ce moment les communications terre-mer deviendront pratiquement instantanées et pourront s'effectuer à plus large bande alors qu'aujourd'hui nous en sommes toujours au stade d'une radiotéléphonie et radiotélégraphie assez élémentaires et relativement peu fiables. Il est évident que l'avènement du satellite dans ce domaine contribuera notablement à l'amélioration des techniques opérationnelles du monde maritime.

POLITIQUE INDUSTRIELLE

Finalement, au terme de ce bref aperçu concernant les télécommunications spatiales, il importe de faire quelques remarques à propos du marché de fabrication ouvert aux industriels. Si, du point de vue du nombre global de circuits mis à la disposition des utilisateurs, les chiffres deviendront impressionnants, il n'en reste pas moins que la quantité de satellites à fournir n'atteindra pas, dans l'immédiat, un niveau très élevé, surtout si l'on prend en compte l'accroissement de capacité unitaire des engins. Le nombre de fabricants devra donc nécessairement demeurer restreint. Par conséquent, dans le cadre de la politique industrielle des approvisionnements, il faudra veiller à ce que chacun des fabricants de matériel spatial puisse acquérir une proportion suffisante des contrats de développement et de production sans lesquels ces industries ne pourront maintenir le degré de qualité désirable ni un niveau de coût suffisamment attrayant. Ces deux facteurs, compétence et compétitivité, seront en effet fondamentaux pour l'épanouissement de ce secteur industriel et opérationnel par ailleurs très prometteur.

CONCLUSION

En conclusion, en observant l'évolution de la capacité mise en orbite pour l'ensemble des systèmes géostationnaires, on peut aisément conclure, par extrapolation, que l'avenir des télécommunications par satellite est remarquable et que cette technique est appelée à jouer un rôle très important en parallèle avec les autres moyens de transmissions développés jusqu'à ce jour.

forward to a remarkable future and that this technique will be called upon to play a major role side by side with the other communication methods developed so far. It is also clear that space systems will in general be used in association, rather than competition, with the ground networks. Moreover, more and more new services will be set up for which the satellite will be a particularly suitable component. Improvements in reliability and in the cost of the hardware will also contribute to greater economy, and this will stimulate expansion all the more.

As regards the organisation of operations, it can easily be imagined that, in order to cope with this increased and diversified traffic, a number of new national and international institutional frameworks will need to be set up. □

Il est d'autre part clair que les systèmes spatiaux seront en général utilisés en association plutôt qu'en compétition avec les réseaux terrestres. Par ailleurs, de plus en plus de services nouveaux seront mis sur pied pour lesquels le véhicule spatial sera particulièrement bien adapté. La fiabilité et le coût de fabrication du matériel continueront également d'aller dans le sens de l'économie, ce qui stimulera d'autant plus le processus d'expansion.

Au titre de l'organisation des opérations, on peut facilement imaginer que, pour faire face à cet accroissement et cette diversification du trafic, un certain nombre de cadres institutionnels nouveaux seront créés aux niveaux nationaux et internationaux. □

W. Luksch

Director of Communication Satellite Programmes

Directeur des Programmes de Satellites de Communications

A Possible Evolution of European Communications Satellite Systems

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Europe has a well-developed infrastructure of telecommunications networks which are continually being improved to meet increasing demands for communications. New advanced networks for services such as public data transmission will be operational in several countries at the end of this decade, and digital multiservice high-level networks foreseen for the next decade may be forerunners of future nation-wide and European integrated-service digital networks interconnecting regional and local wideband networks. The long-term evolution of the CATV (cable television) network may be the advent of local wideband networks accessible to individual households, carrying a variety of two-way communications services in addition to locally and nationally generated broadcast programmes.

The evolution of European communications satellite systems will progress with the launch of the Orbital Test Satellite, OTS, in 1977 and the introduction of the first-generation European regional communications satellites in the early 80's. These first-generation satellites will mainly provide traditional communications services such as telephony and television distribution involving one or two large earth stations in each participating country. Nevertheless, satellite links provide an ideal medium for the relay of high-quality wideband digital transmissions and it may be anticipated that future European communications satellites will provide a variety of 'specialised' wideband communications services which may benefit economically and operationally from using small earth stations located close to the origins of the traffic through the satellite. These satellite communications services could be valuable complements to the traditional services.

This article discusses the possible evolution of the European Communications Satellite (ECS) system against the background of the developing European terrestrial telecommunications services and facilities. The possible effects of an early implementation of technically and economically attractive satellite links on the growth of telecommunications services which are not widely used today because of limitations on the terrestrial networks or the high costs of providing the services using terrestrial means are considered.

* Relying on signal reflection from the earth's tropospheric layer to 'bounce' signals from transmitter to receiver.

SPECIAL COMMUNICATIONS SATELLITE SERVICES

During the course of ESA's work on a European regional system, a number of studies have been made to identify possible missions which may be filled either by direct use of the technology being developed for the basic mission, or by its minimal adaptation. Overall, the possible missions can be characterised as 'specialised communications', including:

- Communications to areas of difficult access (e.g. North-Sea oil rigs)
- Data network communications
- Computer communications
- Remote printing
- Teleconference service
- Videophone service
- Electronic mail service

Of the missions listed, the last two are somewhat long-term in their needs, but, conversely, the communication links to offshore oil exploration and production facilities in the North- and Celtic-Sea regions have already reached the stage of being incorporated in the mission model for the first ECS operational satellites, which will carry at least one dedicated transponder for this purpose.

Offshore Communication Service

Offshore oil and gas exploitation activities on the continental shelf below the North Sea and the adjacent sea areas are expected to increase considerably during the next decade. Consequently, the number of offshore installations and the geographical area covered by exploration and production facilities will increase considerably. A widening of the oil and gas exploitation activities beyond the current level and geographical extent must be matched by a corresponding increase in the coverage and capabilities of the communications facilities available to the offshore operators. Given the technical and economic limitations of current terrestrial communications systems, satellite links may offer a flexible and economic solution for the overall communications needs in the North Sea area after 1980.

Offshore production complexes are currently using a network of line-of-sight and troposcatter* links to communicate between structures belonging to the same complex and between the centre platforms in the complexes and shore stations. These communications systems provide adequate facilities for voice, data and teleprinter messages, but difficulties in obtaining frequencies for additional troposcatter

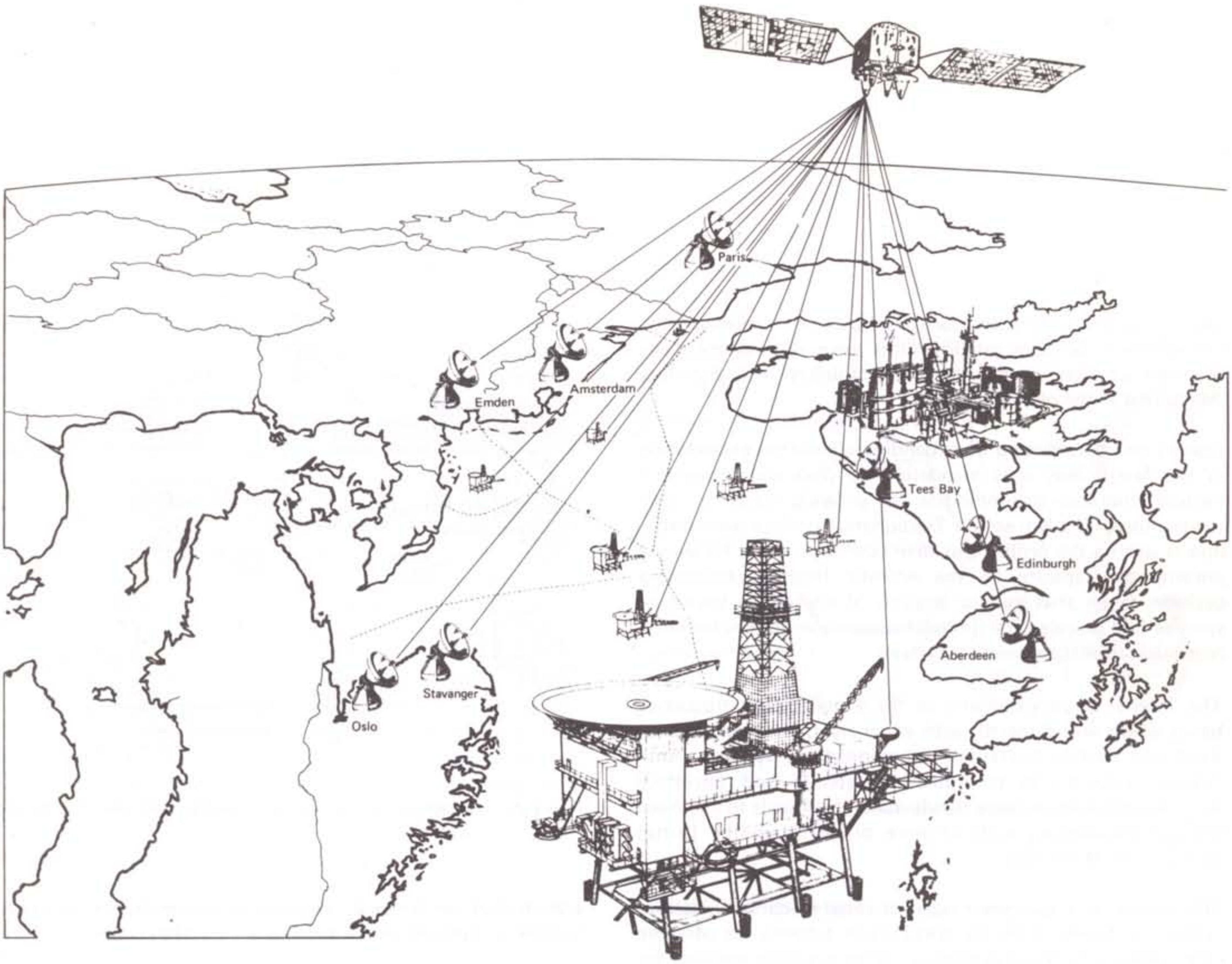

Figure 1 — Offshore satellite communication system.

systems and their inherent inflexibility limit their growth capacity. In fact, the available troposcatter bands (2 – 2.5 GHz) are already close to saturation.

The Ekofisk project, in the centre of the North Sea, exploits one of the largest offshore oil and gas fields in the world. When completed, it will comprise about 30 permanent offshore structures arranged about a central field terminal. All of these structures will be connected by line-of-sight radio links and the central platform will be in contact with Teeside in England and Emden in Germany via troposcatter links. The central Ekofisk platform will also be connected to Stavanger in Norway via satellite links operating in the 4 and 6 GHz frequency bands.

Troposcatter links also provide reliable communications channels to pump and compressor stations associated with the sea-bottom oil and gas pipelines connecting the Ekofisk complex to England and Germany. Reliable communications facilities are mandatory for continuous monitoring of flow rates, pressures and temperatures in the pipelines to allow instantaneous detection of any anomalies and to facilitate remote computer operation of the pipeline system. Ekofisk is the world's first computer-controlled offshore production facility.

The shortage of frequency bands and the high cost of troposcatter systems make it highly desirable to utilise existing links to the full. This is borne-out by the current trend to use the field terminals equipped with troposcatter facilities to communicate with shore stations, as communications hubs serving nearby fields via radio links and additional troposcatter systems.

During the planning and implementation of the Ekofisk complex, various alternative means of communication were investigated. These included submarine cables, which could provide the capacity and the quality required of the system. However, difficulties associated with reliability of the cables, in addition to the high cost of providing redundancy, indicated radio-transmission (e.g. troposcatter) systems to be the preferred solution. Suitable satellite links were not commercially available at that time and this possibility was therefore discounted at the planning stage.

Against this background of expanding oil and gas exploitation in the North Sea, it is mandatory to plan and implement facilities that can accommodate the growing needs for communications. The Norwegian Telecommunications Administration is solving the problem in their country's sector by leasing pre-emptible capacity on the Atlantic Intelsat satellites, a decision taken after careful analysis of alternative terrestrial systems had revealed the limited frequency resources for radio communications/troposcatter systems.

The Intelsat system operates in the 4 and 6 GHz frequency bands which are allocated, with equal right, to fixed satellite, fixed and mobile terrestrial communications systems. Anticipated problems in co-ordinating satellite and terrestrial services operating in these bands make it difficult to use them for communications with offshore platforms in the British sector of the North Sea.

The advent of a European regional satellite communications system operating in bands particularly suitable for offshore communications could provide a highly desirable medium for expanding satellite communications in the British sector and providing the Norwegian sector with additional capacity when the satellite system presently serving it is saturated, some time after 1980. The European ECS system, which is planned to be operational in 1980, is expected to include capabilities for offshore communications in the 11 and 14 GHz frequency bands. These bands are not yet congested by terrestrial facilities and planning for their future use could take the requirements of the offshore operating companies into account.

The earth segment of the ECS system would comprise two types of ground station:

- Main stations operating as central shore stations and communicating with several offshore platforms.
- Remote stations located on offshore platforms (i.e. production, drilling and pipeline booster pump and compressor platforms).

An overall impression of the communications possibilities is given in Figure 1.

It is hoped to be able to perform a representative pre-operational experiment with OTS, to test system and modulation approaches and to verify and improve the operational

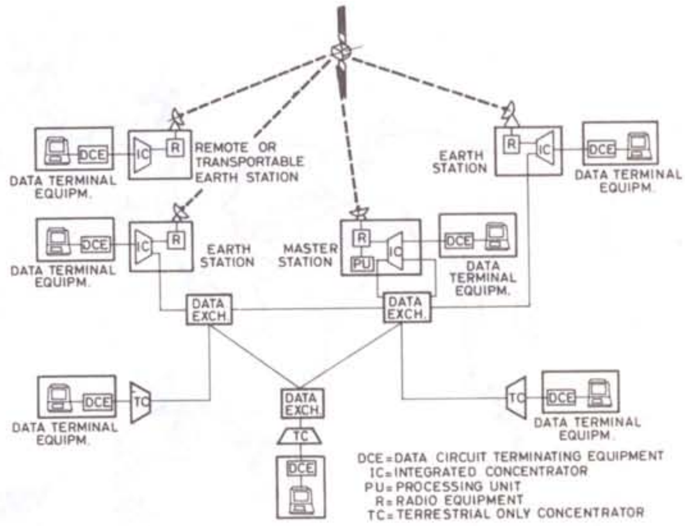

Figure 2 — Integrated terrestrial and satellite data communication system.

system that can be made available to potential users prospecting for and producing oil and gas in European waters.

Data Transmission Service

Several European countries are planning dedicated public data transmission networks separate from or partly integrated with the public switched telephony network. These data transmission networks will be operational at the end of this decade and will include processor-controlled data switching exchanges and digital multiplexers or concentrators. The associated long-haul networks connecting multiplexers and data switches will evolve into fully digital networks during the next decade.

The dedicated public data transmission networks are generally designed to meet the requirements of a large variety of data services, varying from interactive communication between remote data terminals to text-retrieval and bulk-data-transfer systems. Low-speed (300 bit/s), medium-speed (600–4800 bit/s) and high-speed (9600 bit/s) data rates can be accommodated in the same network. Data rates not compatible with the bandwidth of the telephony channel (e.g. 48 and 64 kbit/s) can be accommodated using dedicated wideband circuits between the users and the multiplexers or concentrators in the network. Generally, the user is connected to the high-level data transmission network via dedicated local telephony circuits.

Satellite links can be used to upgrade dedicated terrestrial (national and/or international) data transmission networks, the satellite system adding a centralised data switching function and a flexible wideband capability to the integrated satellite and terrestrial data transmission network. The flexibility of the satellite system can be fully explored when its earth stations are of low cost and equipped with fixed-pointed antenna systems suitable for roof mounting. Generally, the interfaces between the satellite links and the terrestrial network would be at the data switching exchanges, the multiplexers or the concentrators in the terrestrial network. An example of the network that can be envisaged is shown in Figure 2.

The use of satellite links during the implementation of the data transmission network is particularly attractive in view of the flexibility they offer. The links can be allocated to the users according to their varying traffic demands and the economic consequences of uncertainties in forecasted growth can be reduced significantly.

Computer Communication Service

Several large computer communications networks interconnecting computer centres and data bases in various European countries are expected to be operational during the next decade. In fact, the equipment and systems currently being developed for the experimental European Informatics Network (EIN) will provide the elements for designing an operational European computer communications network, 'Euronet'.

Satellite links provide an ideal medium for the transmission of high-quality digital data and, in view of the possible large distances between European computer centres and data bases, they may become an economic proposition for the long-haul communications networks of future European computer systems. The satellite system provides a star-shaped communications network with the satellite acting as a central 'traffic node' or communications hub, along the lines shown in Figure 3.

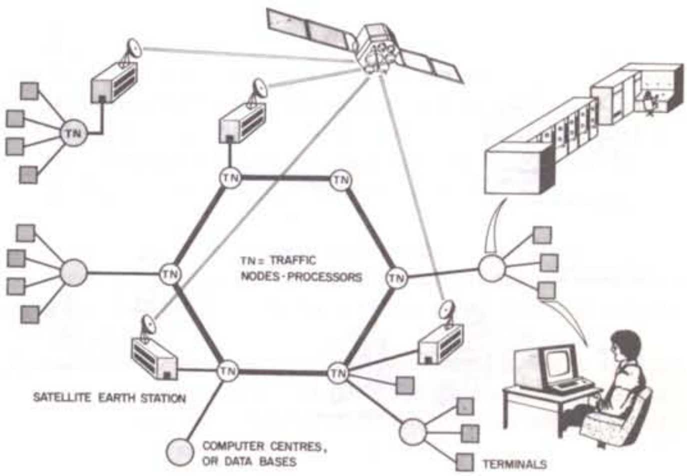

Figure 3 — Computer communication network employing satellite links.

The satellite and the terrestrial communications networks would operate in an integrated fashion and the flexibility and the wideband traffic-routing capability of the satellite links would be emphasised in the design of the integrated network.

A preliminary analysis has been made of the satellite-system requirements for such a network and again it is hoped to be able to conduct representative experiments with OTS. An indication of the type of experiment planned is given in Figure 4.

The proposal envisages, in its basic form, the installation of satellite earth stations, with transmitting and receiving capabilities, at three high-energy physics laboratories; CERN (Geneva), Rutherford (UK) and DESY (Hamburg). The main objective is the transmission of large data samples from CERN to the Rutherford and DESY laboratories via OTS. Typically, the transmitted data sample would be 100 Mbit and the transmission rate over the satellite link 1 Mbit/s, with a low bit error rate ($\leqslant 10^{-9}$), corresponding to that available to physicists at CERN using its central computers for sample data analysis. This experiment will permit the use of computers in the experimenters' home laboratories to control the running of experiments at CERN.

In the proposed experiment, two modes of returning operational information and results of data analysis from collaborating laboratories to CERN are envisaged. The transmitting capability of the earth stations can be used to provide return channels via the satellite. Scheduling and simple switching systems will guarantee that the return transmissions do not interfere with the wideband 'forward' transmissions. Secondly, the European Informatics Network or some other terrestrial communication link, can be used to provide a return channel from a collaborating laboratory to CERN. In this case any

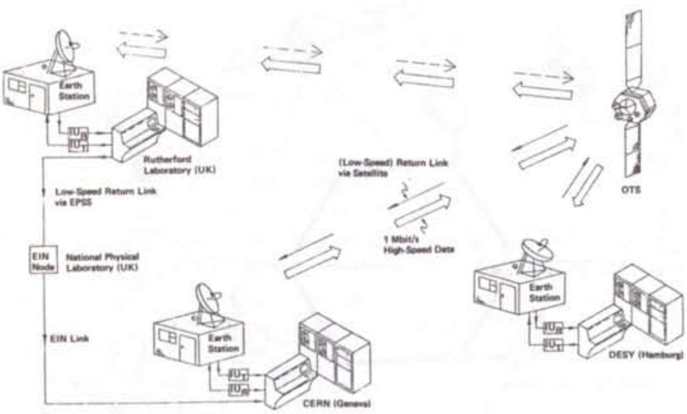

Figure 4 — Example of wideband satellite data distribution.

transmission via a return channel will be completely independent of the wideband forward satellite transmission, which should substantially improve the efficiency of the system. This is thus an extremely important experiment in the integration of terrestrial and satellite communications.

Remote Printing Service

Remote printing for press and news dissemination, requiring wideband multidestination communications channels, is a developing communications service (e.g. La Stampa, Herald Tribune, etc.) which is not yet widely used in Europe. The broadcast feature of the downlink transmission from a communications satellite makes it an ideal medium for the future communications needs of the press and publications users.

The remote-printing satellite service generally requires unidirectional multidestination wideband links from a central composing site to a number of remote printing sites. The central composing site can be connected to a large multipurpose earth station with transmit and receive capabilities (e.g. the ECS earth stations) via terrestrial communication channels. Low-cost receive-only earth stations would be located at the remote printing sites. The antennas of these earth stations could be fixed-pointed and suitable for roof mounting, i.e. the receive-only earth stations are located close to the printing equipment.

Low-speed data channels from the remote printing sites to the composing centres may be required for operational reasons. These channels could be provided via dedicated terrestrial data transmission networks or via the switched telephony network (e.g. teletype transmissions).

It should be noted that the current trend for news agencies to provide data-bank services may lead to extensive use of satellite links for such purposes in the not too distant future.

Teleconference Communication Service

A limited video conference ('Confravision') service is already available in some European countries (e.g. UK, Sweden), provided via standby television-broadcast distribution links. In addition, international video conference circuits are occasionally established using the International Switched Video Service (e.g. Eurovision) network.

The demand for an international video conference service may well be stimulated when the television channels on the operational ECS satellite system become available. The terrestrial International Switched Video Service may then be used increasingly for transmissions between video conference studios located close to the switching or traffic centres of the Switched Video Service network, and as early as the beginning of the next decade occasional use may be made of the ECS television channels for this service.

The future (after 1985) teleconference service in Europe may need to include a variety of services ranging from purely audio conferences to video conferences with a picture quality similar to that of present television broadcasts. In addition, a videophone system can be used for conferences of short duration and with limited attendance, or when the transfer of high-quality graphical or pictorial material is emphasised. Audio conference services in combination with narrow-band visual display systems such as the electronic blackboard, may also prove both useful and economical.

Future expansion of European teleconference services to include at least one conference studio in each major European city may depend on the availability of wideband satellite links operating in frequency bands that do not require frequency co-ordination with fixed and mobile terrestrial services.

Use of flexible low-cost earth stations which can be located at the premises of major teleconference users, as indicated in Figure 5, is highly desirable for both international and national systems. System analyses have again shown the adaptability of OTS/ECS technology to this service, and it is hoped to

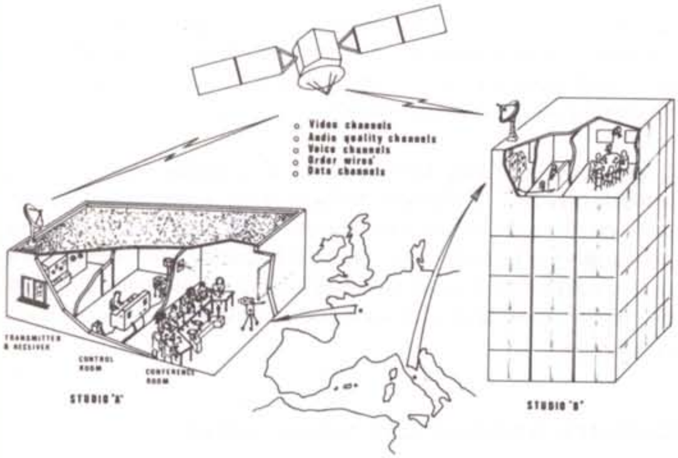

Figure 5 — Satellite 'teleconference' system.

perform system experiments with OTS.

Videophone Service

The technical facilities for the videophone service have been available for several years, but the service has not yet grown to a significant level and is mainly used for demonstrating the capabilities of future public telecommunications services. The major obstacles preventing growth are the shortcomings of the existing public telecommunications networks and the high costs associated with dedicated communications links.

A limited switched wideband service may be available in some European countries after 1980, but the videophone service is not expected to attain a significant level compared to other (narrowband) public telecommunications services over the next ten years. In fact, the videophone service may evolve as a form of video conference service and the availability of flexible wideband satellite links may prove to be a factor in its future growth.

Electronic Mail Service

The electronic mail service has been studied extensively in the USA, where it is oriented towards the transmission of short routine messages, the ultimate goal being to relieve the postal system of the transfer of vast amounts of printed material which can readily be transmitted and delivered by electronic means. The future evolution of a nationwide electronic mail service, if it becomes a reality, could include the following two development phases:

(i) Long-distance messages carried via telecommunications facilities, with local distribution by conventional mail

(ii) Long-distance transfer and local distribution of messages via telecommunication facilities. Bi-directional CATV systems may be used to transmit the local messages.

The use of satellite links would probably be limited to the interregional and long-haul communications system associated with an international and/or national electronic mail service.

An electronic mail system between satellite earth stations located at major postal offices is one approach that has been considered and may deserve further attention with a view to possible implementation before 1990.

CONCLUSIONS

A number of European communication service needs have now been outlined. One of these, that of communication to oil exploration and production platforms in the North and Celtic Seas, has been the subject of detailed work, and it now appears probable that a dedicated transponder for this service will be flown on the first operational European regional satellites in 1980, satellites whose basic mission until now has been bulk telephony and television-programme exchange.

As far as the other services are concerned, they have not yet reached the same advanced stage of implementation. For several of them it is hoped to be able to perform representative experiments with the OTS satellite scheduled for launch in mid-1977. In particular, analysis to date has shown that all of these services can be provided by equipment and technology as already developed within the basic OTS/ECS programme, or with only minor modifications. The basic question that remains is whether the demand for these services in Europe will become large enough to warrant a separate, specialised-service space segment, or whether they can be incorporated into an expanded ECS mission as it develops during the 1980's. □

Problèmes et possibilités de la radiodiffusion par satellites

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Les systèmes de télécommunications par satellites appartenant au service fixe ont pris une place des plus importantes dans l'arsenal des moyens modernes de télécommunications et ont prouvé rapidement non seulement leur haut rendement économique, mais aussi leur fiabilité. Ces systèmes étaient dès le début capables de relayer des images de télévision, mais l'état de développement de la technique ne permettait pas encore la transmission de ces images vers des petits terminaux de réception, accessibles au grand public.

Avec le développement progressif des techniques spatiales et en particulier le développement des tubes amplificateurs à puissance et rendement élevés, fonctionnant en ondes centimétriques, ainsi que des antennes à faisceau étroit, est apparue la possibilité d'effectuer des émissions de télévision directement vers des utilisateurs individuels équipés de récepteurs de type domestique.

L'apparition de ce nouveau type de système ne suscite plus le scepticisme des utilisateurs sur le plan technique mais pose des problèmes d'ordre politique et juridique liés à son utilisation. Ces problèmes ne devraient pas être difficiles à résoudre car il n'y a pas de différence majeure entre un système de radiodiffusion utilisant des émetteurs de Terre et un système utilisant des satellites, sauf pour le rendement technique et économique de ce dernier.

Dans le cas d'une application particulière de la radiodiffusion par satellite, notamment les émissions éducatives, le scepticisme des spécialistes a été provoqué principalement par des expériences exécutées à l'aide d'émetteurs à Terre, expériences qui sont loin d'avoir donné les résultats escomptés.

Les causes de ces défaillances sont très variées. Elles sont dans certains cas dues à une mauvaise adaptation des techniques pédagogiques aux media, au fait de substituer un appareil de télévision au professeur ou maître d'école tout en utilisant des méthodes qui en requièrent un. Dans d'autres cas, c'est la mauvaise qualité du logiciel qui est en cause, sa production ayant été confiée souvent à des débutants, ou bien encore le manque de moyens financiers nécessaires pour produire des programmes de bonne qualité.

Quelles qu'en soient les raisons, on ne peut pas faire de l'instrument de transmission le bouc émissaire de ces défaillances, sauf dans les cas où ses caractéristiques techniques ou économiques ont été mal définies.

Il est donc essentiel, tant pour les producteurs que pour les utilisateurs de l'instrument technique de transmission, d'une part de trouver les caractéristiques techniques les meilleures par rapport à la zone que l'on se propose de servir, et d'autre part d'adapter le logiciel aux possibilités spécifiques du moyen de transmission et aux besoins socio-culturels de la population concernée.

CLASSIFICATION DE CAS PARTICULIERS

Bien que les caractéristiques du systèmes doivent être adaptées à chaque cas particulier, il est possible de réunir les différents cas possibles en quelques groupes principaux:

(a) *Pays industrialisés de faible étendue,* qui peuvent être (ou sont) bien servis à l'aide de réseaux de Terre. Ces pays n'ont aucune motivation pour adopter des systèmes de satellites pour la radiodiffusion.

(b) *Pays industrialisés de moyenne et grande superficie,* possédant des réseaux de radiodiffusion de Terre bien développés. Ces pays sont dans la plupart des cas confrontés au problème de la production de programmes de radiodiffusion nécessaires pour 'remplir' les chaînes existantes et non pas à un problème d'augmentation du nombre des chaînes. De plus, si pour des raisons économiques plaidant en faveur du satellite, il est souhaitable de changer de système, on est confronté avec le problème de la transition du segment récepteur qui peut compter des millions d'équipements vers un système nouveau, avec lequel les équipements existants ne sont pas directement compatibles. Le problème de l'introduction d'un système à satellites pourrait se poser pour ces pays seulement dans l'optique des plans à moyenne ou longue échéance.

(c) *Pays industrialisés de moyenne et grande superficie ayant des réseaux de radiodiffusion de Terre peu développés et une densité ou configuration démographique particulière.* Pour ces pays le satellite peut être dans l'immédiat la solution la meilleure.

(d) *Pays en voie de développement* où souvent les infrastructures énergétiques, de radio et de télécommunications ont une faible étendue. Ces pays connaissent à l'heure actuelle

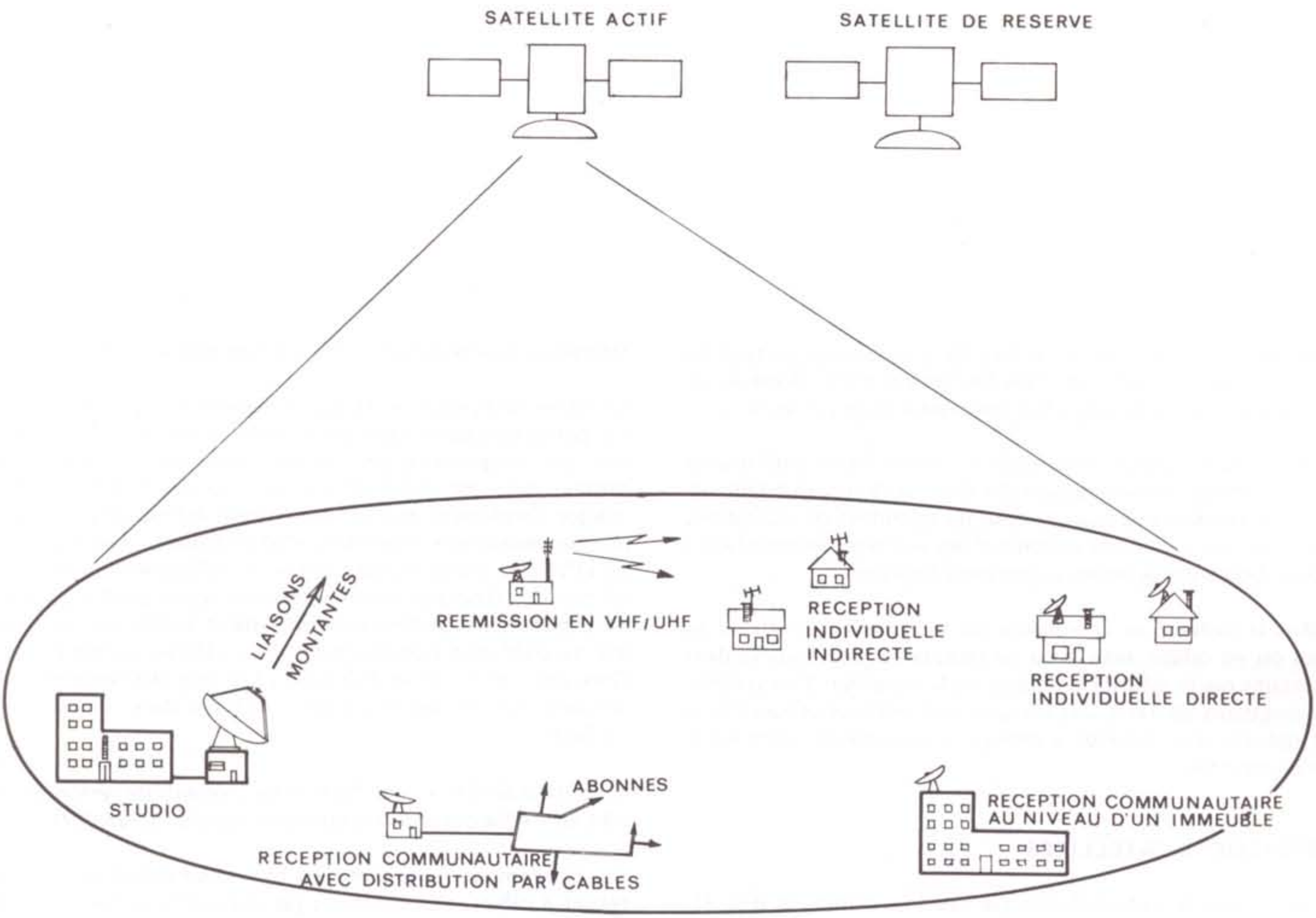


Figure 1 — Un système de radiodiffusion par satellites

un taux élevé d'expansion sociale, et l'implantation des moyens de diffusion doit s'adapter au mieux à cette expansion rapide. Ceci veut dire que parmi les différents moyens techniques il faudra choisir celui qui, pour un investissement initial modeste, assure la couverture totale du pays dans les délais les plus courts avec toute la flexibilité voulue. Seules les caractéristiques des satellites paraissent répondre à ces contraintes.

QUELQUES CARACTERISTIQUES DES RESEAUX D'EMETTEURS TERRESTRES ET DES SYSTEMES A SATELLITES

Pour servir la totalité de la population d'un pays avec des programmes de télévision diffusés par des réseaux d'émetteurs terrestres, il est nécessaire d'implanter un grand nombre d'émetteurs principaux et secondaires, relier entre eux ces émetteurs par des faisceaux hertziens, assurer au site de l'émetteur l'énergie électrique, les voies d'accès et surtout le potentiel technique et humain requis pour la maintenance et l'exploitation des installations.

Le nombre d'émetteurs requis pour assurer une couverture convenable d'un pays varie selon ses dimensions et ses caractéristiques géographiques en fonction desquelles doivent être calculés les frais d'investissement et d'exploitation technique du réseau.

Pour des territoires d'une superficie de 250 000–400 000 km^2 et ayant un relief varié, le coût d'exploitation annuel d'une chaîne de télévision de Terre assurant un taux de couverture de 90% environ se monte à 20–30 millions de dollars US. Le calendrier de réalisation d'un tel réseau est de l'ordre de 10 à 15 ans. Ces chiffres sont basés sur des données caractéristiques à certains pays de l'Europe occidentale qui, au moment de l'implantation des premières chaînes de télévision, avaient d'ores et déjà le bénéfice d'un inventaire assez complet pour ce qui concerne les infrastructures énergétiques et de télécommunications. Dans les pays en voie de développement, le coût et le calendrier indiqués pourraient être plus importants.

Un satellite pour la radiodiffusion offre l'avantage d'assurer, pour un investissement initial modeste, la couverture à 100% d'un territoire, dès sa mise en orbite.

Les coûts annuels d'exploitation et de maintenance du segment spatial d'un système à satellites, estimés dans les mêmes conditions que ceux indiqués ci-dessus pour un réseau terrestre, se montent selon le système choisi, à 2–5 millions de dollars US, c'est-à-dire entre 4 et 15 fois moins qu'un système d'émetteurs terrestres et dans les limites d'un calendrier de réalisation qui ne pourrait être concevable pour ces derniers.

On constate donc, en comparant seulement les caractéristiques des segments de transmission des deux systèmes, que tant sur le plan économique que sur celui du calendrier de réalisation, les systèmes à satellites présentent des avantages incontestables par rapport aux systèmes à émetteurs terrestres.

Mais le système ne se compose pas seulement d'émetteurs au sol ou en orbite, mais aussi de récepteurs. Ceci soulève dans certains cas le difficile problème de la transition d'un système à émetteurs de Terre vers un système à satellites et constitue à l'intérieur d'un système à satellite un paramètre économique très important.

SYSTEMES A SATELLITES

Un système de radiodiffusion par satellites comprend (Fig. 1):

- un ou plusieurs émetteurs montés à bord d'un satellite géostationnaire et transmettant des programmes dans un ou plusieurs faisceaux d'antenne;
- des équipements de réception au sol – (selon les caractéristiques du système, ces équipements de réception peuvent soit adapter un poste de télévision classique pour la réception des signaux transmis par le satellite, soit recevoir les émissions du satellite et les distribuer aux utilisateurs par l'intermédiaire d'un réseau de câbles ou par un ré-émetteur);
- une ou plusieurs station(s) transmettant les programmes à partir du studio vers le satellite, et pouvant remplir en plus des fonctions de contrôle du fonctionnement du satellite.

Enfin, pour assurer une haute fiabilité au système, il est nécessaire de placer en orbite, outre le satellite opérationnel, un satellite de réserve qui le remplace immédiatement en cas de panne.

SEGMENT TERRESTRE (RECEPTEUR) – SON INFLUENCE SUR LE CHOIX DES CARACTERISTIQUES DU SYSTEME

Comme on peut le voir sur la Figure 1, il existe trois systèmes principaux de réception:

Réception directe à l'aide d'installations individuelles

Le terme 'individuel' n'est pas entièrement exact car de tels équipements peuvent être utilisés pour la visualisation 'collective' des programmes, par exemple dans une maision de la culture, dans une classe d'école, etc. Le terme 'indidividuel' indique simplement que cet équipement est, du point de vue prix, accessible aux possibilités d'achat d'une personne privée. En effet si la puissance du satellite est suffisamment élevée, il est possible d'obtenir une réception de bonne qualité à l'aide d'équipements à performance modeste et à coût relativement bas. Le coût de ces équipements varie selon les estimations de l'industrie entre 150 et 350 dollars US pour des équipements pouvant recevoir des émissions effectuées dans la bande de 12 GHz.

Réception semi-directe à l'aide d'équipements de performance plus élevée (ce qui réduit la puissance requise du satellite)

Les programmes reçus sont dans ce cas soit distribués dans un réseau à câbles, soit rediffusés par des émetteurs terrestres et reçus à l'aide de récepteurs classiques. Le coût de l'équipement varie (toujours dans l'hypothèse de l'utilisation de la bande de 12 GHz), selon les performances requises, entre 600 et 8000 dollars US (ou plus). Dans la comparaison entre les caractéristiques économiques des différents systèmes, il faut ajouter le coût du réseau de distribution soit à celui du satellite, soit au prorata, à celui des équipements de réception. Le choix des caractéristiques du segment récepteur d'un système de radiodiffusion par satellites est extrêmement important car dans un système développé, la partie la plus chère est représentée justement par le segment récepteur terrestre.

En fait, dans certains cas, le coût du segment émetteur spatial représente à peine 5–10% du coût total du système. Ceci veut dire qu'il y a intérêt à maximiser la puissance du satellite afin de minimiser le coût des équipements de réception.

Le choix d'une puissance maximale du satellite offre en outre un avantage supplémentaire. En fait, si l'on choisit une puissance modeste, on est forcé d'utiliser exclusivement des équipements de réception de haute performance (et d'un coût plus élevé), appelés d'habitude 'équipements communautaires' et compléter le réseau par câbles et ré-émetteurs, ce qui n'est pas toujours économique. Par contre, le choix d'une puissance plus importante à bord du satellite donne la possibilité de choisir les techniques de réception les plus économiques, et les mieux adaptées aux caractéristiques géographiques et démographiques particulières aux différentes régions du pays à servir.

Système mixte (réception individuelle et communautaire)

Dans le cadre d'un tel système, les régions urbaines pourraient envisager l'utilisation de stations communautaires performantes alimentant des réseaux de distribution, ainsi que l'utilisation des équipements de réception individuelle, tandis que dans les régions à population dispersée, il serait également possible d'utiliser des systèmes de réception communautaire à ré-émetteurs en VHF/UHF et d'installations de réception individuelle dans les endroits où les systèmes à ré-émetteurs ne seraient pas rentables.

Dans ce même contexte, il est important de mettre en évidence la différence entre les critères d'évaluation applicables au cas de la plupart des pays industrialisés et ceux applicables au cas des pays en voie de développement.

Dans les pays industrialisés, l'investissement, le coût d'exploitation et de maintenance du réseau sont à la charge de l'organisme utilisateur, tandis que le prix des équipements de réception est payé par chaque utilisateur individuellement.
Dans ce cas l'optimisation au niveau du *système* entier n'est pas essentielle. Il suffit de choisir des caractéristiques qui rendent le système acceptable tant pour l'organisme d'exploitation que pour les moyens financiers des utilisateurs individuels.

Il est difficile de supposer que dans les pays en voie de développement, surtout s'il s'agit de systèmes à vocation éducative, le coût des équipements de réception soit payé par des utilisateurs privés; il sera donc à la charge de l'autorité compétente qui met en place le système et, dans ce cas, l'optimisation dans le sens de la minimisation du coût au niveau du système entier prend une grande importance, les économies réalisables étant considérables.

DEFINITION DE LA ZONE DE SERVICE DU SATELLITE

Deux possibilités existent pour la définition de la zone de service des satellites de radiodiffusion:
– couverture multinationale (régionale)
– couverture nationale.

Bien que la couverture multinationale (régionale) offre l'avantage d'un coût par habitant moins élevé pour le segment spatial du système, il a été indiqué précédemment que ce coût représente un faible pourcentage du coût total du système. Ce type de service présente en outre des inconvénients importants qui peuvent en compromettre la faisabilité:

Problèmes politiques et juridiques: il serait dans la plupart des cas bien difficile de produire des programmes de radiotélévision et, en particulier, des programmes éducatifs qui puissent satisfaire aux habitudes, aux traditions socio-culturelles de chaque pays appartenant à une région. Les problèmes de droits d'auteur qui se poseraient dans le cas d'un service multinational soulèveraient en outre des difficultés supplémentaires.

Diversité des langues: dans certains pays en voie de développement, même un service de radiotélévision à couverture nationale se heurterait au problème de la diversité des langues. Ce problème devient d'autant plus difficile à résoudre dans le cadre d'un service multinational.

Différences de fuseaux horaires: les différences horaires entre les extrémités d'une région supranationale pourraient être suffisamment importantes pour susciter des contraintes opérationnelles.

Pour toutes ces raisons, il est probable que les services à couverture nationale auront plus de chances de s'imposer.

CHOIX DE LA BANDE DE FREQUENCES

Le choix de la bande de fréquences pour un système de radiodiffusion par satellite a une importance capitale tant pour l'économie que pour les possibilités d'évolution ultérieure du système.

En fait le règlement des radiocommunications prévoit pour la radiodiffusion par satellite trois bandes de fréquences qui, du point de vue de la disponibilité de la technologie, peuvent être utlisée à moyenne échéance. Il s'agit des bandes de fréquences autour de 800 MHz, 2500 MHz et 12 GHz. Les deux premières sont extrêmement étroites et assujetties par la règlementation à une limitation de la puissance rayonnée par le satellite. Ceci impose l'utilisation d'équipements de réception à performance élevée et donc relativement chers et limite le système à la réception communautaire, sans possibilité d'évolution ultérieure. Enfin, l'utilisation des bandes de fréquences de 800 et 2500 MHz pour des services à couverture nationale dans des pays de superficie moyenne (200 000–400 000 km^2) serait extrêmement difficile, car les dimensions des antennes du satellite soulèveraient des problèmes d'encombrement difficiles à résoudre.

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. □

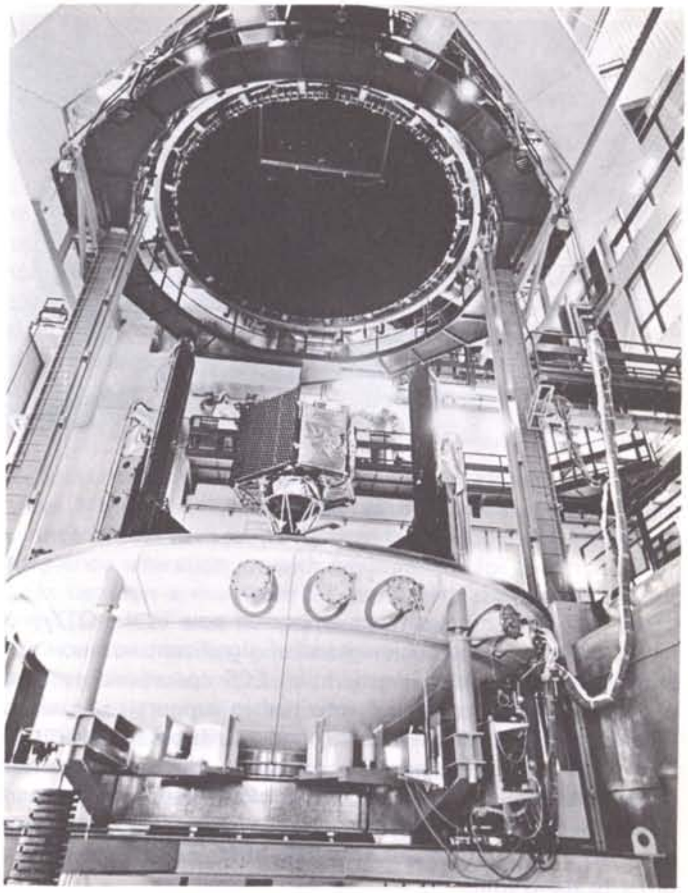
Technological Developments needed for Communications Satellite Systems

B. Stockwell et al., Communications Satellite Programme Office, Directorate of Communications, ESTEC, Noordwijk, The Netherlands

The first several generations of commercial communications satellite systems were intended to meet relatively modest mission requirements and operated in the 4/6 GHz frequency band. They employed spin stabilisation, and were based to some extent upon military predecessors. These satellites became progressively more complex from generation to generation, culminating in the early 70's in the Intelsat IVA vehicle. At the same time interest in the advantages of three-axis (body) stabilisation concepts, in different missions in communications terms, and in alternative operating frequencies gained ground, and the power demands and payload complexity for the various missions increased considerably.

Thus the Symphonie project was started, leading to a first launch in 1974, and employing momentum-wheel spacecraft stabilisation and a deployed solar array. Also in the early 70's the Intelsat V requirement appeared to lead naturally to a departure from the spin-stabilised concept (with four of the five current offers to INTELSAT employing body-stabilised configurations), and to the use of frequencies other than 4/6 GHz.

In parallel, the aeronautical and maritime missions gained ground, while the semi-direct or even direct broadcast TV mission became of more and more interest, and implied considerable technical advance in terms of power levels, beam width and pointing-accuracy requirements.



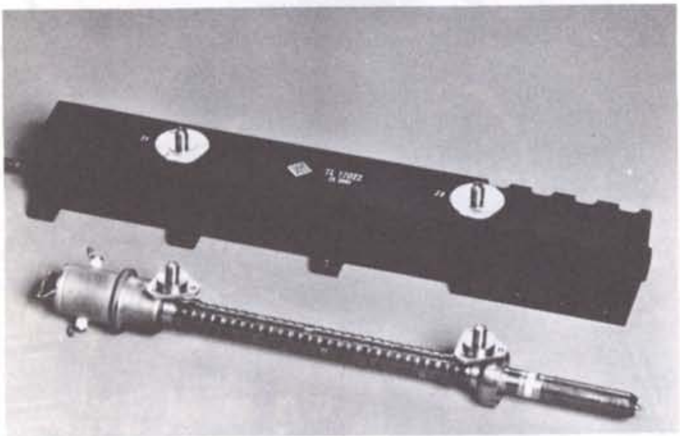
In ESRO, interest in the late 60's in the communications satellite field initially centred on body-stabilised configurations for telephony and for television distribution. Then in 1969 concentration switched to a limited mission with a relatively low capacity spin-stabilised vehicle, in order to meet a simple television distribution mission. From 1970 onwards, with the mission again broadened, all emphasis was placed on body-stabilisation, and on use of the 11/14 GHz frequencies (the latter for reasons both of spectrum crowding, and because of the need for a European regional system to get in close to the cities).

At the same time, ESRO investigated derivative programmes aimed towards the maritime and aeronautical applications, the latter in particular being rather demanding in terms of power and antenna complexity.

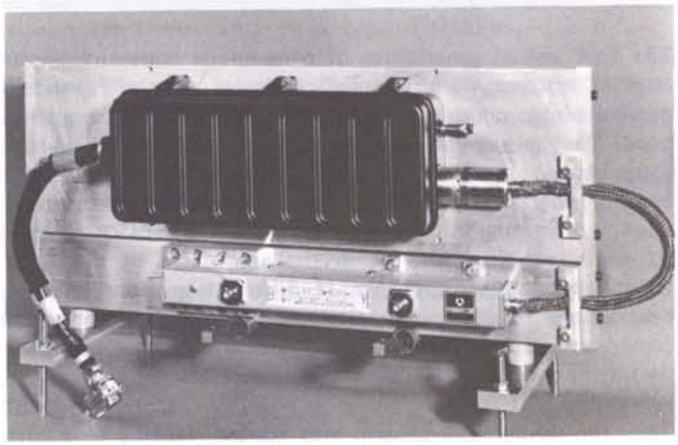
The movement towards more sophisticated stabilisation systems, more complicated repeaters, and new and higher frequencies brought in train the need for significant technological advances. In the United States these could in some cases at least be supported from military programmes, but in Europe national and international funding became necessary if these advances were to be realised.

The ESRO Telecommunications Programme of the early 70's contained, therefore, a significant technological development effort. At the same time the national agencies (in particular in France and Germany) devoted considerable funding to such development, and as a coherent whole the programme allowed relatively major activities to be undertaken.

The main lines of such activity are described below, with particular reference to the OTS/ECS Supporting Technology Programme of ESA, taken in the context of other ESA and of national efforts. The overall result has been a broad technol-



Travelling-wave tube developed by AEG, Germany.



Travelling-wave-tube amplifier developed by Thomson-CSF, France and CGE-Fiar, Italy.

ogical first-generation advance embodied now in the OTS and Marots satellites, the achievement of significant advances for application to the second-generation ECS operational system, and the commencement of activities in support to missions beyond that (an improved ECS, and television broadcast, in particular). At the same time of course, the world has not stood still since 1970, and a number of domestic, regional and international satellite systems and system proposals have emerged embodying major advances. It is necessary to run in order to stand still.

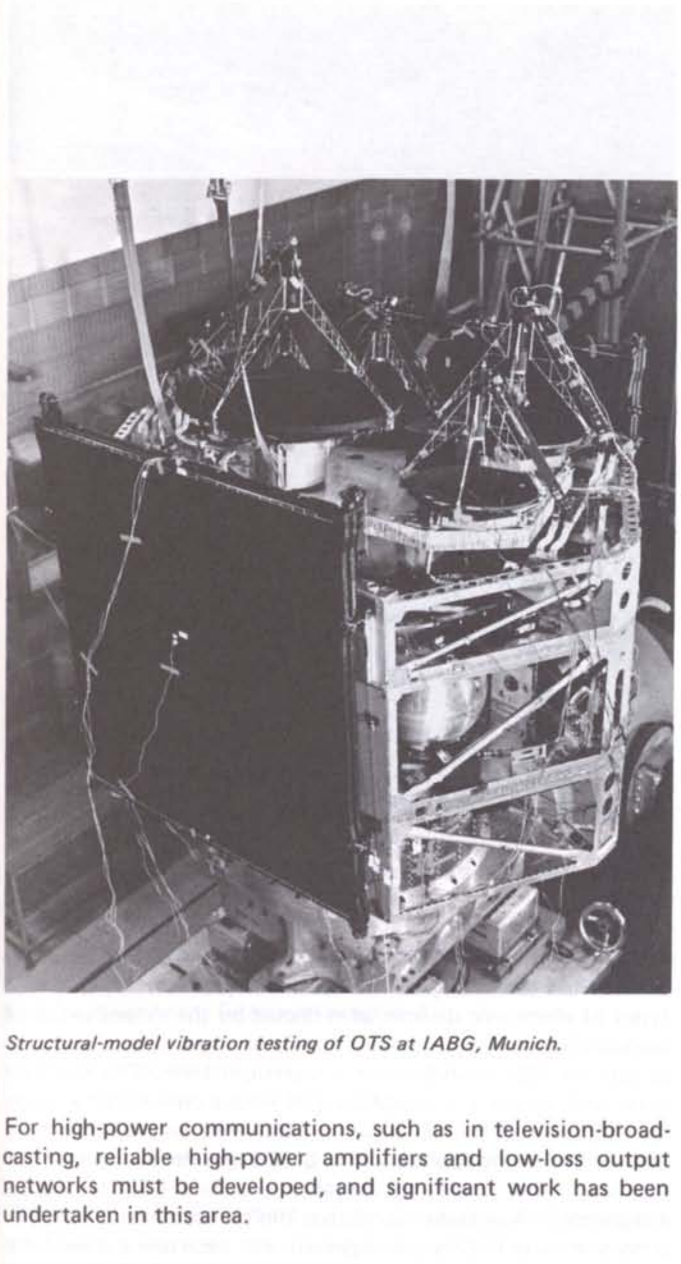
COMMUNICATION REPEATERS

In the pre-development phase for the Orbital Test Satellite (OTS), major efforts have been devoted to the development of a modular repeater operating in the 11/14 GHz bands. The repeater uses the dual conversion principle with down conversion from 14 GHz, and amplification of the signals in the 1 GHz frequency region. The signals are then again up-converted to the 11 GHz frequency region with radio-frequency (RF) power sufficient to drive the 20 W travelling-wave tubes (TWT's) used as power output stages. Particularly challenging and successful developments include the 14 GHz parametric amplifier, the high-gain, high-power TWT's associated with their power conditioners, special linear phase IF (intermediate frequency) filters and an Impatt diode oscillator/amplifier. These developments are incorporated in OTS (to be launched in mid-1977), which carries a main communication repeater with two 40 MHz and two 120 MHz channels, each pair operating with frequency re-use and opposite linear polarisations. OTS also carries two narrow-band repeaters (together with the Impatt diode oscillator beacons) for propagation and data-transmission experiments, the two chains operating again in frequency re-use, but this time with opposite circular polarisations.

For the European Communications Satellite (ECS), the OTS-developed technology will be re-used, the hardware being modified to meet ECS requirements. In this case up to twelve 80 MHz channels are to be operated in frequency re-use.

In the last few years, the technology of field-effect transistors for the 11/14 GHz frequency region has made considerable progress. Therefore, the use of single-conversion-type repeaters may now be considered in order to obtain the benefits of simplicity and low mass inherent in this design, and significant work has been put in hand in this area.

For communications missions requiring increased traffic capabilities, hardware developments using higher frequencies (20–30 GHz) are of interest. Combination of systems using the 20–30 GHz and 11–14 GHz frequency bands would become very attractive through the use of satellite on-board baseband signal switching, for which demodulators, modulators and switching matrices need to be developed. Together with multibeam, high-gain antennas, the use of solid-state, medium-power-output amplifiers could become cost effective, and again development work has been and has to be undertaken.



Structural-model vibration testing of OTS at IABG, Munich.

For high-power communications, such as in television-broadcasting, reliable high-power amplifiers and low-loss output networks must be developed, and significant work has been undertaken in this area.

COMMUNICATION ANTENNAS

ESA-supported development activities on antennas have been directed particularly towards meeting the various communications mission requirements. These call for antenna ground coverages extending from continental coverage in the case of European telephony and television distribution missions, to (for the future) very narrow, spot-area coverage in the case of television-broadcast missions. Special development emphasis has been placed on mass- and cost-effective design, high electrical efficiency and, for the European telecommunication mission, dual channel operation with high cross-polarisation purity to allow frequency re-use in the 11–14 GHz frequency bands. These particular programme requirements have been met through the development of front-fed parabolic antennas using conventional, glass-fibre, honeycomb circular dish constructions of various sizes, both for circular and elliptical coverage patterns.

In parallel with the work related to specific projects, investigations have been undertaken to improve the performance of these first-generation antennas. More demanding telecommunication missions become feasible through the use of special-design offset feeds, special dish profiling, and use of materials such as carbon fibre, leading to improvements in electrical efficiency, optimised gain shaping across the desired coverage area and, in particular, cross-polarisation purity.

New antenna developments will be needed, and indeed in many areas are underway, for missions with requirements which cannot be met with presently used frequency bands because of frequency saturation, or with requirements for communication links between a multitude of small earth stations distributed over a regional area. In particular, large, accurate and stable multibeam antennas producing a number of narrow spot beams at frequencies possibly higher than those used now need to be developed, together with special beam-shaping techniques for improved power-flux illumination. Along with these developments, RF sensing and associated antenna steering needs to be developed in order to maintain the desired high antenna pointing accuracies, and a number of studies have been completed in this field.

POWER

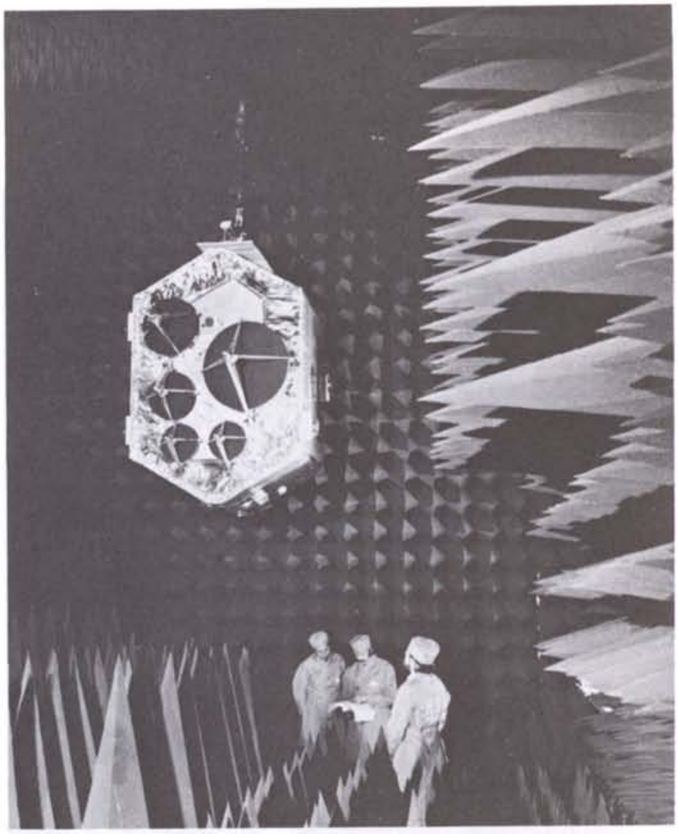
In view of the relatively high power requirements of communications satellites, mass and cost considerations more and more impose the use of three-axis-stabilised spacecraft with sun-tracking solar arrays. An important effort has been devoted in the past years to the development of mass-effective solar arrays, including participation by ESA in the Canadian CTS programme, where flexible solar-array blankets were developed for integration into a fold-out system, the development of a flexible-solar-array roll-out system, and the development of lightweight, rigid solar arrays to be flown on OTS and Marots (Maritime Orbital Test Satellite). Particular effort was required to develop special solar-cell interconnections able to withstand the extreme temperature excursions to which extended solar arrays are subjected during the sunlight-eclipse transients. For future applications, higher efficiency solar cells need to be developed to flight standard, i.e. violet solar cells with special shallow junctions which convert to useful energy more of the ultraviolet portion of the solar spectrum, and so-called 'black' solar cells, which should significantly reduce sunlight reflection, thus enhancing the amount of sunlight that can be converted to useful power. For higher power applications, these developments, together with flexible/rigid hybrid solar arrays or ultra-lightweight rigid solar arrays, as the need may arise, will be extended to flight application.

In the area of storage batteries, most of the activities have been directed towards obtaining well-understood and therefore well-designed nickel-cadmium battery systems for reliable operation over seven-year lifetimes and longer. Special test programmes have been undertaken to investigate the behaviour of such batteries with various capacities during geostationary cycling and storage in terms of electrochemical, temperature and reliability performance. Weight reductions will be achieved through optimisation of battery cell design and thermally efficient packaging techniques. For future applications, new electrochemical elements need to be investigated and developed, e.g. nickel-hydrogen and silver-hydrogen cells, the use of which would improve storage capability per unit mass by at least a factor of two.

In the field of power conditioning, efforts have been directed towards the improvement of designs for main-bus shunt regulators and battery-discharge regulators. Multiphase AC power-distribution systems have been studied as alternatives to the common DC distribution system. A major effort has been started to reduce the size, mass and power consumption of power systems through the introduction of hybrid thick-film techniques. Activities have now started to develop breadboard typical thick-film circuits into qualified, high-reliability components. Future activities are required to achieve higher efficiencies together with more mass-effective packaging of power-subsystem equipments.

TELEMETRY, TRACKING AND COMMAND (TTC)

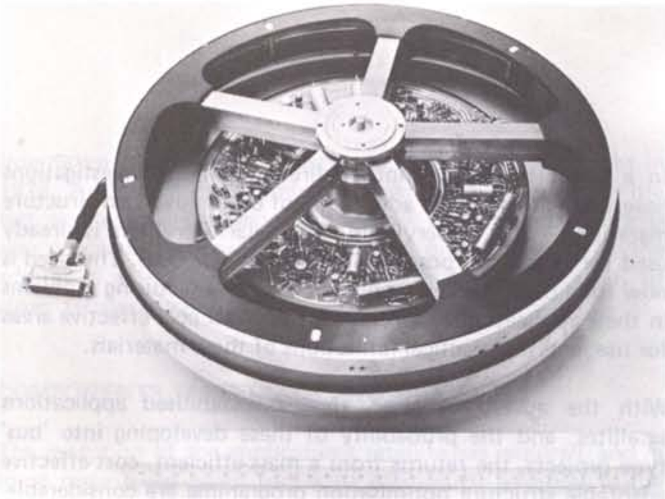
TT&C radio-frequency links in European programmes have been implemented in a mission-specific manner, the evolution of the technology resulting in the development of VHF systems which are compatible with ground-station networks, but more particularly with the peculiar demands of large-body satellites. In the case of OTS, the TT&C frequency has been placed both in VHF and in the operations communication band of the satellite. This has involved the development of a telemetry transmitter operating at 11 GHz and a command receiver operating through the communications payload.



OTS model in acoustic chamber.

Current methods of processing and transmitting data are constrained essentially by the availability of suitably qualified types of electronic devices, as reflected by the extensive use of medium/low-power, bi-polar, transistor logic in discrete component or MSI (middle-scale integration) form. The resultant mass and power consumption still leaves considerable scope for improvement and future programmes will undoubtedly include increasing application of CMOS and thick-film technology until the advent of suitably qualified LSI (large-scale integration) functions (analogue/digital converters, microprocessors, etc.). This development will facilitate a standardised modular data-handling system suitable for a variety of missions in a cost- and mass-effective manner.

Future TT&C systems are expected to evolve towards single-frequency systems, possibly operating in the main communications band (as opposed to the dual SHF/VHF systems of OTS and Marots). This would both simplify the ground segment and give mass and power advantages on the satellite. This evolution will require the development of technologies to produce a standardised range of band-specific transponder units and standard antenna designs which may be accommodated without interference with the satellite, and which are relatively independent of the satellite configuration.



Double-gimballed momentum wheel developed by Teldix, Germany.

OTS fixed momentum wheel developed by Philips, The Netherlands.

ATTITUDE AND ORBIT CONTROL

The advancing demands of this subsystem have, in recent years, given rise to major development activities, and in particular to an extensive phase of equipment development within the framework of the ESA Supporting Technology Programme. This development has covered actuators, sensors, and propulsion devices and as a result of this programme (taken together with national fundings), the following equipments are now sufficiently developed for application to current and future-generation missions (and indeed are qualified by at least two European suppliers):

- Fixed momentum wheels
- Two-axis infrared horizon sensors
- Low-thrust hydrazine thrusters
- Propellant tanks for zero-gravity application.

The next investment effort will be devoted to cost reduction, mass reduction and increased reliability, while at the same time improved sensing accuracy and improved efficiencies have to be sought.

Cost reduction can be achieved by the standardisation of equipments, while there will be an increasing tendency for the electronics boxes to be designed around these equipments, with the trend being towards the standardisation of the electronics boxes as well. The first steps in this direction are presently being taken by ESA with the introduction of standard thick-film modules for frequently used circuits within the electronics boxes.

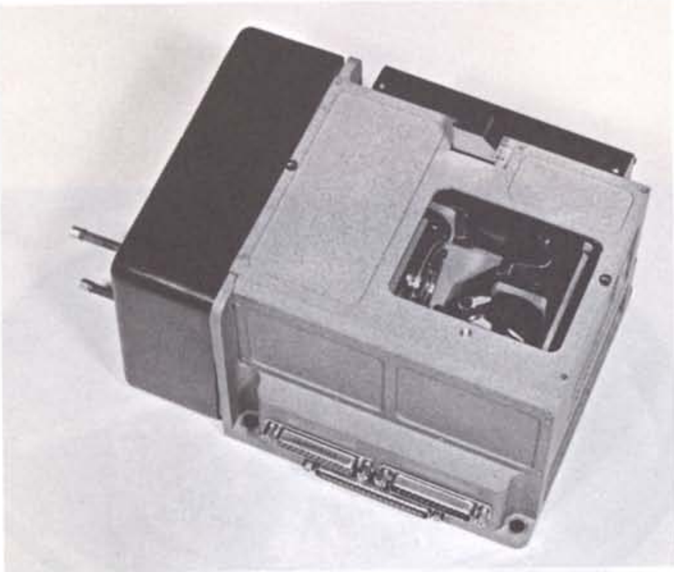
As for mass reduction, if mission requirements permit, the most efficient way to reduce the mass of communications satellites is by suppression of north-south stationkeeping. In this case, at least one additional degree of freedom between the spin axis of the momentum wheel and the spacecraft is required, leading to the development and qualification of a single gimbal mechanism that together with any one of the standard momentum wheels forms a single gimballed momentum wheel. A breadboard model has already been manufactured under an ESA supporting-technology contract and a prototype is expected by end of this year. Alternatively, multiple fixed wheels can be employed to provide the same function.

If north-south stationkeeping is necessary, then significant mass reduction can be achieved by increasing the specific impulse of the propellant, leading to the development of power-augmented electrothermally decomposed hydrazine systems and electric propulsion systems. Development activities in both areas are continuing on a national basis in the United Kingdom, France and Germany.

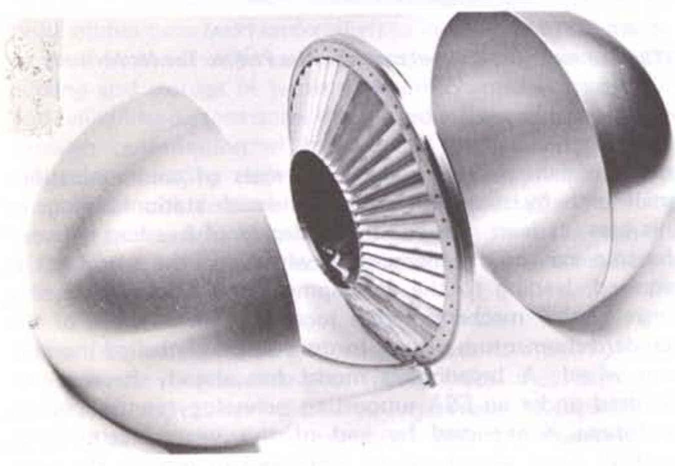
Further mass reduction can be expected from increased packaging density due to the introduction of thick-film technology and large-scale integrated circuits.

STRUCTURE DEVELOPMENTS

There is an obvious need for more lightweight structures and much work is underway in this area. This involves developments in structural materials, test methods, and in analytical techniques.



Infrared horizon sensor developed by Galileo, Italy.



Capillary expulsion tank developed by SEP, France.

Under ESA auspices, considerable work has been undertaken as part of Structural Mass Optimisation Programme, which was directed to accumulating experience in the use of advanced materials, such as carbon-fibre-reinforced plastics, and improving construction methods using both these new materials and conventional materials.

The representative structure produced during this programme enabled studies to be made of different and more adaptable analysis and test methods, such as modal survey techniques, with a view to enhancing, or even replacing, certain tests. Such modal surveys offer promise of better understanding of the entire spacecraft dynamic performance, and allow identification of both prime structures and major equipment (such as solar arrays and antennas) that could be optimised to improve performance. This method could also be a powerful tool for the development of a 'bus' capability for alternative payloads, indicating the efficient modifications available to accommodate such wider applications of any given structure.

In a support role in another direction, initial investigations have been made of the advantages of other advanced structure materials – such as beryllium and kevlar. Beryllium is already used for special purposes on mechanisms in OTS. The need is now for a better understanding of the manufacturing problems in their application to structures, the most cost-effective areas for use, and the practical limitations of these materials.

With the advent of large, three-axis-stabilised applications satellites, and the probability of these developing into 'bus' type projects, the returns from a mass-efficient, cost-effective adaptable structure optimisation programme are considerable.

THERMAL CONTROL

Thermal control can often be achieved, at least in principle, using available materials and finishes, as is the case with OTS, but a lengthy programme of tests is normally needed to qualify these materials for the required long-life exposure in the orbit environment. As part of the technology preparation of ESA, a test programme has been undertaken, and the test series is now in its second phase (in collaboration with CNES), the irradiation of surfaces to electrons, protons, and UV radiation being carried out at the DERTS facility at Toulouse. Electrically conductive paint and second surface mirror materials are included in the current test series, it being possible to measure the sample electrical resistance during test to support current interest in charge-build-up phenomena. An additional, fuller study is now commencing in this important area of high-voltage charge build-up on materials exposed to radiation in a geosynchronous orbit, it being realised that arc discharges precipitated by this build-up are a potential cause of thermal material degradation and also a potential source of spurious RF signals. Qualification of conductive materials could assist in the prevention of such charge build-ups, with benefit to current and future communications spacecraft.

In another area, the difficulties of correlation of thermal analysis and test data from thermal vacuum test have prompted the development of a set of computer programs which could eventually enable these correlations to be carried on in real time, with a potential saving in programme costs and schedule time.

In anticipation of higher powered payloads for later generation satellites, a development programme for heat pipes has also been set up. Several contractors have made valuable contributions in the area of bendable heat pipes for radiators, and two heat pipes were successfully tested at zero-gravity on the

International Heat Pipe Experiment sounding-rocket flight in 1974. Additionally, a number of heat pipes presently on life test are maintaining very satisfactory performance. Work is also proceeding on gas-controlled heat pipes, which offer the additional advantage, besides normal high heat transfer, of closer temperature control.

COMPONENTS, MATERIALS AND PROCESSES

The evolution of the applications satellite has required, and in some cases given cause for, quite spectacular advances in the fields of electronic and mechanical components, material and process technology, and reliability assessment.

The increased miniaturisation and package density of electronic equipments is requiring a rapid translation of discrete component designs to integrated-circuit technology with maximum utilisation of custom-built 'chip'-level thick/thin-film integrated modules. Logic, amplification and signal-conditioning circuitry, optimised for response time, power consumption, reliability and mass, are now being designed and manufactured and considerable effort is being devoted to achieving qualification for a seven to ten-year geostationary orbit life. ESTEC-initiated supporting technology programmes have addressed, and still are addressing, such aspects as: radiation effects, microwave component characterisation changes under certain operating conditions, long-term high parametric stability, and catastrophic 'degradation' failure mechanisms. Technologies currently under qualification for the second-generation applications satellites (ECS) include CMOS, Schottky, gallium-arsenide-based transistor diodes, thick- and thin-film technologies. Component behaviour, in general, is being analysed, in minute detail, and tested over long periods of time. Acceleration testing techniques have been developed, e.g. for slip-ring assemblies and radiation testing, but much work is needed in this area. Nonaccelerated life testing, however, is still necessary and due to the early ESTEC commencement of such activities, e.g. TWT amplifier (cathode) and momentum-wheel tests, orbit-correlatable data – and hence orbit-useable hardware – is now available. Interface effects in the communications payload equipments must be predicted and complex component-level modelling testing techniques have been, and are being, developed, e.g. microwave transistor/diode reliability models.

An applications satellite is essentially a carefully designed and fabricated set of components, materials and processes. The stringent performance, lifetime and 'cleanliness' requirements – in a radiation-exposed, hard-vacuum, thermally changing environment – require careful selection and development qualification of materials, coatings, and material joining processes. Significant developments undertaken for OTS, with direct applications on later satellites, include high-stability/reliability microwave, and high-density single and multilayer printed-circuit boards.

EARTH SEGMENT

The earth segment required to establish a satellite communications system consists of two main elements, the user communications station network and the system employed to monitor and control satellite operation. Of concern here is the latter system, which consists mainly of a network of earth stations and an Operations Control Centre (OCC). During the launch process, a global network of stations is necessary to receive telemetry from, send commands to, and track the satellite as it is manoeuvred in transfer orbit, injected into near-synchronous orbit, and placed in its final orbit location. During this phase also the OCC has a high level of round-the-clock activities to compute and control the execution of the required manoeuvres. In contrast, the on-station routine monitoring and control of a geostationary communications satellite can be accomplished with a single station and require a relatively low level of OCC activity.

To perform the functions outlined above, Europe has developed a sophisticated system of stations, communications links, and control-centre software, computer hardware and man/machine interactive devices, utilising equipment which is almost exclusively of European manufacture. Traditional reliance on NASA for stations and control facilities is diminishing, and during 1974/75 the Symphonie satellites were successfully placed in orbit under CNES/DFVLR control, with NASA support being required only for supplementing the CNES/DFVLR station network. By 1978, and probably in time for the launching of Marots, it is intended that a suitable global network of European stations will have been completed as a final step in achieving independence. Routine on-station control of the European communications satellites is to be performed from project-dedicated control stations (for OTS, for example, from the Satellite Control and Test Station at Fucino, described elsewhere in this Bulletin) linked to an OCC, with a future trend being towards simplification of the monitoring task such that it could be performed by a small real-time computer located at the project station with only occasional recourse to the more powerful (and expensive) main OCC facilities.

□

Mesures et expériences de propagation dans le cadre du programme ECS

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Lorsque les dix pays membres du CERS décidèrent en 1970 de mettre sur pied un programme de satellites de télécommunications, l'objectif qu'il convenait de donner à ce programme fut naturellement la mise en place d'un système régional en Europe, qui serait utilisé conjointement par les Administrations des Postes et Télécommunications nationales. La condition que ces administrations mirent immédiatement à ce projet fut que le système en question ne pourrait en aucune façon fonctionner, comme le réseau INTELSAT, dans les bandes de 4 et 6 GHz allouées à titre non exclusif au service de radiocommunications par satellite entre points fixes. Un service régional, en effet, ne pouvait se concevoir que si les stations terriennes se trouvaient à proximité des centres de transit téléphonique, c'est-à-dire en général près des capitales. Or la densité des liaisons terrestres par câble hertzien opérant dans ces bandes était telle qu'elle avait forcé les administrations à installer leurs stations INTELSAT dans des régions éloignées des centres urbains afin d'éviter les interférences mutuelles. Il n'y avait donc pas d'autre issue que de chercher refuge dans des bandes moins encombrées à des fréquences plus élevées.

CHOIX DES BANDES DANS L'ECHELLE DES GIGAHERTZ

Le choix existait entre la bande de 10 à 15 GHz déjà partiellement utilisée ou en voie de l'être, et d'autres à 20 et 30 GHz où le champ était totalement libre. Aussi attrayante que fut l'idée de gravir l'échelle des gigahertz pour échapper aux sujétions du partage des fréquences, il convenait de ne pas perdre de vue les problèmes techniques que cela ne manquerait pas de soulever. De plus, il était bien connu que l'atmosphère devient de moins en moins transparente quand la longueur d'onde diminue et qu'il y aurait à compter avec des affaiblissements non négligeables des signaux dus à l'absorption causée par les chutes de pluie et de neige.

Il fut donc décidé de choisir deux bandes de 500 MHz, l'une pour les liaisons Terre-satellite aux environs de de 14 GHz et l'autre pour les liaisons en sens inverse aux environs de 11 GHz.

La première tâche était de rassembler d'urgence des données statistiques sur l'importance des affaiblissements causés par les précipitations atmosphériques et sur la fréquence à laquelle ils se produisent. De la connaissance que l'on avait des taux de pluviosité rencontrés en Europe, on pouvait déduire à l'aide de modèles mathématiques que l'ordre de grandeur des affaiblissements atteindrait une dizaine de dB, mais on était dans l'impossibilité de décider si la marge à introduire dans les calculs des liaisons par satellite pour obtenir un pourcentage de disponibilité de 99,9%, par exemple, devait être de 5 ou de 10 dB. On conçoit qu'avec une telle marge d'incertitude correspondant à un rapport de puissance de 1 à 3, le risque était grand de mettre en oeuvre un système qui aurait été soit sous-dimensionné soit au contraire trop largement calculé.

Un autre problème en rapport avec la propagation dans l'atmosphère se posa dès qu'il apparut nécessaire de recourir à des techniques de réutilisation du spectre des fréquences pour donner au satellite la capacité de transmission requise. Parmi les différentes techniques applicables en principe à un satellite, celle qui paraissait la plus prometteuse pour le système ECS était la transmission sur deux polarisations parfaitement orthogonales, soit rectilignes et perpendiculaires, soit circulaires et de sens opposés. Cette technique permettait de transmettre deux signaux différents dans le même canal de fréquence, ce qui ferait passer la bande utilisable pour ECS de 500 à 1000 MHz. La faisabilité de cette technique était bien entendu étroitement liée à la possibilité de maintenir entre les deux polarisations une isolation telle que les interférences mutuelles restent négligeables.

Une telle isolation devait être maintenue d'un bout à l'autre de la chaîne de transmission qui va d'un émetteur d'une station terrienne au récepteur d'une autre en passant par un certain nombre d'éléments tels que transitions orthomodes, polariseurs, antennes et milieu de propagation. Parmi tous les éléments constituant cette chaîne, l'atmosphère, en tant que milieu de propagation susceptible d'altérer la polarisation des ondes, était le moins bien connu et le seul dont on ne pouvait modeler les caractéristiques. Il fut donc décidé de se mettre sans tarder à l'étude du comportement de signaux à polarisations orthogonales se propageant dans l'atmosphère.

MESURES D'AFFAIBLISSEMENT A 11 ET 14 GHz

En l'absence d'un satellite émettant des signaux aux fréquences de 11 et 14 GHz, force fut de recourir à une méthode indirecte pour mesurer l'absorption atmosphérique. Cette méthode dite du *radiomètre passif*, consiste à mesurer le bruit radioélectrique du ciel dans la direction d'un satellite hypothétique et à en déduire l'affaiblissement qu'un signal subirait s'il se propageait dans la même direction. Elle repose sur le principe suivant.

L'atmosphère se comportant comme un corps noir à la tempéra-

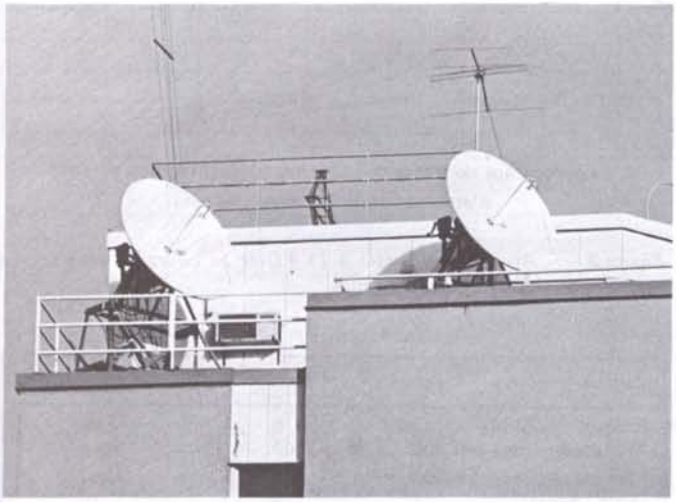


Figure 1 — Antennes de radiomètres à 11 et 14 GHz, installées sur le toit du siège de l'Administration suédoise des Télécommunications à Farsta, Stockholm.

ture T_a dont le facteur de transmission est t, la température de bruit rayonnée est égale à $(1-t)T_a$. En l'absence d'atmosphère, la température de bruit du ciel perçu par une antenne pointée vers le cosmos serait T_c. Affaiblie par l'absorption atmosphérique, cette température est en réalité $t.T_c$. La température perçue par l'antenne est donc $T = t.T_c + (1-t)T_a$. Les valeurs de T_c et T_a étant connues (5 et 270 K respectivement), on voit que l'affaiblissement atmosphérique peut être aisément déduit de la valeur de T mesurée par un radiomètre. En fait, le principe même de la méthode est tel que la température de bruit mesurée tend asymptotiquement vers la température physique de l'atmosphère, c'est-à-dire vers 270 K lorsque l'absorption augmente, et la mesure devient très imprécise lorsque l'affaiblissement dépasse 10 dB, ce qui dans le cas considéré était parfaitement acceptable.

Neuf radiomètres, dont huit fonctionnent à 11,4 GHz et le neuvième à 14 GHz, furent installés en plusieurs endroits d'Europe représentatifs de différents climats, à savoir Stockholm, Darmstadt, Berne, Milan, Fucino, Porto, Madrid et Graz. Tous ces radiomètres dont le premier fut placé à Milan en 1972 sont encore en activité aujourd'hui. Leurs antennes sont dirigées dans la direction supposée du futur satellite ECS, de sorte que les angles d'élévation du pointage varient entre 20 et 45°. Le radiomètre à 14 GHz est installé à Stockholm où il fonctionne en parallèle avec un autre à 11 GHz, ce qui permet de comparer directement les atténuations aux deux fréquences. Ces deux équipements, confiés aux soins de l'Administration suédoise des Télécommunications, sont installés sur le toit du siège de cette administration (Fig. 1).

Les données des mesures sont enregistrées automatiquement sur bande de papier perforé et envoyées à l'ESTEC où elles sont dépouillées et analysées sur ordinateur pour obtenir des courbes de répartition statistique mois par mois. De l'examen des résultats, on a pu tirer plusieurs conclusions importantes:

(i) On constate en chaque endroit la même concentration des périodes d'affaiblissement élevé au cours des mois d'été, le reste de l'année étant nettement plus calme. Chaque année comporte son plus mauvais mois pour lequel la courbe de répartition est très différente de la courbe des douze mois réunis. Il n'est donc pas indifférent que les spécifications de performance du système, établies en termes de pourcentage de disponibilité, s'appliquent à un mois ou à une année.

(ii) Les courbes de répartition du plus mauvais mois varient considérablement d'une année à l'autre. On ne peut obtenir de données statistiques valables à long terme qu'en poursuivant les mesures pendant plusieurs années. Les statistiques de pluviosité qui sont récoltées par ailleurs depuis de nombreuses années dans la plupart des pays d'Europe confirment qu'on ne peut établir une image statistique valable en moins de dix ans.

(iii) Etant donné la dispersion des résultats obtenus d'un endroit à l'autre, d'un mois à l'autre et d'une année à l'autre, il est impossible de mettre en évidence une relation quelconque entre les statistiques d'affaiblissement recueillies et l'angle d'élévation de la direction dans laquelle les mesures sont faites, du moins dans la gamme réduite de 20 à 45° couverte par le réseau des radiomètres. Les mêmes marges d'affaiblissement peuvent donc être appliquées en tous endroits, au moins provisoirement.

(iv) Il n'existe aucune corrélation instantanée entre l'affaiblissement et le taux de pluie mesuré à côté du radiomètre. Toutefois une assez bonne corrélation existe à long terme, ce qui laisse entrevoir la possibilité de déterminer de façon assez précise des statistiques d'affaiblissement à partir de statistiques de pluviosité déjà disponibles dans de nombreux pays.

L'ensemble des résultats recueillis jusqu'à maintenant à 11 GHz est présenté à la Figure 2 sous forme d'atténuation dépassée pendant un certain pourcentage de temps. Chaque point se rapporte au mois le plus défavorable d'une année pour un des huit endroits énumérés plus hauts. On voit qu'aux faibles pourcentages de temps la dispersion est considérable.

Pour la conception d'un système à satellite, il serait toutefois excessif d'utiliser les valeurs les plus élevées qui correspondent au pire mois de la pire année; on a donc décidé d'utiliser pour le système ECS les valeurs médianes qui vont de 0,4 dB par temps clair à 7 dB au niveau de 0,03% (99,97% de disponibilité).

Quant à l'affaiblissement à 14 GHz, on constate que ses courbes de répartition sont fort semblables à celles obtenues à 11,4 GHz, le rapport entre les valeurs en dB étant de l'ordre de 1,3.

LE SATELLITE ATS-6

Le satellite ATS-6 de la NASA comporte entre autres expériences des balises à 20 et 30 GHz ainsi qu'un répéteur construit par la COMSAT capable de recevoir des signaux à 13 et à 18 GHz et de les renvoyer après transposition à 4 GHz. Ces équipements ont été conçus pour permettre d'étudier la propagation et ont été utilisés jusqu'en mai 1975 pour une campagne de mesures aux Etats-Unis. Le satellite, qui a été déplacé au cours de l'été 1975 et est maintenant au-dessus du Kenya, a ses antennes pointées alternativement sur l'Inde et sur l'Europe. Il est mis à la disposition des expérimentateurs indiens et européens qui font des mesures de propagation. L'ASE se charge de la coordination de leurs activités et des contacts avec la NASA et la COMSAT avec laquelle elle a passé un contrat pour le dépouillement des données.

MESURES DE DEPOLARISATION

Pour l'étude du comportement des signaux de polarisations orthogonales se propageant dans l'atmosphère, il fallait nécessairement disposer de liaisons point-à-point répondant aux exigences suivantes:

- extrémités équipées d'antennes à double polarisation présentant un degré d'isolation très élevé entre les deux modes;
- trajet suffisamment dégagé pour être exempt de réflexions parasites sur le sol susceptibles d'affecter la polarisation des signaux transmis.

Trois bases de mesures furent mises sur pied, la première à Bradford (Royaume-Uni), la deuxième près de Fucino (Italie) et la troisième au Jungfraujoch (Suisse). Ces trois expériences ont des caractéristiques différentes (voir Tableau).

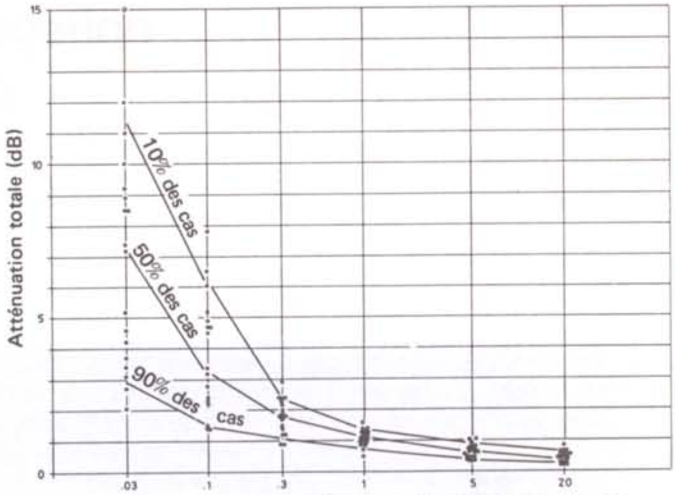


Figure 2 — Atténuation totale à 11,4 GHz au cours du mois le plus défavorable de l'année.

Caractéristiques	*Bradford*	*Fucino*	*Jungfraujoch*
Longueur (km)	13,6	8	10
Altitude émetteur (m)	400	2000	3690
Altitude récepteur (m)	200	800	1090
Pente (degrés)	1	9	14
Fréquence (GHz)	11	11,6	13
Polarisation	Horizontale et verticale	Rectiligne puis circulaire	Circulaire
Antennes	Réflect. parab. à source frontale	Casshorn	Réflect. parab. à source frontale
Isolation par temps clair (dB)	40	35	35

A l'inverse des radiomètres dont le traitement des données est centralisé, les trois expériences sont confiées aux soins de l'Université de Bradford, de la société Telespazio et de l'Entreprise des PTT suisses respectivement, qui se chargent également du traitement des données et de l'analyse des résultats. De l'ensemble des renseignements recueillis jusqu'à présent sur ces trois expériences, on a pu établir un certain nombre de conclusions importantes pour la conception du système ECS:

(i) Les polarisations rectilignes orthogonales, horizontale et verticale, sont relativement peu affectées par les précipitations. L'isolation ne tombe guère en-dessous de 25 dB à moins d'événement exceptionnel tel que tempête ou forte chute de neige fondante où elle peut descendre jusqu'à 20 dB.

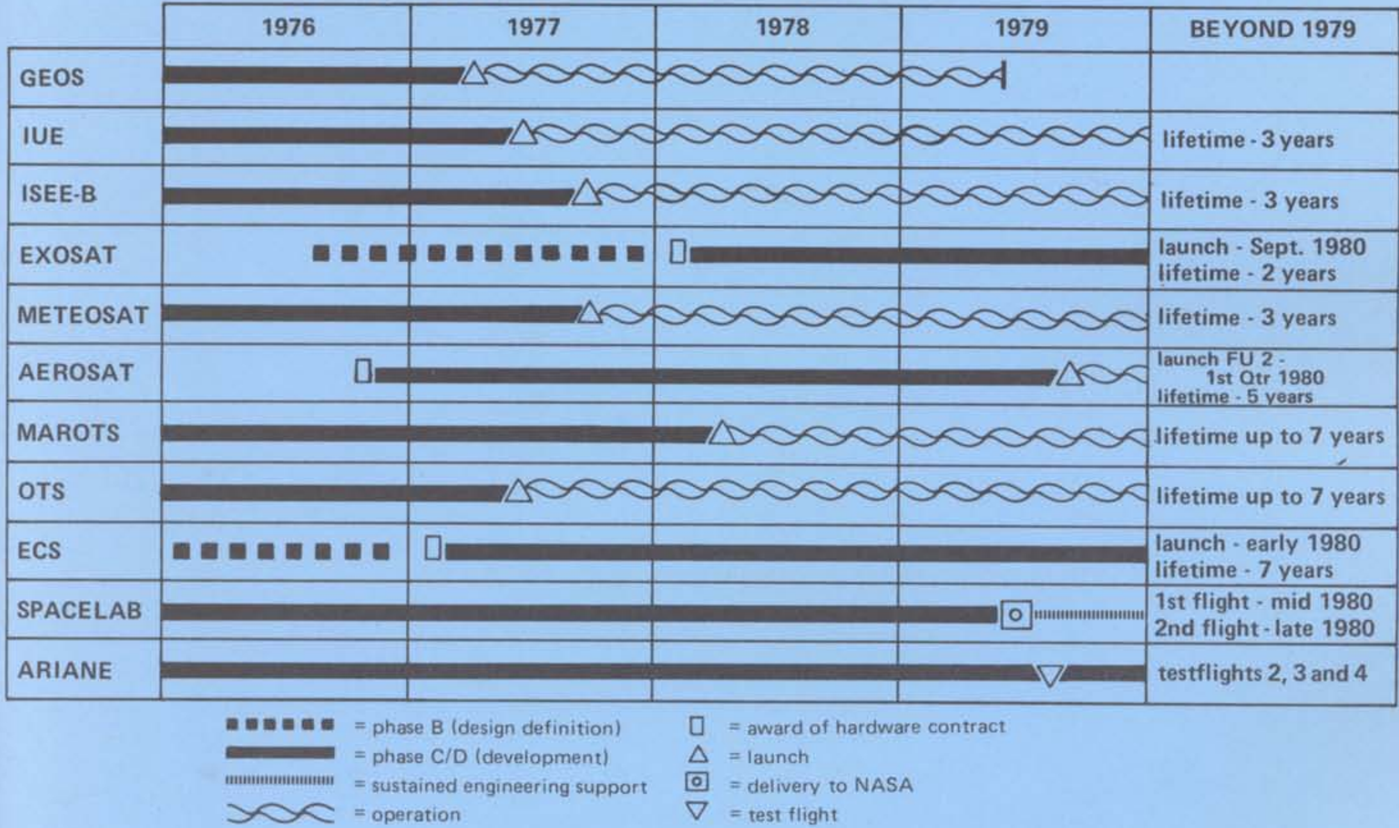
(ii) La polarisation circulaire est, comme la théorie le prédit, plus vulnérable aux effets des précipitations. Les chutes de l'isolation à 20 dB sont moins rares et, exceptionnellement, peuvent atteindre 15 dB. Il s'agit dans ce dernier cas d'événements ne se produisant guère qu'une fois par an et ne durant que quelques minutes.

(iii) Dans un cas comme dans l'autre, on n'observe pratiquement pas de corrélation entre l'atténuation et la diminution d'isolation, excepté lorsqu'on a affaire à une forte chute de

(suite page 43)

Projects under Development
Projets en cours de réalisation

THE ESA DEVELOPMENT AND OPERATION PROGRAMME (as at April 1976)



GEOS

To maximise the chances of maintaining a launch in April 1977, the spacecraft development programme has been revised, so as to concentrate all available resources on the integration, testing and preparation for launch of the flight model. Activities on the qualification model will continue on a nonpriority parallel line, this spacecraft being utilised for auxiliary system tests including the final compatibility tests with the ground segment.

Flight model
Integration of the flight model has made good progress. As part of the revised programme, it was decided that critical spacecraft units which would arrive too late for the integration deadline would be replaced by prototype units. This implied that the corresponding units on the qualification model would be drawn from the earlier development model, but this will detract only slightly from the value of the tests.

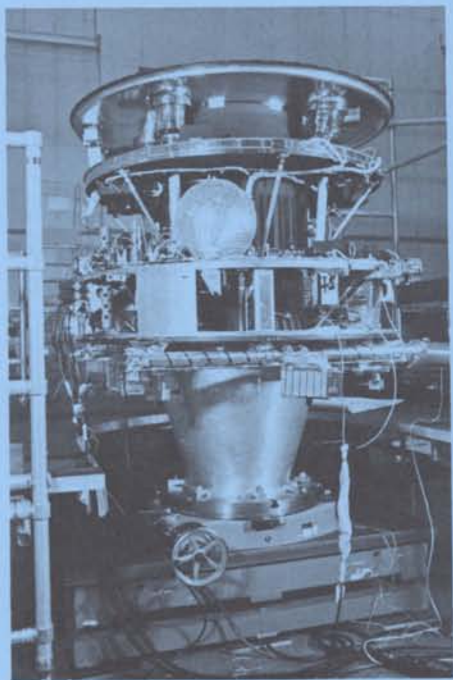
Qualification model
Formal functional tests on the integrated qualification model have been completed and will be followed by electromagnetic-cleanliness tests with all experiments operating. The spacecraft will then proceed to DC magnetic tests at IABG Ottobrunn.

Scientific payload
All flight experiments have undergone or are completing acceptance tests and will be delivered for integration during April.

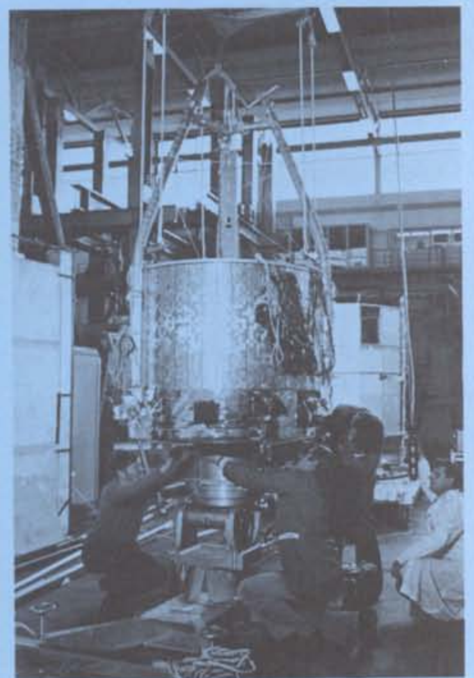
Propulsion system
The batch of four acceptance apogee motors has been assembled, loaded with

propellant, and X-ray inspected at the cold temperature condition. Selection of two motors for flight usage will be made in April. [In the previous Bulletin a typographical error ascribed this motor to SNIAS-SEP; its development is a collaborative effort by SNIA (Italy) and SEP (France)].

Ground segment
The MSSS computer system has successfully completed its acceptance tests. Software for control of flight dynamics is well advanced. The Odenwald ground station is expected to be in operation for early testing in June.



GEOS flight model during integration at BAC, Bristol. ▶



ISEE spacecraft prior to mating, at IABG, Munich. ▶▶

IUE

Solar array
The first series of flight array tests (vibration, acoustic noise, deployment) have been completed successfully at SNIAS. In the first week of March, the flight array arrived at ESTEC where the second series of acceptance tests is continuing with electrical measurements, rapid depressurisation (all completed successfully), and thermal cycling of both paddles.

Ground system
Civil-engineering work at the Villafranca station was completed and the station passed its acceptance test during March. Completion and acceptance of the electrical and air-conditioning installations is expected in April. Installation of the hardware will begin soon after, with the arrival of the computer system.

The S-band antenna has been formally accepted and an arrangement with NASA is in preparation for the loan of the VHF command antenna.

Ground-station and observatory-system design work is in progress and it is planned to review the design concept in the course of May.

Agreement has been reached with the Spanish Authorities on the provision of a microwave link between the station and Madrid in support of telephone, telex, and data-traffic requirements. This facility must be operational by the end of 1976 to allow ground-station testing and commissioning prior to the IUE launch.

ISEE

The structural model of the spacecraft has completed mechanical qualification. The mass models of the various electrical subsystems have been removed and the structure is being refurbished and thermally painted in readiness for its second role as the basis for the integration-model spacecraft.

By using an improved manufacturing process for the hinge booms, it is hoped to eliminate the stiffening webs without a recurrence of the buckling previously observed.

The delays in the delivery of the power and telecommunications subsystems for the integration-model spacecraft have been somewhat reduced by technical and managerial actions. The remaining delays have been compensated for by a replanning of the integration schedule by ESA and the prime contractor. A number of small manufacturing problems have occurred on most subsystems, but actions on the part of design and product-assurance staff have so far prevented these from having any major schedule or cost impacts.

GEOS

Pour s'assurer le maximum de chances de réaliser le lancement en avril 1977, le programme de développement du véhicule spatial a été révisé de façon à concentrer toutes les ressources disponibles sur l'intégration, les essais et la préparation au lancement du modèle de vol. Les activités relatives au modèle de qualification se poursuivront parallèlement mais sans priorité, ce modèle étant utilisé pour les essais de systèmes auxiliaires et notamment les essais définitifs de compatibilité avec le segment sol.

Modèle de vol
L'intégration du modèle de vol avance de façon satisfaisante. Dans le cadre du programme révisé, il a été décidé que les éléments critiques du véhicule spatial qui arriveraient trop tard pour pouvoir respecter la date limite d'intégration seront remplacés par les éléments prototypes. Il s'ensuit que, pour le modèle de qualification, il faudra prélever les éléments correspondants sur le modèle de développement antérieur, mais ce fait jouera peu sur la valeur des essais.

Modèle de qualification
Les essais fonctionnels officiels sur le modèle de qualification intégré sont achevés. Ils vont être suivis des essais de propreté électromagnétique avec toutes les expériences en fonctionnement. Le véhicule spatial subira ensuite chez IABG, à Ottobrunn, les essais magnétiques statiques.

Charge utile scientifique
Tous les modèles de vol des expériences ont déjà subi ou terminent actuellement les essais de recette; ils seront livrés, pour intégration, dans le courant d'avril.

Système de propulsion
Les quatre moteurs d'apogée constituant le lot de recette ont été assemblés, remplis de propergol et contrôlés aux rayons X au niveau de froid spécifié. La sélection des deux moteurs destinés au vol se fera en avril. (Par suite d'une erreur typographique, le précédent Bulletin attribuait le moteur d'apogée à SNIAS-SEP alors que ce moteur a été développé en collaboration par SNIA (Italie) et SEP (France).

Segment sol
Le système de calculateur MSSS a passé avec succès les essais de recette. Le logiciel de contrôle de la dynamique de vol est bien avancé. La station sol dans l'Odenwald devrait être prête à fonctionner pour les premiers essais en juin.

IUE

Réseau solaire
La première série d'essais du réseau solaire (vibrations, bruit acoustique, déploiement) s'est achevée avec succès à la SNIAS. Dans le courant de la première semaine de mars, le réseau de vol est arrivé à l'ESTEC où la deuxième série des essais de recettes se poursuit avec des mesures électriques, des essais de pressurisation rapide (tous réussis) et le cyclage thermique des deux panneaux.

Système sol
Les travaux de génie civil à la station de Villafranca sont terminés et la station a subi avec succès son essai de recette dans le courant de mars. On prévoit pour avril l'achèvement et la recette des installations électriques et de climatisation. La mise en place des matériels commencera peu après, avec l'arrivée du système de calcul.

L'antenne en bande S a été officiellement réceptionnée et un arrangement avec la NASA est en cours d'élaboration pour le prêt de l'antenne de télécommande VHF. La conception de la station au sol et du système d'observation est en cours et il est prévu qu'elle sera réexaminée dans le courant de mai.

Un accord a été conclu avec les autorités espagnoles pour la fourniture d'un liaison hyperfréquence reliant la station à Madrid, en soutien des besoins en téléphone, télex et lignes de données. Cette liaison devra être opérationnelle pour la fin 1976, de telle sorte que la station sol puisse être testée et mise en service avant le lancement d'IUE.

ISEE

La qualification mécanique du modèle structurel du véhicule spatial est achevée. Les modèles de masse des différents sous-systèmes électriques ont été enlevés, et l'on procède au reconditionnement et à la peinture thermique de la structure pour préparer celle-ci à jouer son deuxième rôle comme base du modèle d'intégration du véhicule spatial.

Grâce à une amélioration des procédés de fabrication des bras articulés, on espère pouvoir supprimer les raidisseurs sans que se reproduise le flambage observé auparavant.

Des mesures prises sur le plan technique et sur celui de la gestion ont quelque peu réduit les retards de livraison des sous-systèmes de puissance et de télécommunications destinés au modèle d'intégration du véhicule spatial. Pour compenser les retards qui restent, l'ASE et le contractant principal ont remanié le calendrier d'intégration. Des problèmes de fabrication mineurs se sont posés pour la plupart des sous-systèmes, mais les mesures prises par le personnel responsable de la conception et de l'assurance de qualité du produit ont jusqu'à présent permis d'éviter que ces retards aient de graves répercussions sur le calendrier ou sur les coûts.

Parallèlement aux tâches techniques, les négociations contractuelles se sont poursuivies et des prix forfaitaires sont désormais fixés pour tous les sous-systèmes.

In parallel with the technical work, contract negotiations have been proceeding and fixed prices have now been agreed for all subsystems.

NASA will start integration of the ISEE-A spacecraft in the near future. The task of liaison between the ESA ISEE-B and NASA ISEE-A project teams is becoming more important as spacecraft development advances, although no insuperable problems have yet been encountered. A mission operations working group has been set up to facilitate the establishment of the ISEE operations centre at Goddard Space Flight Center and in particular to co-ordinate the software tasks.

The European and American manufactured experiments are all on schedule for the integration-model spacecraft and most have already completed unit-level testing. The extent of the problem caused by the low radiation resistance of CMOS components and in particular the possible effect on the delivery of the experiment flight units is still under investigation.

In general, the project is proceeding as planned and the problems encountered so far do not affect the scheduled launch date of October 1977.

EXOSAT

Following the formation of a project team, which replaces the working groups set up in late 1975, all documentation required for the Invitation to Tender (ITT) was completed for sending out to industry on 2 April.

Current planning, which has been delayed so as not to clash with the tender action for Aerosat, anticipates a tender-preparation period of four months. The first in-house evaluation will therefore start on 2 August.

In the meantime, ESOC are studying mission constraints imposed by the Earth, Moon and Sun on the one hand, and the availability of suitable stars for satellite attitude-reference purposes on the other. The results of the study will be used in establishing a suitable star-sensor configuration.

Scientific experiment
Definition of the Exosat payload has progressed satisfactorily, both in industry and at the institutes of the experimenters. The scientific-model development phase is well in hand and the first experimental results are expected at mid-year.

At present work is going on to develop the X-ray optics (both in the direct and replica techniques), the position-sensitive detector, and its associated electronics. A contract for the development of the medium-energy experiment has recently been placed. In-house activities are continuing at the experimenters' home institutes and at ESTEC on the channel multiplier array detector, the gas-supply system for the position-sensitive detector and the transmission gratings and filters for the low-energy systems.

At the end of March, a meeting was held between the experimenters and the Exosat Observation Programme Panel representing the user community — at which the baseline mission was discussed and the present payload configuration presented.

METEOSAT

Space segment
All P1 subsystems have now been delivered, as well as all test equipment. P1 satellite integration was completed in March and testing at satellite system level was to start in the first week of April. To improve efficiency, the Development Results Review has been rescheduled to the second half of 1976, in order to take into account subsystem qualification results as well as P1 satellite results.

On 29 January, the Meteorological Programme Board decided to fly a three-channel radiometer on Meteosat. Inclusion of this promising experiment makes Meteosat unique among first-generation geostationary meteorological satellites.

Ground segment
The Data Acquisition Telecommand and Tracking Station (DATTS) antenna was accepted in November, and the last set of receivers is now undergoing acceptance testing.

The plan of activity for station integration has been modified, and completion is now expected in August, with space/ground compatibility tests scheduled to start in October.

The Data Collection Platform (DCP) study report has been issued in January and it is expected that the platform itself will be available by November.

The tenders for the Primary and Secondary Users' Stations (PDUS/SDUS) are under evaluation and it is planned to place the contract with industry by June.

The ICL 2980 service has started and some programmes are already running. However, due to the prototype nature of this computer, it will be some time before a full service is available. Most of the peripherals for the 2980 machine have been delivered to ESOC and the software has now entered its 'development phase'. Coding of basic programmes has started.

SESA has issued the full set of technical and implementation specifications and the system review phase has been completed.

A special effort is now being made to

La NASA va commencer très prochainement l'intégration du véhicule spatial ISEE-A. Assurer la liaison entre les équipes projet ASE/ISEE-B et NASA/ISEE-A devient de plus en plus important à mesure que progresse le développement des véhicules spatiaux, mais aucun problème insurmontable ne s'est posé jusqu'à présent. Un Groupe de travail chargé des opérations de mission a été créé pour faciliter la mise sur pied du Centre des opérations ISEE au GSFC et en particulier pour coordonner les travaux de logiciel.

Toutes les expériences fabriquées en Europe et aux Etats-Unis sont prêtes pour le modèle d'intégration du véhicule spatial et la plupart d'entre elles ont déjà subi les essais au niveau des unités. On continue à étudier le problème posé par la faible résistance aux rayonnements des composants CMOS et en particulier par son incidence éventuelle sur la livraison des unités de vol des expériences.

Le projet continue dans l'ensemble à se dérouler comme prévu et les problèmes qui se sont posés jusqu'ici ne modifient pas la date de lancement fixée pour octobre 1977.

EXOSAT

Après la constitution d'une équipe de projet, qui a remplacé les groupes de travail créés fin 1975, toute la documentation requise pour l'appel d'offres a été définitivement mise au point pour être envoyée à l'industrie le 2 avril.

Le planning actuel, qui a été retardé de façon à ne pas gêner l'appel d'offres pour Aérosat, prévoit une période de quatre mois pour la préparation des soumissions. La première évaluation interne commencera donc le 2 août.

Entre-temps, l'ESOC étudie d'une part les contraintes de missions imposées par la Terre, la Lune et le Soleil et d'autre part la possibilité de trouver une étoile pouvant servir de point de référence pour l'attitude du satellite. Les résultats de l'étude doivent permettre de définir une configuration de senseur stellaire appropriée.

Expériences scientifiques

La définition de la charge utile d'Exosat a progressé de façon satisfaisante tant dans l'industrie que dans les instituts des expérimentateurs. La phase de développement du modèle scientifique est bien avancée et les premiers résultats expérimentaux sont attendus vers le milieu de l'année.

Les travaux se poursuivent actuellement sur le développement du système d'optique à rayons X — en technique directe et en technique 'réplication' — du détecteur de position et de son électronique. Un contrat a été récemment passé pour le développement de l'expérience à moyenne énergie. Les activités internes dans les instituts des expérimentateurs et à l'ESTEC se poursuivent sur le détecteur du réseau de multiplicateurs d'électrons à microcanaux, le système d'alimentation en gaz du détecteur de position et les réseaux et filtres de transmission pour les systèmes à faible énergie.

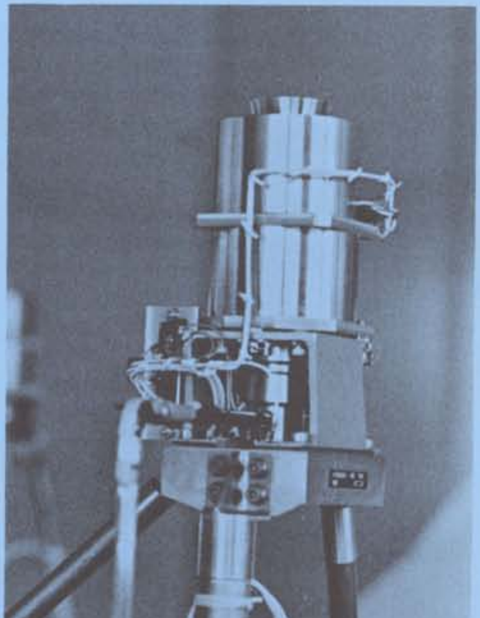
A la fin de mars a eu lieu une réunion entre les expériementateurs et le Groupe chargé du programme d'observation Exosat — représentant la communauté des utilisateurs — réunion au cours de laquelle la mission de référence a été discutée et la configuration actuelle de la charge utile a fait l'objet d'une présentation.

METEOSAT

Secteur spatial

Tous les sous-systèmes du modèle P1 ont maintenant été livrés ainsi que tous les équipements d'essai. En mars, l'intégration du satellite P1 était terminée et les essais au niveau satellite prêts à démarrer au cours de la première semaine d'avril. Dans un souci d'efficacité, l'examen des résultats du développement a été reportée au deuxième semestre de 1976 de telle sorte qu'il soit possible de prendre en considération les résultats à la fois de la qualification des sous-systèmes et des travaux sur le satellite P1.

Le 29 janvier, le Conseil directeur du programme météorologique a décidé l'embarquement sur le premier vol de Météosat d'un radiomètre à trois canaux. Il s'agit d'une expérience prometteuse et sans précédent sur les satellites météorologiques stationnaires de la première génération.

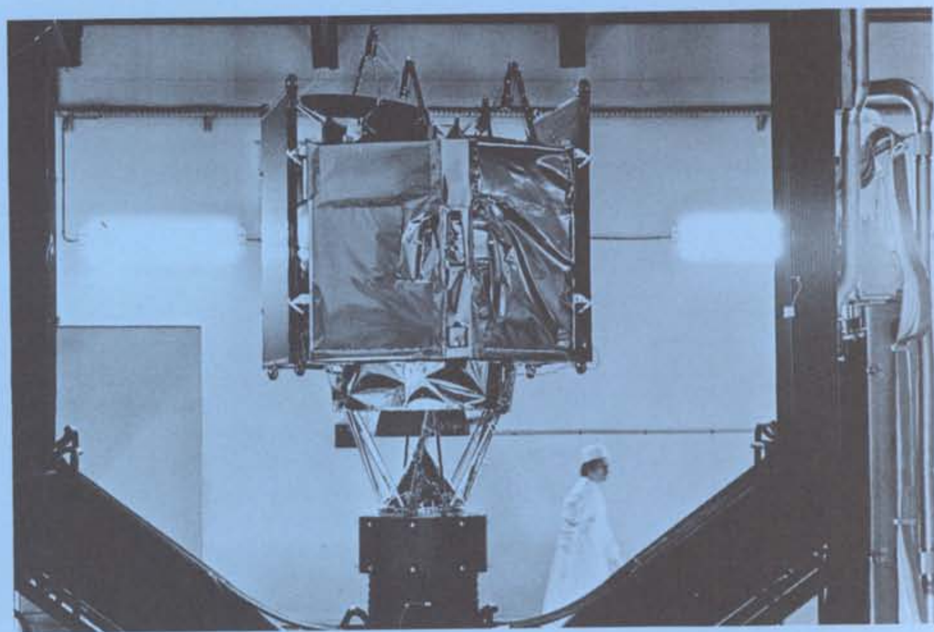


Tuyère verticale de Météosat.
Meteosat vertical thruster.

synchronise the results of minor spacecraft modifications with the related software.

Operations
The Sixth Co-ordination Meeting on Geostationary Meteorological Satellites (CGMS-VI) convened in Washington in early April to refine the operational patterns for data collection, dissemination and special meteorological projects.

In the same period a Meteosat team will visit NOAA/NESS to study operational experience with the SMS and GOES satellites.



OTS thermal model in Toulouse.
Modèle thermique d'OTS à Toulouse.

AEROSAT

Space segment
The RFP (Request for Proposals) for the supply of the two Aerosat spacecraft was issued on 1 March 1976, with the following schedule:

- submission of proposals by 15 June
- target contract award date 15 November.

European co-ordinated programme
This part of the programme will be run by an ESA team in association with a European Civil Aviation team, the two working in close collaboration and both located at ESA Headquarters in Paris. These two teams are presently being set up.

MAROTS

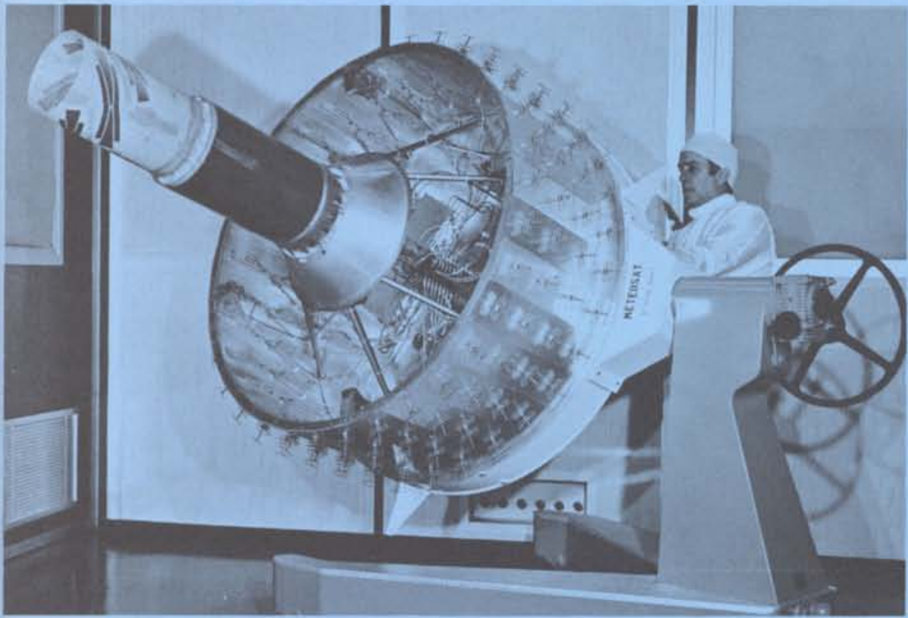
Work on the Marots satellite is somewhat less advanced than that on OTS, due to the later launch date. However, work is continuing and the engineering model is currently being manufactured.

In November 1975, the Agency's Industrial Policy Committee approved the choice of Siemens as contractor for the design and construction of a satellite control facility. This station will be located at Villafranca del Castillo and will be connected to the main Operations Control Centre at ESOC.

During the Second INMARSAT Conference held in February 1976, ESA's Director General, Mr. R. Gibson, offered the space segment capacity of the Marots satellite to INMARSAT as a European contribution to a world-wide maritime system. This offer, which would be valid from soon after launch to the end of the satellite's useful life, was made on behalf of the ESA Member States participating in the programme, after consultation in the Agency's Joint Board on Communication Satellite Programmes. The new organisation will, it is anticipated, constitute a Preparatory Committee and it is in this forum that the Marots offer will be considered.

OTS

The satellite is now more than half way through development and has reached the stage of qualification-model manufacture. In parallel with this, activities in the ground-support area have continued. Major software milestones have been passed and it is anticipated that the Satellite Control and Test Station at Fucino will be available early in January 1977. Work has also progressed on planning the utilisation of OTS, in association with the Permanent Nucleus of CEPT and its specialised subgroups.



Assemblage du sous-système d'antenne de Météosat.
Assembly of Meteosat antenna subsystem.

Secteur terrien
L'antenne de la Station d'acquisition des données de télécommande et de poursuite (DATTS) a été réceptionnée dans le courant de novembre 1975 et le dernier jeu de récepteurs subit actuellement les essais de recette.

Le planning d'intégration de la station a été remanié, la date d'achèvement étant maintenant prévue pour le mois d'août le démarrage des essais de compatibilité secteur spatial/secteur terrien pour octobre 1976.

Le compte rendu de l'étude sur la plate-forme de collecte de données (DCP) a été publié dans le courant de janvier et la DCP sera en principe disponible pour le mois de novembre.

Les soumissions relatives aux Stations primaire et secondaire d'utilisation des données (PDUS/SDUS) sont en cours d'évaluation, le contrat devant être passé avec l'industrie d'ici juin.

Le service ICL 2980 a commencé de fonctionner et des programmes passent déjà en machine. Toutefois, ce calculateur étant au stade prototype, il faudra un certain temps avant que le système soit pleinement satisfaisant. La plupart des périphériques reliés aux calculateurs principaux 2980 ont été livrés à l'ESOC et la phase de développement des logiciels a commencé. Le codage des programmes de base est déjà entamé.

La SESA a publié la totalité des spécifications techniques et des spécifications de mise en oeuvre et la phase de réexamen du système est terminée.

Un effort particulier est fait pour synchroniser les résultats des modifications mineures apportées au véhicule spatial et la réalisation du logiciel correspondant.

Opérations
La Sixième Réunion de coordination sur les satellites météorologiques géostationnaires (CGMS-VI) s'est tenue à Washington début avril pour perfectionner les schémas d'opérations relatifs à la collecte et à la diffusion des données ainsi qu'aux projets météorologiques spéciaux.

Au cours de la même période une équipe Météosat se rendra à la NOAA/NESS pour y étudier l'expérience acquise au cours de l'exploitation des satellites SMS et GOES.

AEROSAT

Secteur spatial
C'est le 1er mars 1976 qu'a été lancé l'appel d'offres pour la fourniture des deux véhicules spatiaux Aérosat, le calendrier étant le suivant:

- *remise des offres le 15 juin*
- *date-objectif d'attribution du contrat le 15 novembre.*

Programme coordonné européen
Cette partie du programme sera dirigée par une équipe ASE et une équipe Aviation civile européenne qui, installées toutes deux au siège de l'ASE à Paris, travailleront en étroite collaboration. Ces deux équipes sont actuellement en cours de constitution.

In November 1975, an Engineering Model Design Review was held, upon successful completion of the satellite engineering-model tests. The acoustic and vibration tests on the structural model are now almost complete.

Integration of the qualification model is currently in progress and hardware fabrication for the flight model is continuing.

SPACELAB

Instrument Pointing Subsystem (IPS)
On 3 March, the Agency's Industrial Policy Committee awarded a contract to Dornier System (Germany) for the development and manufacture of an Instrument Pointing Subsystem (IPS) for Spacelab. The IPS will be designed to provide a pointing accuracy of few arc seconds for Spacelab experiments of various scientific and application disciplines, in particular those for astronomy and earth resources. It is planned to use the IPS, which will be installed on the Spacelab pallet and will be able to carry payloads of up to 2000 kg, for the first time in late 1980 on the second Spacelab flight.

The fixed-price contract for the IPS will cover work of approximately 16.5 million accounting units. The major subcontractor to Dornier System is MBB, and ERNO will be associated with the contract for the IPS/Spacelab interface tasks.

NASA and ESA have agreed to the development of the IPS by ESA under the terms of the Spacelab Memorandum of Understanding.

Interface control
Major progress has been achieved in the detailed definition of the Orbiter/Spacelab interface specifications. Three Interface Control Documents (ICD), signed by NASA, ESA, VFW-Fokker/ERNO and Rockwell International, were established for the mechanical, structural, avionics and environmental control and thermal interfaces. Approximately 80% of the interface specifications have been agreed upon. Changes to the agreed specifications require approval from both NASA and ESA, and the Space Shuttle and Spacelab contractors.

Spacelab hard mock-up in manufacture at Aeritalia
Fabrication de la maquette en dur du Spacelab chez Aeritalia

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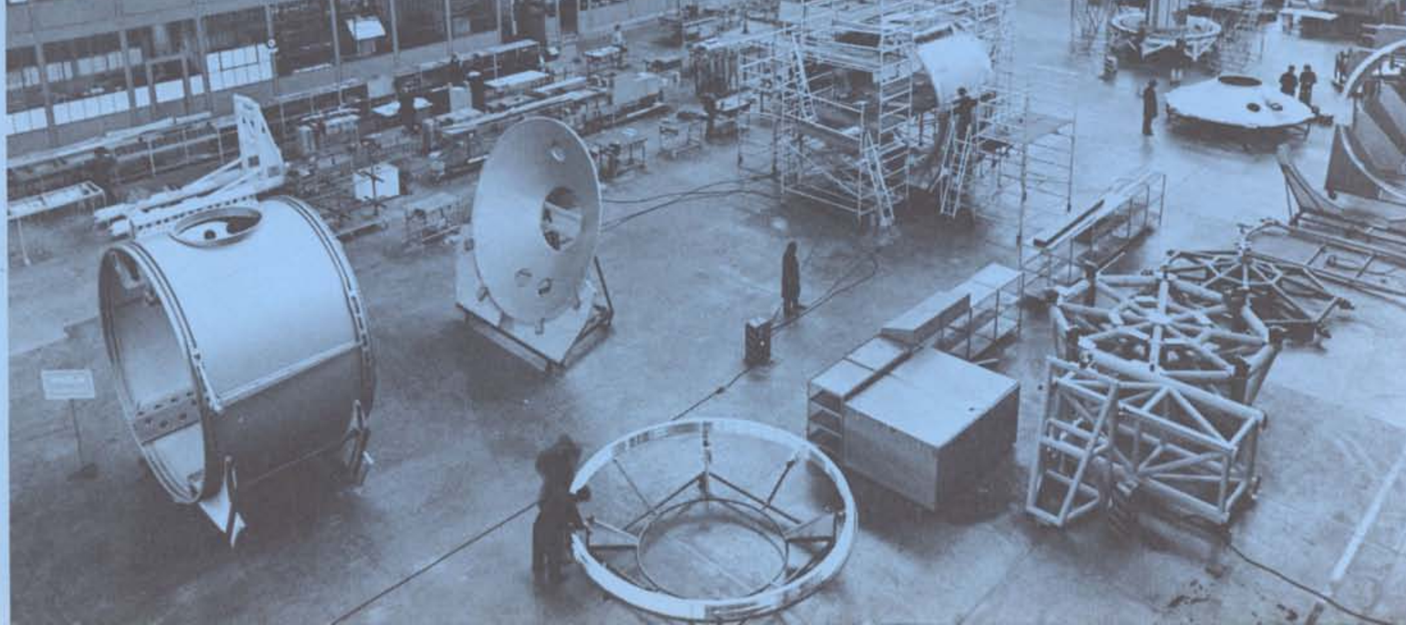
Main antenna under construction at Fucino Satellite Control and Test Station.
Antenne principale en construction à la Station de contrôle et d'essai de satellite à Fucino. ▶



MAROTS

Les travaux sur le satellite Marots sont relativement moins avancés que ceux de l'OTS, car la date de lancement est plus tardive. L'activité ne s'en poursuit pas moins et, à l'heure actuelle, la fabrication du modèle d'identification est en cours.

En novembre 1975, le Comité de la Politique industrielle de l'Agence a approuvé le choix de Siemens comme contractant pour l'étude et la construction de l'installation de contrôle du satellite. Cette station, qui sera installée à Villafranca del Castillo, sera reliée au Centre de contrôle des opérations de l'ESOC, où auront lieu toutes les opérations de contrôle et de télécommande.

Au cours de la deuxième conférence INMARSAT, qui s'est tenue en février 1976, M. Gibson, Directeur général, a offert à INMARSAT, à titre de contribution de l'Europe à un système maritime mondial, la capacité du secteur spatial Marots. Cette offre, dont la validité s'étendrait de quelques mois après la mise sur orbite du satellite à la fin de sa vie utile, a été faite au nom des Etats participant au programme, après délibération au sein du Conseil directeur des Programmes de satellites de communications de l'Agence. Il est à prévoir que la nouvelle Organisation constituera une Commission préparatoire à laquelle il appartiendra dès lors d'examiner l'offre Marots.

OTS

Le programme de développement du satellite est plus qu'à moitié réalisé et le stade de la fabrication du modèle de qualification est atteint. Parallèlement, les activités se sont poursuivies dans le domaine du soutien au sol. les principales étapes du développement du logiciel ont été franchies, et l'on prévoit que la Station d'essai et de contrôle du satellite de Fucino sera prête au début de janvier 1977. Le planning d'utilisation de l'OTS en association avec le Noyau permanent de la CEPT et avec ses sous-groupes spécialisés a également progressé.

En novembre 1975 a eu lieu l'examen de conception du modèle d'identification du satellite, les essais de ce modèle ayant donné toute satisfaction. En ce qui concerne le modèle de structure, les essais acoustiques et vibratoires sont maintenant presque achevés. L'intégration du modèle de qualification est en cours et la fabrication des éléments du modèle de vol se poursuit.

Industrial work
The emphasis of the work has shifted from development definition and documentation to the detailed design and hardware development phase. A hard mock-up and development units are presently being built.

A schedule review initially showed some delay in certain subsystem areas. Study of recovery options has led to an improved concept for the integration and test cycle, especially for use of the Electrical Systems Integration (ESI) unit, qualification of components, and manufacture of the engineering model. As a result, the schedule has been consolidated to the point of still being compatible with NASA's need dates for the flight unit and the engineering model.

Spacelab plate structure during manufacture at Dornier System
Structure en tôle de chaudière du Spacelab en cours de fabrication chez Dornier

ARIANE

A 720 ton tower was raised by 6.5 m in seven hours at the Ariane Launch Site in Guiana on 24 March. The task was to raise the 50 m high Europa II tower to make it compatible with the Ariane launcher, which is 47 m high compared with the 32 m of the Europa II rocket.

The tower's new lower section was erected during the next two days. Jointing work began immediately afterwards and is expected to be finished late in April. This relatively long time span is due to the rain, which makes welding particularly difficult.

The remaining civil-engineering work on the launch site is on schedule. The launch table foundation is 60% complete and will be finished by the end of July. Work on the propellant-storage areas has started recently, and the situation is now as follows:

UDMH: retention lagoon protecting wall completed
N_2O_4: retention lagoon completed
LH_2: work started recently.

Construction of the iced-water tank has also begun. This will constitute a reserve for cooling stored propellants and for airconditioning the premises within the launch table foundation and the Control Centre.

The roadways have been laid out and will be complete at the end of the summer. The assembly building has been refurbished and the acceptance inspection should take place in May.

APEX PROGRAMME

As already forecast, the number of experiments initally proposed has been considerably reduced – from 71 to 37 – principally through the abandonment of French experiments.

The proposed scientific experiments pose a major problem as regards funding. The scientists are able to fund the experiments they propose, but not the associated costs for the platform to carry them nor the costs of integration. The working assumption now under consideration is use of a COS-B model as a platform on which to integrate the experiments, the costs being borne by the Agency. If this is agreed by the Council, the experimenters will only have to bear the cost of their experiments. Potential experimenters will be consulted along these lines, and final selection is expected to take place in September/October. This satellite, named COSARI, would – together with the radio-amateurs satellite and the Indian telecommunications satellite – be a candidate for flight LO2.

The technological experiments that are still proposed are elements of the satellites considered for APEX and in particular elements of the Ariane-type heavy platform that would result from a concerted European effort.

Apart from the heavy platform, which would be launched on flight LO4 the autonomous experiments at present under consideration for launch on LO3 or LO4 are:

- a communications satellite using an OTS platform
- a Meteosat satellite, possibly modified
- a Symphonie satellite
- a satellite derived from the Canadian Telecommunications Satellite (CTS).

Final selection of passenger experiments for flights LO3 and LO4 is expected at the end of the year.

SPACELAB

Sous-système de pointage d'instruments (IPS)
Le 3 mars, le Comité de Politique industrielle de l'Agence a approuvé la passation avec Dornier System (Allemagne) d'un contrat pour le développement et la fabrication d'un système de pointage d'instruments (IPS) destiné au Spacelab. L'IPS sera conçu de façon à permettre une précision de pointage de quelques secondes d'arc pour les expériences embarquées et touchant à différentes disciplines scientifiques et d'applications, en particulier à l'astronomie et aux ressources terrestres. Installé sur le porte-instruments du Spacelab, l'IPS pourra supporter des charges utiles d'un poids global pouvant aller jusqu à 2000 kg. Il doit en principe être utilisé pour la première fois sur le deuxième vol du Spacelab fin 1980.

Le contrat à prix forfaitaire pour l'IPS couvrira un montant de travaux d'environ 16,5 millions d'unités de compte. Dornier System a pour principal sous-traitant MBB. La firme ERNO sera en outre associée au contrat pour les activités d'interface entre l'IPS et le Spacelab.

Aux termes du Mémorandum d'Accord ASE-NASA sur le Spacelab, les deux Agences se sont mises d'accord sur le développement de l'IPS par l'ASE.

Contrôle des interfaces
La définition détaillée des spécifications d'interface entre l'Orbiteur et le Spacelab a beaucoup progressé. Trois documents de contrôle des interfaces (ICD) ont été signés par la NASA, l'ASE, VFW-Fokker-ERNO et Rockwell International; ils portent sur les interfaces mécaniques et structurels, l'avionique, la régulation d'ambiance et la régulation thermique. Les spécifications d'interfaces sont approuvées à environ 80%. Toute modification des spécifications exige l'accord des deux Agences et des contractants responsables de la Navette spatiale et du Spacelab.

Travaux dans l'industrie
L'accent, mis jusqu'ici sur la définition et la documentation relative au développement, porte désormais sur la phase de conception détaillée et de développement des matériels. Une maquette en dur et des unités de développement sont actuellement en cours de construction.

Un réexamen du calendrier a fait apparaître un certain retard pour quelques sous-systèmes. L'étude des solutions de rattrapage a abouti à un nouveau concept amélioré pour le cycle d'intégration et d'essai, surtout en ce qui concerne l'utilisation de l'unité d'intégration des systèmes électriques (ESI), la qualification des composants et la fabrication du modèle d'identification. Le calendrier a ainsi pu être consolidé de manière à rester compatible avec les dates auxquelles la NASA aura besoin de l'unité de vol et du modèle d'identification.

ARIANE

Sept heures pour élever de 6,50 m une masse de 720 t, c'est la performance qui a été accomplie le 24 mars à la Base de Lancement Ariane en Guyane. Il s'agissait de surélever la tour Europa II haute de 50 m pour la rendre compatible avec les dimensions du lanceur Ariane. La fusée Europa II mesurait environ 32 m contre 47 m pour Ariane.

La nouvelle structure de base a été mise en place au cours des deux jours suivants. Les travaux de jonction ont débuté aussitôt et doivent être achevés fin avril. Le temps relativement important pour les travaux de jonction est dû à la pluie qui rend l'exécution des soudures particulièrement délicate.

Les autres travaux de génie civil de la Base de Lancement Ariane se poursuivent normalement. La construction du massif de support de la table de lancement est achevée à 60% et les travaux seront terminés à la fin du mois de juillet. Les travaux relatifs aux zones de stockage des ergols ont commencé récement et la situation actuelle est la suivante:

UDMH: cuve de rétention et mur de protection terminés
N_2O_2: cuve de rétention terminée
LH_2: les travaux viennent de commencer.

On a aussi commencé les travaux de construction de la cuve d'eau glacée qui constituera une réserve pour le refroidissement des ergols stockables et pour la climatisation des locaux du massif et du Centre de Contrôle.

L'ensemble des routes a été tracé et les travaux seront terminés après l'été. La réfection du Hall d'assemblage a été terminée et la recette devrait intervenir en mai.

PROGRAMME APEX

Conformément aux prévisions, le nombre des expériences initialement proposées a sensiblement diminué, passant de 71 à 37, principalement en raison de l'abandon d'expériences françaises.

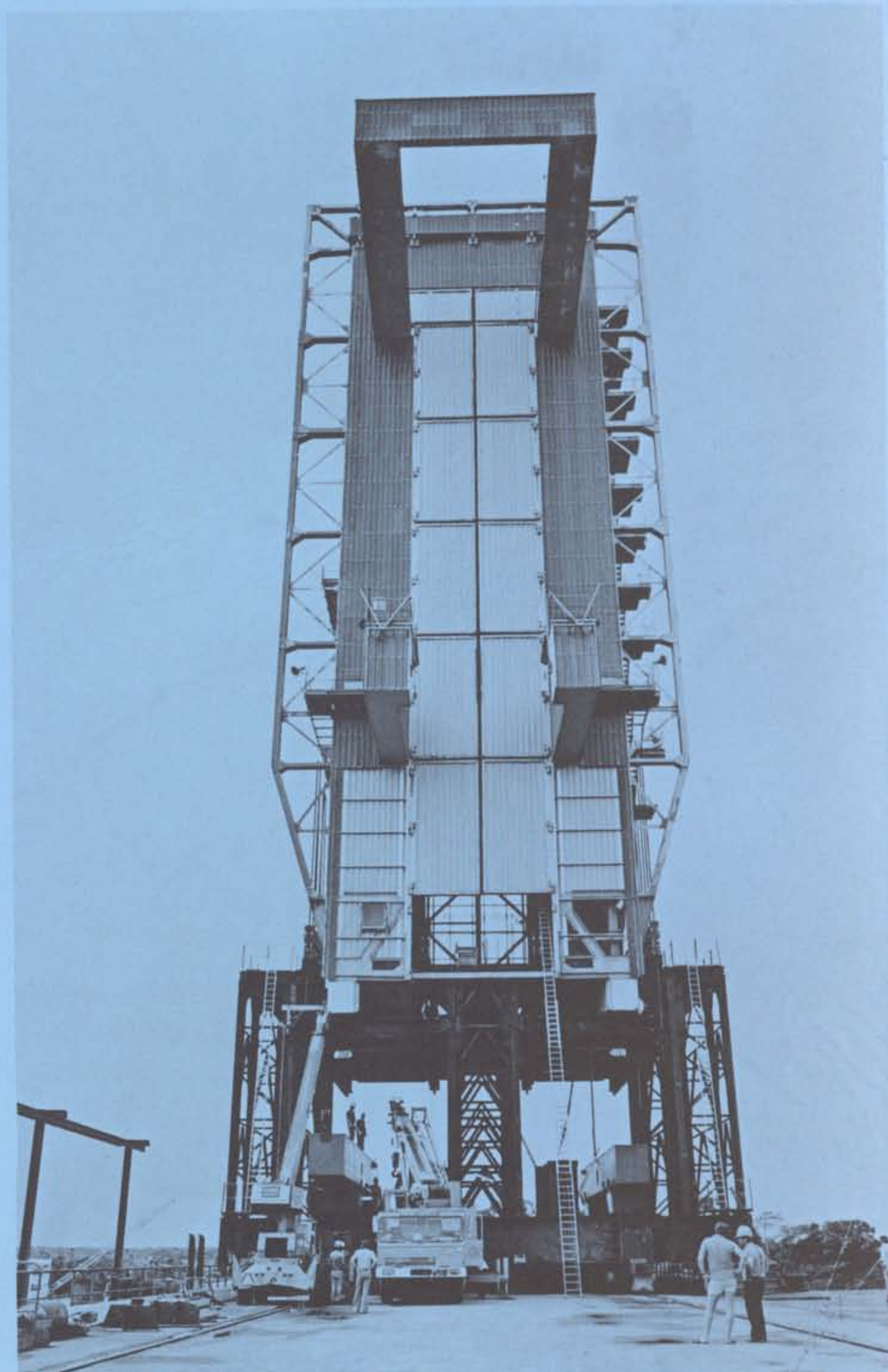
Les expériences scientifiques proposées posent un problème majeur en matière de financement. Si les scientifiques peuvent financer les expériences qu'ils proposent, ils ne peuvent par contre pas supporter les coûts associés de plate-forme d'accueil ni ceux d'intégration. L'hypothèse de travail actuellement considérée est l'utilisation d'un modèle de COS-B comme plate-forme d'accueil sur laquelle seraient intégrées les expériences acceptées, les coûts correspondants étant supportés par l'Agence. Si cette hypothèse est approuvée par le Conseil, les expérimentateurs *n'auront à supporter que le coût de leurs expériences. Une consultation auprès des expérimentateurs potentiels va être faite dans ce sens, la sélection finale étant prévue pour septembre/octobre 1976. Ce satellite, baptisé COSARI, serait avec le satellite Radio-Amateurs et le satellite indien de télécommunications candidat au vol LO2.*

Les expériences technologiques proposées sont des éléments de satellites considérés pour Apex et principalement des éléments de la plate-forme lourde de type Ariane qui résulterait d'un effort européen concerté.

Outre la plate-forme lourde, qui prendrait passage sur le vol LO4, les expériences autonomes actuellement considérées, qui seraient donc embarquées sur les vols LO3 ou LO4, sont

- *un satellite de télécommunications utilisant une plate-forme OTS*
- *un satellite Météosat modifié ou non*
- *un satellite Symphonie*
- *un satellite dérivé du satellite canadien CTS.*

La sélection finale pour les expériences passagers des vols LO3 et LO4 est prévue pour la fin de l'année.



Travaux d'élévation de la tour Ariane sur la Base de lancement, Guyane

Lifting work on tower in progress at Ariane Launch Site, Guiana pluie ou de neige fondante. On peut donc considérer que l'application de la théorie qui consiste à déterminer l'affaiblissement et la dépolarisation à partir du taux de pluie conduit à des résultats légèrement pessimistes puisqu'ils impliquent que les deux phénomènes soient concomitants et cumulent leurs effets, ce qui, l'expérience le montre, ne se produit pas systématiquement.

D'une façon générale, on peut conclure que les perturbations atmosphériques, bien que pouvant causer des chutes perceptibles dans l'isolation entre polarisations orthogonales, ne mettent pas en question la faisabilité de la réutilisation des fréquences dans un système à satellites tel qu'ECS. Toutefois, comme on l'a dejà dit, une voie de transmission par satellite comporte bien d'autres éléments que le milieu de propagation et c'est finalement au vu de la performance de la chaîne entière que l'on pourra porter un jugement définitif. C'est dans cet esprit qu'il fut décidé de mettre en oeuvre une expérience plus élaborée simulant plus exactement les conditions réelles recontrées sur une liaison par satellite.

L'EXPERIENCE DE TRANSMISSION A LARGE BANDE DE LA JUNGFRAU

Tirant parti de la présence d'une station de relais hertziens de l'Entreprise des PTT suisses située à 3700 m d'altitude près du sommet de la Jungfrau, l'ASE a, en collaboration avec cette administration, installé à cet endroit un modèle du satellite OTS avec lequel communique une petite station située dans la vallée près d'Interlaken. Cette station, qui préfigure une station terrienne du futur réseau européen, est capable d'émettre à 14 GHz des signaux à large bande vers le pseudo-satellite qui les renvoie à 11 GHz. On peut ainsi tester une chaîne complète traversant deux fois les couches les plus perturbées de l'atmosphère.

Cette liaison expérimentale a commencé à fonctionner en décembre 1975. La Figure 3 en montre le terminal inférieur qui contient des équipements de mesure entièrement automatiques et dont les données peuvent être transmises par ligne téléphonique au siège des PTT à Berne. Les essais faits jusqu'ici ont porté sur la transmission de signaux numériques à la cadence de 180 Mbit/s et donnent des résultats très encourageants.

On espère également recueillir de cette expérience des données permettant d'établir de façon plus précise les avantages respectifs des polarisations rectiligne et circulaire pour la réutilisation des fréquences. Ainsi qu'on l'a dit plus haut, la polarisation rectiligne semble moins vulnérable que l'autre aux effets de dépolarisation dans l'atmosphère. Ceci n'est cependant vrai que si les deux plans orthogonaux sont le plan vertical et le plan horizontal. Il faut en effet se garder de conclure trop hâtivement à la supériorité de la polarisation rectiligne car la théorie indique que cette supériorité disparaît si les plans tournent à 45°. Or, dans un système à satellite, les plans de polarisation, qui sont fixes par rapport aux axes du satellite, ne peuvent avoir la même orientation pour toutes les stations terriennes, lesquelles se réfèrent toutes à leur verticale locale propre. Pour OTS par exemple, les plans de polarisation des quatre antennes à polarisation rectiligne seront vus vertical et horizontal à Stockholm, seront inclinés à 45° pour les Iles Canaries et les Açores à l'extrémité ouest de la couverture et seront inclinés de 30° en sens opposé à l'extémité est, c'est-à-dire au Proche-Orient.

Figure 3 — Terminal inférieur de la station de la Jungfrau.

Grâce à l'expérience de la Jungfrau, il sera bientôt possible de faire des observations simultanées sur des signaux polarisés différemment et d'étudier de façon systématique l'impact du choix de la polarisation sur la qualité des transmissions.

CONCLUSIONS

Les études entreprises par l'ASE depuis quelques années dans le domaine de la propagation aux fréquences de 10 à 15 GHz ont permis de faire progresser considérablement l'état des connaissances et de lever un grand nombre d'incertitudes qui pesaient lourdement sur la conception du système ECS; en particulier, l'amplitude des affaiblissements est en général moins sévère que prévu et les phénomènes de dépolarisation, dont on ignorait tout, ont des effets qui restent dans des limites acceptables.

Ces activités ont également eu comme résultat secondaire particulièrement heureux l'établissement ou le resserrement de liens de coopération entre l'ASE et un grand nombre d'organismes, administrations, universités et centres de recherche intéressés par les études de propagation et par la mise en oeuvre de systèmes de télécommunications par satellite. Un exemple récent du rôle d'agent catalyseur joué par la propagation dans les relations internationales est l'accord qui vient d'être signé entre l'ASE et les autorités iraniennes pour l'installation d'un radiomètre au Collège de Science et de Technologie d'Iran à Téhéran. □

The Satellite Control and Test Earth Station at Fucino

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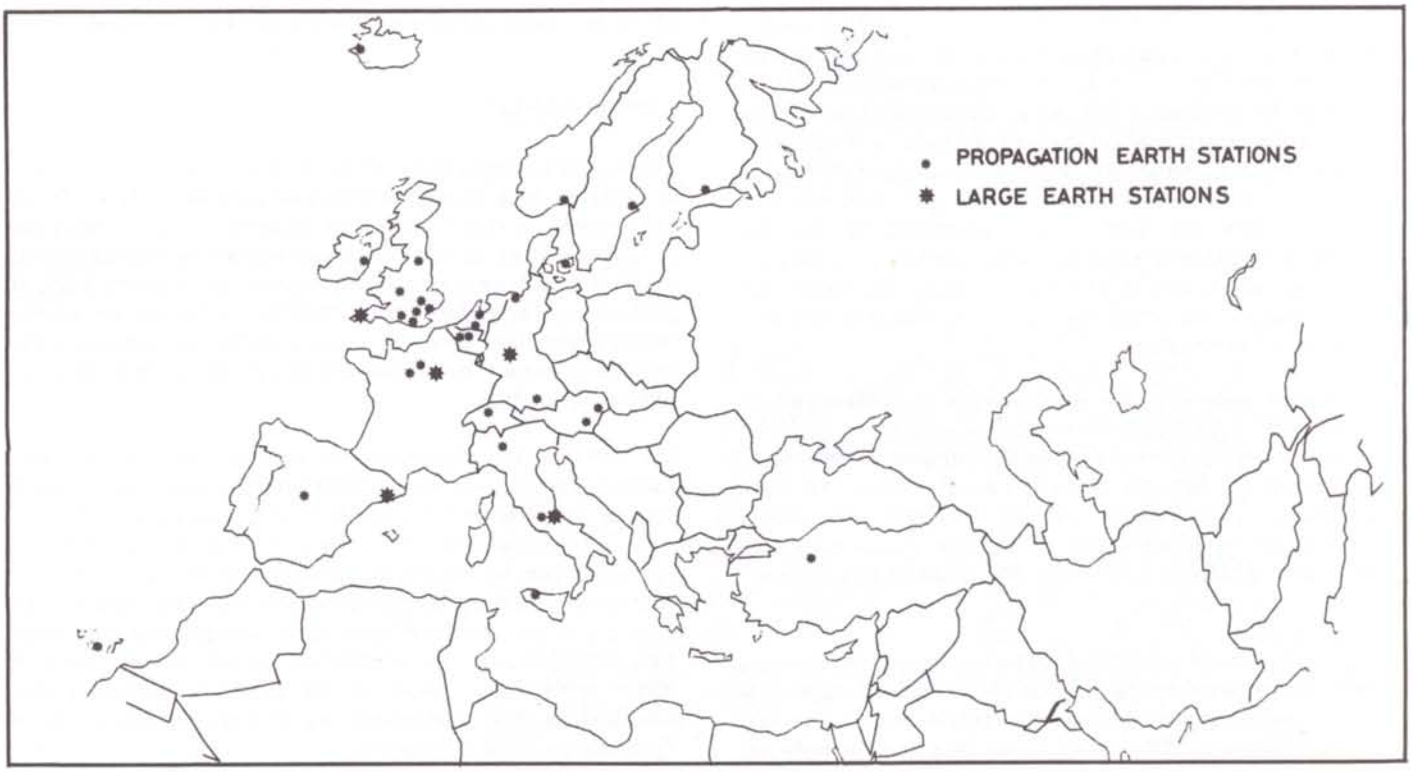
The Satellite Control and Test Earth Station (SCTS) currently being constructed at Fucino, near Rome, will be the first major terminal to be completed for use with ESA's Orbital Test Satellite (OTS) and the first major terminal in the world to operate with dual-polarisation frequency re-use in the 11/14 GHz frequency band. The station, which is being built by AEG-Telefunken (prime contractor) and will be owned jointly by ESA and Telespazio, is scheduled for completion in November 1976. It will be the principal tracking, telemetry and command station for OTS, and ESA will use the station extensively for a programme of orbital tests following satellite launch. Telespazio will build up their use of the SCTS progressively as a participant in the orbital communications experiments, culminating in the use of the station for live pre-operational telephony traffic via OTS.

Figure 1 – Satellite communications stations planned or already under construction (as per December 1975)



THE ROLE OF THE SCTS

As its name implies, the SCTS has two primary functions:
- Satellite control (tracking, telemetry and command of OTS)
- Test (participation in all aspects of the OTS orbital test programme).

Satellite Control Function

The station will perform the following tasks within the general sphere of satellite control:
- reception of the SHF telemetry from the satellite, with subsequent signal conditioning and transmission to the Operations Control Centre (OCC) at ESOC, Darmstadt
- transmission of SHF commands initiated at the OCC
- ranging of the satellite using a carrier signal modulated with appropriate ranging tones for orbit-determination purposes
- tracking of the satellite to obtain azimuth and elevation angles for orbit-determination purposes.

Test Function

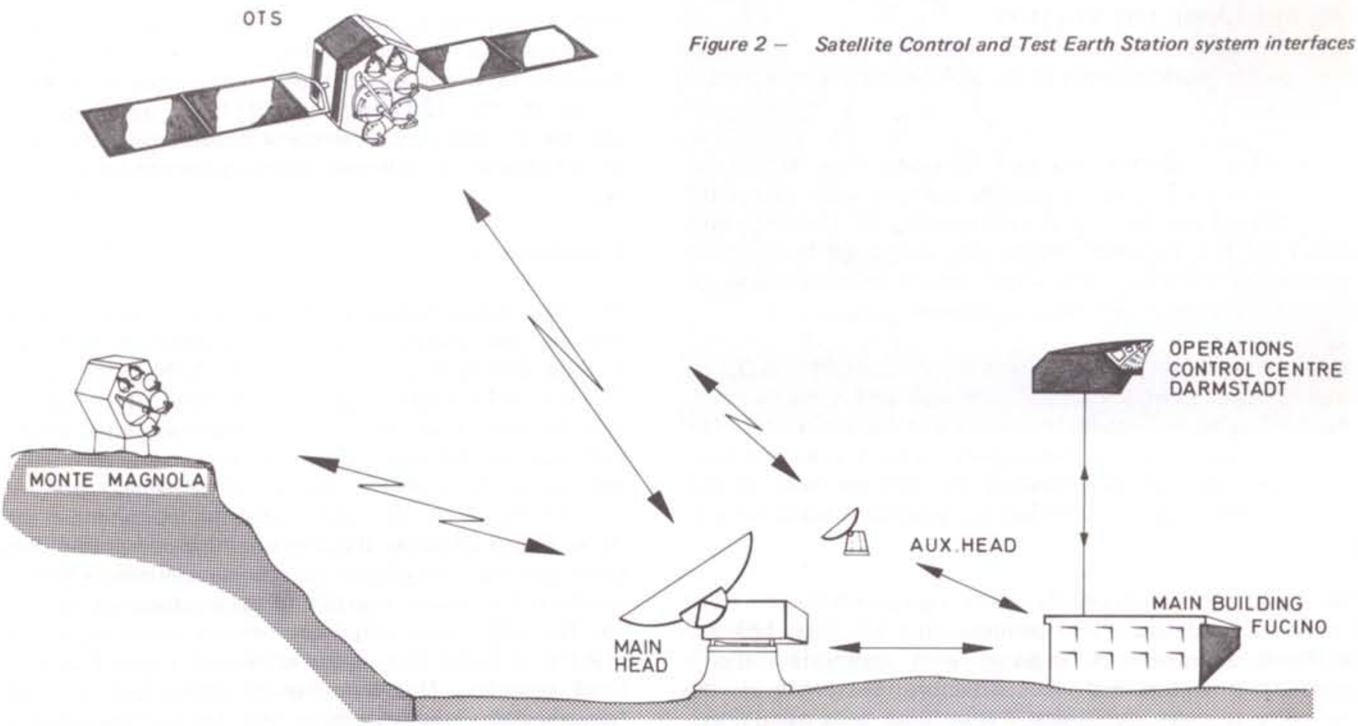
A large number of earth stations of various types, ranging from major stations similar to the SCTS to small receive-only stations, are planned or in course of construction by the national PTT's and other interested bodies (including scientific establishments, universities, and other international organisations), and will take advantage of the wide range of experimental and pre-operational test possibilities provided by OTS's communications payload. Some of the stations currently foreseen are shown in Figure 1. These stations will work together, through the satellite, to achieve a number of experimental and test objectives known collectively as the Orbital Test Programme (OTP). In outline, this programme comprises:

- Determination of the in-orbit characteristics of the satellite payload from measurements on the ground. This includes measurement of satellite antenna gain and pointing, satellite antenna beam shape, polarisation purity of satellite antennas, frequency stability, receiver noise, power output, etc.
- Transmission tests between co-operating PTT earth stations, including test transmissions of 60, 120 and 180 Mbit/s burst-mode digital signals and television signals.
- Pre-operational tests by co-operating PTT administrations, including trials of TDMA (Time Division Multiple Access) operation between a number of stations and television exchanges.
- Propagation measurements by administrations, universities and scientific establishments.
- Data transmission by a number of interested bodies.

There are two antennas at the SCTS, a main antenna for high-speed digital and TV transmission and an auxiliary antenna for propagation measurements and transmission tests. Both antennas and their associated equipment will be utilised initially to perform the in-orbit OTP satellite measurements. In this role the station will be used as a measuring instrument and as such its characteristics will need to be stable and accurately known.

As a prelude to the satellite measurements proper a series of tests will be conducted using the line-of-sight radio path which exists between Fucino and Monte Magnola, a mountain peak approximately 20 km away. Communications equipment similar to that used on the OTS satellite will be installed on Monte Magnola and this will allow most of the OTP tests to be rehearsed in conditions as close as possible to those in operational use. The Monte Magnola link will also be used to test the TTC (Telemetry, Tracking and Command) system and to measure the mutual interference between TTC and OTP transmissions (Fig. 2).

Figure 2 – Satellite Control and Test Earth Station system interfaces



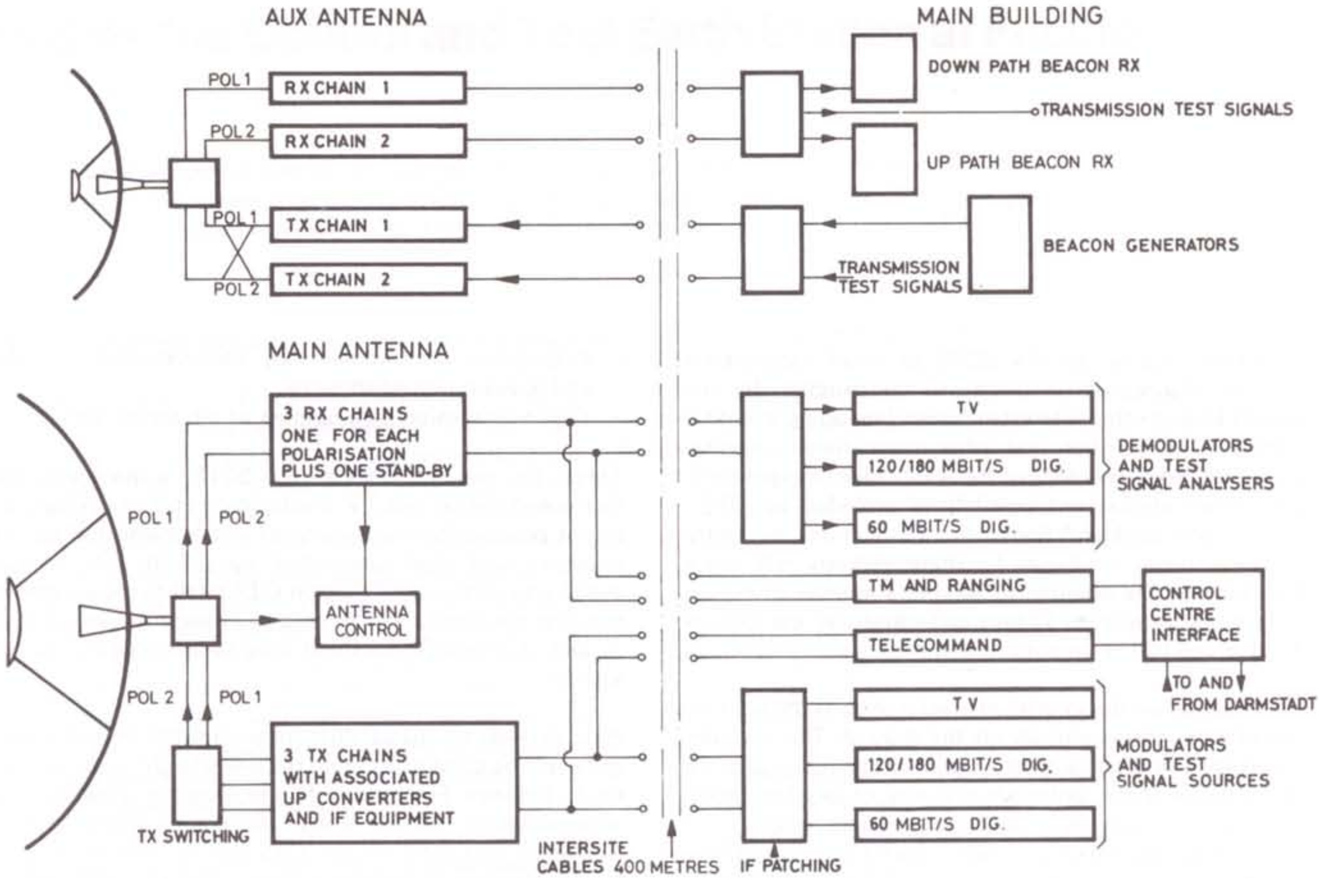


Figure 3 – Simplified block diagram of the SCTS facility at Fucino

THE DESIGN OF THE STATION

A simplified block diagram of the SCTS station is presented in Figure 3.

The station is divided into two physically separate installations, the antennas and their associated equipment being sited some 400 m from the main Fucino building. Most of the signal generation and detection equipment is located in the main building, as is the telemetry-telecommand equipment and the Control Centre Interface (CCI) equipment.

A computer-to-computer data link is provided with the Operations Control Centre at ESOC, through which the telecommand, ranging and telemetry operations are controlled. The link also carries station equipment status signals and vital parameter information, including the antenna azimuth and elevation data, which is needed for orbit-determination purposes.

The signal generation and detection equipment for the OTP comprises modulators and demodulators for 180, 120 and 60 Mbit/s transmissions, together with appropriate digital sequence generators and error detectors. These provide the capability to carry out digital transmission tests using burst-mode signals and to measure the signal impairments caused by the earth station, the satellite repeaters, and propagation phenomena, under various operating conditions. As an alternative to the 120 Mbit/s or 60 Mbit/s transmissions it is possible to send and receive FM television signals, for which test modulation and demodulation equipment has been provided.

Main Antenna

The main head employs a 17 m diameter dual linear polarised antenna operating in the receive frequency band of 11.45 GHz to 11.8 GHz with later extension to 10.95 GHz to 11.8 GHz. The transmit frequency band is 14 to 14.5 GHz, again utilising dual linear polarisation. There are three high-power amplifiers, with associated transmit chains of equipment, each delivering approximately 2 kW of RF (radio-frequency) power. The transmit chains are arranged so that the telecommand capability is always available through one high-power amplifier, the other two being employed for communications or OTP transmissions, but always available to carry telecommand if required. The high-power amplifiers employ travelling-wave tubes (TWT's) and the carriers are combined together using wide-band couplers. This arrangement allows full flexibility in frequency allocation within the 500 MHz transmit band. Three receive chains are employed, two for normal operation and one stand-by. Each receiver has an input bandwidth of 750 MHz and employs an uncooled parametric amplifier with a noise temperature of approximately 200 K.

Auxiliary Antenna

The auxiliary head employs a 3 m diameter antenna which operates in dual circular polarisation. The transmit and receive frequency bands are located above those employed for the main-antenna transmissions and have a maximum bandwidth of approximately 10 MHz.

There are two chains of transmit equipment, one for each polarisation sense. The two power amplifiers have RF power outputs of 10 W and 175 W, respectively. On the receive side, two identical receive chains are employed, each with a noise temperature of approximately 200 K, achieved with parametric amplifiers identical to those employed in the main head. As with the main head the signal generation and detection equipment is contained in the main building. The auxiliary head can be used for propagation measurements, as a measuring instrument to measure satellite static characteristics (group delay, frequency response, etc.), or for transmission tests.

THE TECHNOLOGY

As far back as 1972 it was realised that there were a number of critical components that would be required for OTS and ECS earth stations which had not yet been developed, in Europe or elsewhere. This situation arose primarily because OTS and ECS would employ new frequency bands (11/14 GHz), frequency re-use by polarisation, discrimination, and high-speed digital transmission in the burst mode at up to 180 Mbit/s. None of these techniques had previously been utilised for satellite communication. The critical subsystems of the SCTS will therefore be briefly reviewed, with reference to their development background where relevant.

Antenna Feeds, Antennas and Calibration

Figure 4 shows the dual-polarisation antenna feed developed by AEG-Telefunken for an ESA transmission experiment on the Jungfrau in Switzerland. This feed is almost identical to that used in the auxiliary head of the SCTS and employs most of the critical electrical components necessary for the main antenna feed. The subsystem has a bandwidth of more than 500 MHz in both the transmit and receive directions, and

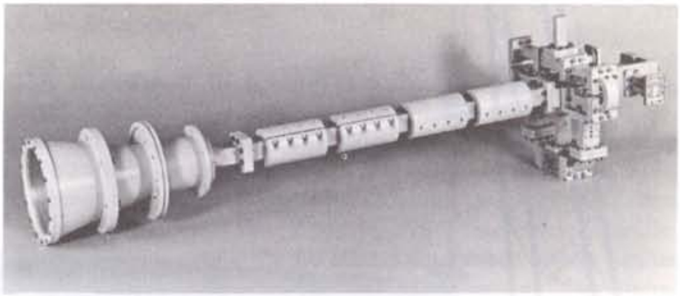


Figure 4 – Feed horn for the auxiliary 3 m antenna

Figure 5 – Auxiliary 3 m diameter antenna

produces a linear polarisation discrimination of better than 40 dB (35 dB for circular polarisation) within the 1 dB beam width of the secondary pattern when used with a suitable reflector. Figure 5 shows the AEG-Telefunken 3 m diameter antenna tested on the Jungfrau. It is almost identical to that under construction for the SCTS auxiliary head.

Figure 6 shows the main antenna at Fucino being raised onto its pedestal, a rather unusual approach for this size of antenna, which is normally assembled in position. This method of erection does, however, allow some preliminary alignment before mounting and also allows both pedestal mount and antenna to be constructed in parallel, with a consequent time saving. The Fucino antenna has been designed and constructed by Alpha Engineering (Netherlands) to SCTS requirements. It is fully steerable and has a surface accuracy of better than 0.5 mm RMS at the working elevation angle. Two further antennas of the same design have been ordered by Telespazio for use with the Sirio satellite and these are also in the course of construction.

Before going into service, the main antenna will be calibrated as accurately as possible, using cosmic radio sources (stars). This is standard practice for large antennas used in satellite communications, but in the case of the SCTS, because the frequency of operation is such that the available star flux is small, more refined measurement techniques are necessary. The antenna is therefore equipped with a built-in radiometer which will be used to calibrate the gain and also to measure pointing accuracy with respect to the indicated azimuth and elevation angles from the digital encoders.

This last point is particularly important since accurate knowledge of satellite angular position will be an essential part of the OTS orbit determination.

High-Power and Parametric Amplifiers

The high-power amplifiers for the SCTS are being designed and fabricated by SIT Siemens, Milan. The most critical components here are the high-power travelling-wave tubes, developed by Thomson-CSF (France) which have an output power of 2 kW and a bandwidth of more than 500 MHz.

The parametric amplifiers are being developed for the SCTS by GTE of Milan. They are room-temperature stabilised and have a bandwidth of 750 MHz and a noise temperature of 200 K. Five identical units are employed, three for the main head and two for the auxiliary.

Figure 6 — Main 17 m diameter antenna being lifted onto its pedestal

Digital Equipment

OTS is designed to handle two digital transmission rates, namely 180 and 60 Mbit/s, but recent decisions concerning the preferred design for later ECS satellites have made it desirable to introduce a third 120 Mbit/s capability into the SCTS equipment. The 180 Mbit/s modulation and demodulation equipment has been developed by AEG-Telefunken specifically for Fucino, while the 60 Mbit/s equipment is very similar to that already developed for other applications. The digital equipment includes random sequence generators to simulate live traffic and error detectors to measure overall error rate.

CONCLUSIONS

It is hoped that the SCTS will be the forerunner of many earth stations to be built by PTT administrations and others for the European communications system. In fact, one other major terminal is already under construction in France, and work is starting on similar terminals in Germany, the United Kingdom and Spain. There is little doubt that much useful experience has been and is being derived from the design, construction and testing of the Fucino station. It is hoped that this experience can be efficiently applied to other stations now being considered or in the course of construction.

Although the Fucino station has been designed specifically for operation with OTS, a number of features in its design, such as the 750 MHz receivers, will ensure its continued usefulness for the future operational European communications satellite system.

□

Maritime Satellite Payloads

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ESA is presently developing a maritime communication satellite, Marots (Maritime Orbital Test Satellite), intended for launch in 1978. Its design is based on that of the Agency's OTS satellite and is characterised by a modular construction and the adoption of three-axis stabilisation (Fig. 1). The Marots payload is designed to meet a series of technical parameters for a first-phase Maritime Satellite System as laid down by the Panel of Experts of the Inter-Governmental Maritime Consultative Organisation (IMCO), an agency of the United Nations.

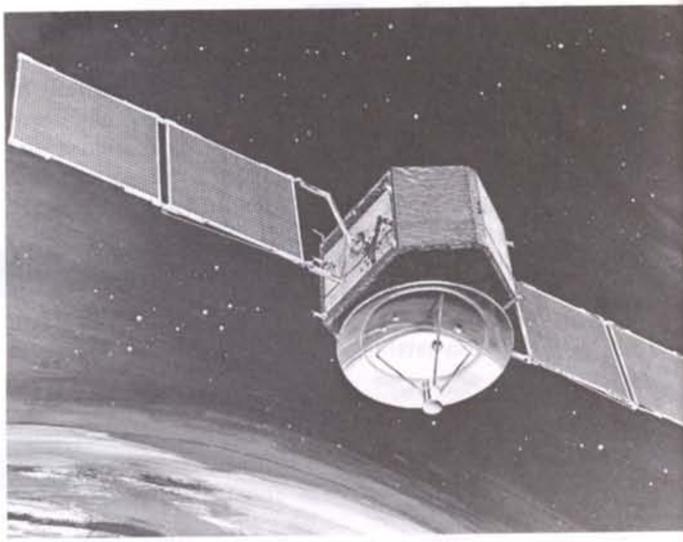


Figure 1 – The Marots three-axis-stabilised spacecraft.

The main conclusions of this Panel, formulated in 1975 after a three-year study of the operational requirements for an international 'maritime mobile satellite system', can be summarised as follows:

(a) The system should use a geostationary satellite, in order to provide a permanent service.
(b) Although a Thor Delta-launched, spin-stabilised dedicated satellite would meet the lowest traffic-demand estimate, a three-axis stabilised satellite would be required to meet the highest estimate.
(c) The maritime satellite should provide an earth coverage.
(d) High-quality voice/data and teletype communications should be provided.
(e) Frequency Division Multiple Access (FDMA) transmission techniques should be used in both the shore-to-ship and ship-to-shore directions (i.e. different channels should be assigned to different frequency bands).

Requirements (c) and (e) lead to a payload design which is based essentially on the use of earth-coverage antennas and high-power amplifiers.

With the requirement for high-quality communications and the gain limitations of ship-terminal antennas, most of the critical problems that arise in designing a maritime satellite payload are associated with the forward repeater, and in particular its L-band (maritime band) transmitter, for which a rather complex trade-off between linearity and efficiency is necessary. This trade-off is made more complex by the imposed bandwidth limitations.

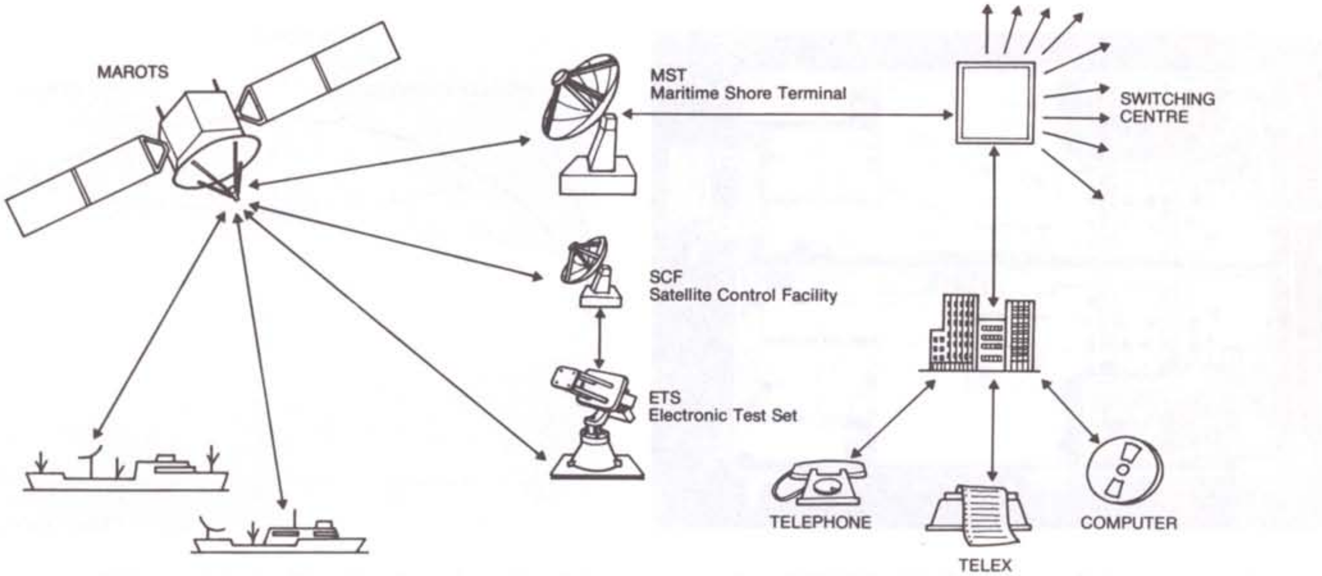
MARITIME PAYLOAD CHARACTERISTICS

To comply with the objectives of a maritime communications mission, the satellite payload should meet the following requirements:

(i) It should have the ability to cope with multiple access, from either shore or mobile terminals.
(ii) It should be able to cope with very different types of traffic; e.g. voice, high-speed data, low-speed data (telex or facsimile), network organisation messages (access), distress calls.
(iii) It should make efficient use of the allocated frequency spectrum.
(iv) It should make efficient use of the power available from the satellite's 'generators'.

The first generation of transponders (combined receivers and transmitters) for maritime satellites will be of the multiple-frequency-conversion type, either 'channelised' or 'broad band'. The number of channels foreseen for Marots precludes the 'channelised' solution, which is mass-consuming and prevents subsequent modification of channel characteristics when the satellite is in orbit. The broadband solution, on the other hand, leads to a minimal payload mass and provides the highest flexibility of operation, but the operating powers of the shore stations participating in the system must then be more strictly controlled (to equalise the power of carriers retransmitted by the satellite).

The Marots payload consists essentially of three repeaters:



Outline of Marots system

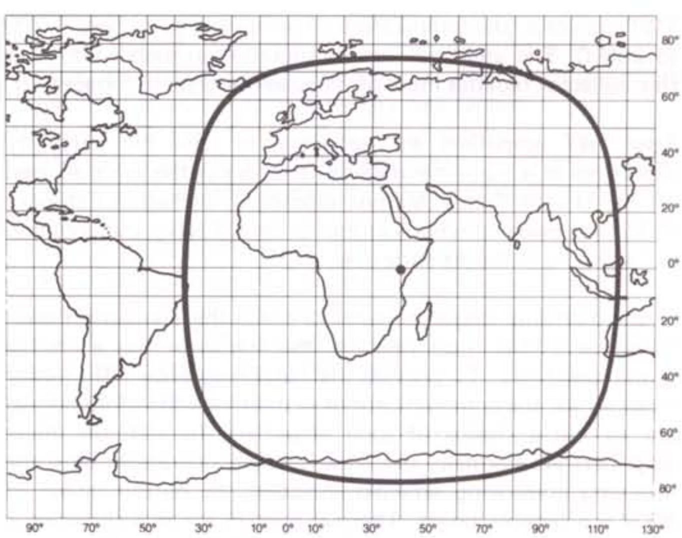
- a forward repeater (6 or 14.5 GHz/L-band) for shore-to-ship communications
- a return repeater (L-band/4 or 11.7 GHz) for ship-to-shore communications, and
- a shore-to-shore repeater (6 or 14.5 GHz/4 or 11.7 GHz) for shore-to-shore communications (ground network co-ordination).

In general, the various items of the payload rely on standard techniques, microwave integrated circuitry being employed whenever possible (Fig. 2). Nevertheless, two payload units merit special attention: the L-band amplifier and the L-band antenna.

THE L-BAND POWER AMPLIFIER

The L-band power amplifier, in the transmitting circuitry of the shore-to-ship transponder, will have to provide an output power of more than 60 W, while maintaining optimum efficiency and linearity, these being two conflicting requirements. Within the limits of available technology, three solutions can be envisaged.

- a travelling-wave-tube amplifier
- a transistorised power amplifier
- a triode amplifier.



Initial Marots coverage

The Travelling-Wave-Tube Amplifier (TWTA) is not power-limited and when used in the L-band can deliver powers in excess of 150 W. Its efficiency at saturation can be higher than 50%, but for the multicarrier operation and linearity required of Marots, this figure will be closer to 30% Thermal control for the TWT amplifier does not give rise to any major difficulties, most of the dissipated power being radiated by the

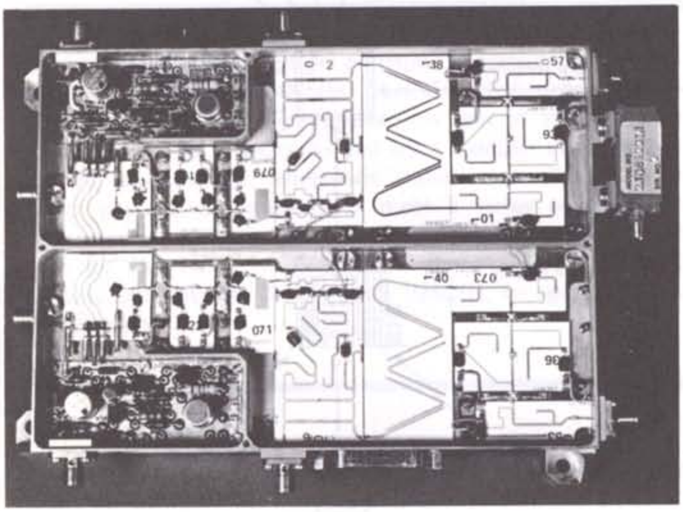


Figure 2 – Example of Marots payload integrated circuitry; the L-band receiver.

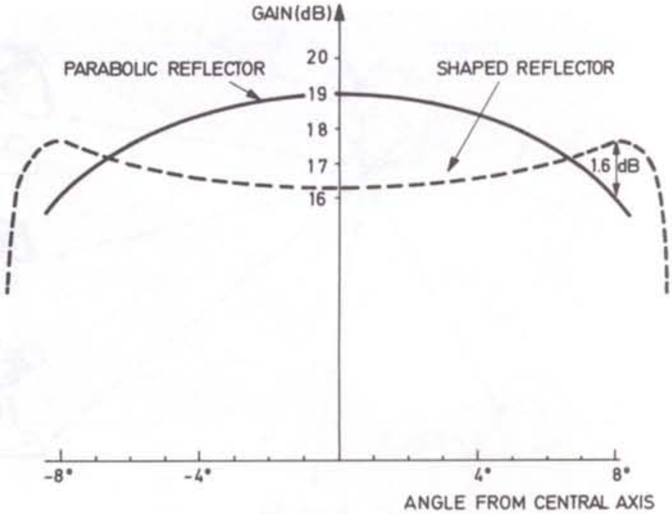


Figure 3 – Shaped-beam and parabolic antenna radiation curves, showing shaped reflector's superior edge-of-coverage performance.

TWT collector, the temperature of which can be as high as 200 to 250°C. The amplifier can be mounted in such a way that this collector radiates most of its power outside the spacecraft.

Two TWT amplifiers are necessary to fulfil the reliability objectives of a maritime mission, and this is the solution used on the United States' Marisat satellite, launched in February 1976 to provide communications to the US Navy and commercial shipping in the Atlantic area.

In the maritime frequency band in which the Transistor Power Amplifier (TPA) must operate, the transistor has a limited power capability. To provide the radio-frequency (RF) power required for the communications system, it is therefore necessary to use a cluster of such amplifiers. In addition, these amplifiers are normally nonlinear in their operation. With the necessary linearising schemes included, an output power of 60 W is a feasible target. Thermal control for this amplifier is much more difficult than for the TWT type. First, safe transistor operation requires low temperatures (40° C), and secondly the multi-amplifier concept imposes severe requirements on temperature gradients. One of the advantages of the transistor amplifier solution is its flexibility as regards power consumption. By changing the number of operating modules, it is possible to match closely the prime power delivered by the satellite. The TP amplifier solution is preferred to the TWT for the Marots payload because the latter's development and qualification programme was found to be very costly and its duration incompatible with the satellite's scheduled launch date.

Like the TWT amplifier, the Triode Amplifier is not power limited, but its higher cathode current leads to a lower reliability. Special cathode designs or the inclusion of additional standby amplifiers (redundancy) could be used to overcome this problem.

THE L-BAND ANTENNA

The maximum gain that would be provided for earth coverage by using a standard parabolic-dish satellite antenna would not exceed 16 dB. The power flux density produced at the earth's surface by such an antenna would be about 5 dB greater at the centre than at the edge of coverage, which would lead to nonoptimal system performance. The shaped-beam type of antenna, on the other hand, is intended to equalise the power flux density at the earth's surface, by use of a specially shaped reflector (Fig. 3).

Depending on the technical approach chosen, the antenna can be classified into one of two categories:

(a) *Reflector-type antenna*
This is the classical solution and when applied to Marots's shaped-beam antenna it leads to a 2 m diameter, shaped

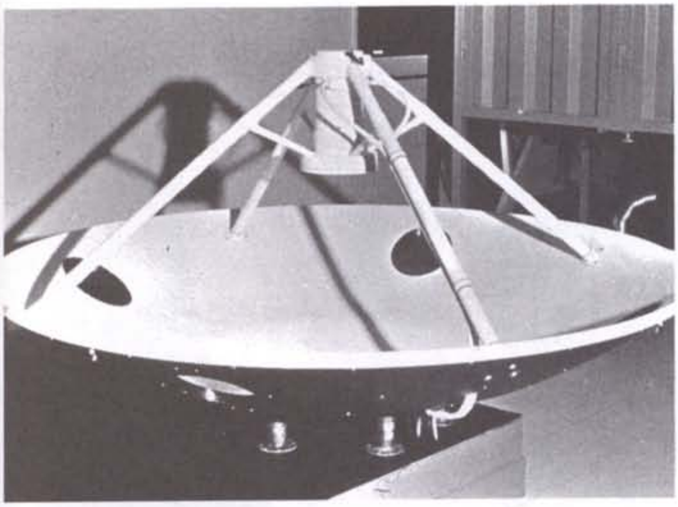


Figure 4 — Shaped-reflector antenna to be used on Marots.

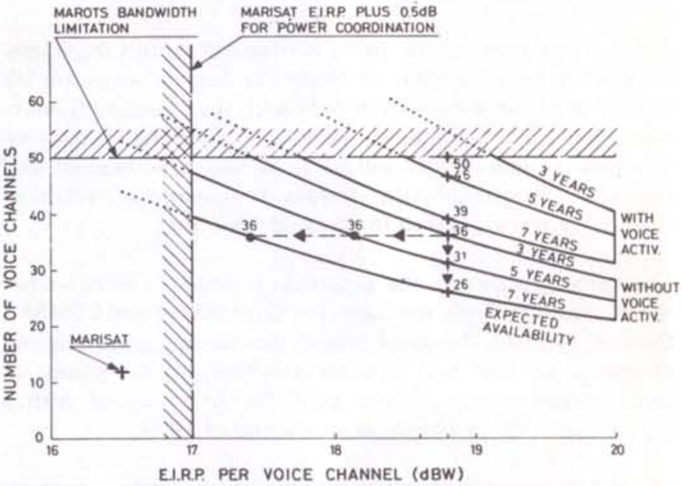


Figure 5 — Radiated power as a function of number of voice channels for Europe's Marots satellite and the USA's Marisat.

profiled reflector. Use of this reflector causes some interface problems with the spacecraft, as the earth-oriented antenna tends to mask the field of view of the satellite's earth sensors.

The antenna that has been developed for Marots is shown in Figure 4.

(b) *Phased-array antenna*

It is also possible to use a phased-array antenna for L-band operation and this would be rather easy to install on the spacecraft and would provide a gain in excess of 16 dB, or perhaps even 17 dB, at the edge of the earth-coverage area. Marisat uses a four-helix phased-array antenna, but this has a lower gain because here it forms only a part of a more complex antenna system.

MAROTS COMMUNICATION CAPACITY

The communication capacity to be provided by Marots can best be illustrated by considering the number of voice channels as a function of the Equivalent Isotropic Radiated Power (EIRP) per channel in the shore-to-ship direction (Fig. 5). The two sets of curves give the number of voice channels expected after three, five and seven years, with and without voice activation. For comparison purposes, Figure 5 also shows Marisat's communications capacity in the shore-to-ship direction.

Within the limitations of the technology selected — essentially a large, shaped, 2 m-diameter L-band antenna and a linear L-band transistor power amplifier — the communications capacity of Marots is constrained by two factors:

(i) the 2.5 MHz bandwidth of its transponder

(ii) the DC power available for the communications payload, expected to be 460 W after 3 years and 360 W after 7 years.

Marots is expected to provide 36 channels during its first three years in orbit. Thereafter, it will be necessary either to reduce the number of channels to 31 or 26, keeping channel quality constant, or to reduce channel quality (by 0.7 or 1.5 dBW) while maintaining the same number of channels for the subsequent 2 to 4 years.

□

The Space Segment of the Aerosat Communications System

A. Pinglier, Directorate of Communications, ESA, Paris

The Aerosat programme, being carried out within the framework of a Memorandum of Understanding between the US Federal Aviation Administration (FAA), the Canadian Government, and ESA, will provide an aeronautical satellite communications system which will serve as the experimental and evaluatory forerunner of a world-wide operational system of air-traffic control planned for the mid-1980's.

The space segment of the programme, which is being undertaken jointly by ESA, the Canadian Government and COMSAT General, includes the development, production, launching and operation of the two Aerosat satellites, to be placed in geostationary orbit, initially over the Atlantic and with a separation of 25° in longitude, at the end of 1979.

Aeronautical communication services over the ocean routes do not give entire satisfaction at present, particularly with regard to link quality, which can at times be extremely poor. The practice of using high frequencies for communication does not allow a high degree of automation, and sometimes results in a delay in the transmission of messages. As far as aids to navigation are concerned, the existing service seems somewhat better, and no major problems are apparent. In the relatively long term though, it seems that it will be preferable for the navigational aids and surveillance services over the oceans to be comparable in level of operation with those over the continents.

The prospects for using satellites for aeronautical applications have already been considered sufficiently interesting to embark on a phase of 'concrete execution'. They can provide:

- quasi-world-wide coverage: three geostationary satellites can cover the ocean zones between 70° N and 70° S (Fig. 1), six satellites would be required to provide radiolocation in these same zones
- adequate quality and permanence for connections
- rapid access and, where applicable, fairly extensive automation of the service.

Before setting up an operational system, however, a large number of difficulties will have to be overcome and it has already been found necessary to undertake a preliminary phase of full-scale experimentation, described elsewhere in this Bulletin.

It was from these origins that the idea of the Aerosat common evaluation programme was born. This programme, to be

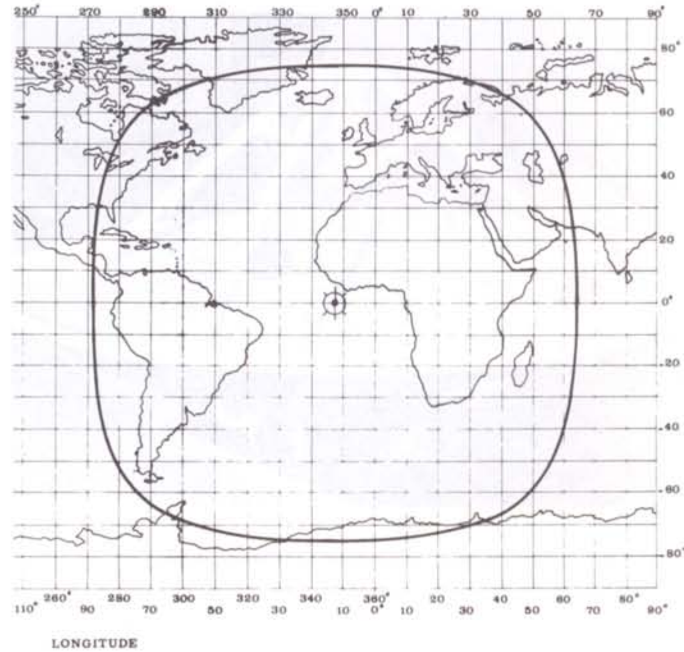


Figure 1 — 5° elevation contour for spacecraft at 12.5° W.

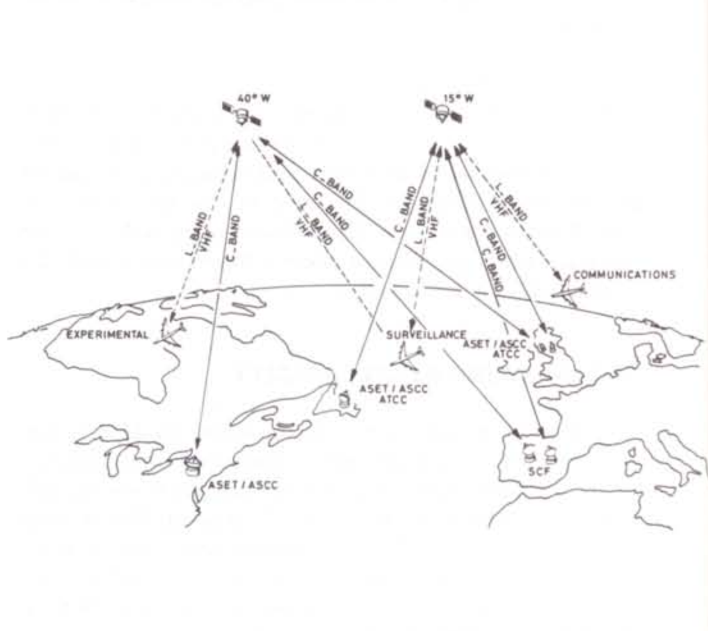
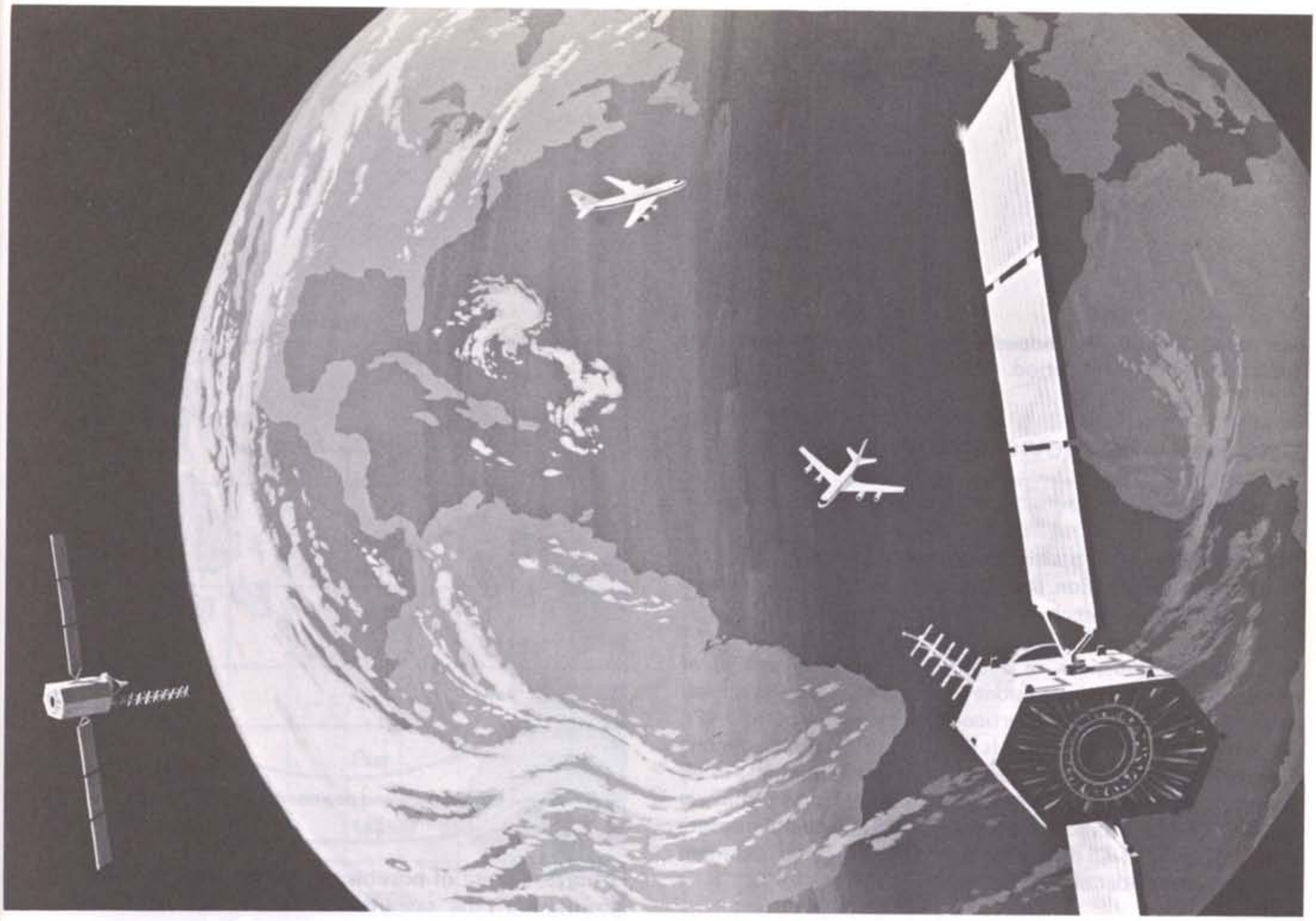


Figure 2 — The Aerosat communications system.



undertaken by, or in close co-operation with, the aeronautical authorities of the United States, Canada, and ESA Member States and encouraged by the International Civil Aviation Organisation (ICAO), should make it possible to progress from current concepts to the implementation of a fully operational aeronautical communications system by the late 1980's

ELEMENTS OF THE SYSTEM

The Aerosat system embraces three sectors of operation:

- *The space segment,* which provides channels of communication that allow users on the ground and on board aircraft to exchange information. It consists essentially of two geostationary satellites, to be positioned over the Atlantic. From a functional point of view, the ground installations required for monitoring the two satellites can be included in this space segment; they are a spacecraft control and TTC station in Europe, and a number of calibration units (Electronic Test Sets), very similar to the equipment installed on board aircraft, and used to check operation of the complete system.

- *The ground segment* will consist of a series of aeronautical telecommunications stations, which allow users on the ground to gain access to the Aerosat system. Each station has an Aeronautical Services Earth Terminal (ASET), for reception and transmission of signals via the satellites. An Aeronautical Satellite Communications Centre (ASCC) will monitor these communications, supervise user access, and distribute messages. Each station will also be equipped with a number of Electronic Test Sets (ETS), to be used to obtain fine orbitographical records for the satellites.

- On-board equipment covered by *the aeronautical segment* provides for reception and transmission of signals to and from the satellites, and also input/output interfacing with a number of on-board units.

The space segment is a shared responsibility, while the aeronautical telecommunications stations and avionics are individually supplied and operated by each of the partners to form part of the co-ordinated programme. In addition to the setting up of the requisite equipment both on the ground and on-board aircraft, the individual programmes include the execution of experimentaal work. Close co-ordination of these activities is the responsibility of the Aerosat Co-ordination Office.

For the moment, a 'half-ASET', incorporating only one antenna and able to communicate with only one satellite at a time, and one ASCC are scheduled for installation in the United States and Canada. Europe will have one complete ASET and one ASCC (Fig. 2). It is hoped to have 30 or 40 avionic units operational in the same period.

FUNCTIONS TO BE PROVIDED

Communications

The prime interest of a satellite system lies in its capacity for transmitting information and evaluatory work will be carried out in the fields of speech and data transmission.

For audio transmissions, a quality factor similar to that of average VHF radio transmissions is aimed at (for aeronautical applications, the acceptable articulation index is around 0.42). Given that the Aerosat system is designed to determine, among other things, the most appropriate type of modulation for an operation environment, various types of modulation technique will be tested. For practical purposes, a C/N_0 value (a measure of link quality) of 43 dB Hz has been selected as the minimum to be achieved under all circumstances.

For testing data transmission, a rate of 1200 bit/s has been selected, with a maximum error rate before coding of 10^{-5}, this being compatible with a C/N_0 of 43 dB Hz. It is also planned to run tests with 2400 bit/s, and in this case the C/N_0 value will be raised to 46 dB Hz.

Surveillance

Aerosat will be used to evaluate the possibilities of independent surveillance, based on the use of two geostationary satellites (Fig. 3). With a system of this type, the position of an aircraft can be determined in real time by measurement of propagation times from only one ground station, assuming that the positions of the two satellites are known at the time of measurement. In practice, transmission from the ground station includes, in addition to the distance-measurement signal, an aircraft identification signal to which only the interrogated aircraft in the zone visible to the satellites replies. A total time of 0.5 s is allocated for localisation.

The accuracy of this surveillance system will be affected by three main sources of error:
- ionospheric errors: the propagation rate of the radio-electric wave varies as it traverses the ionosphere
- errors due to multiple trajectories: a wave reflected by the sea is added to the direct wave, and measurement is falsified
- errors in measured value (propagation time): related to the quality of the link (C/N_0 value).

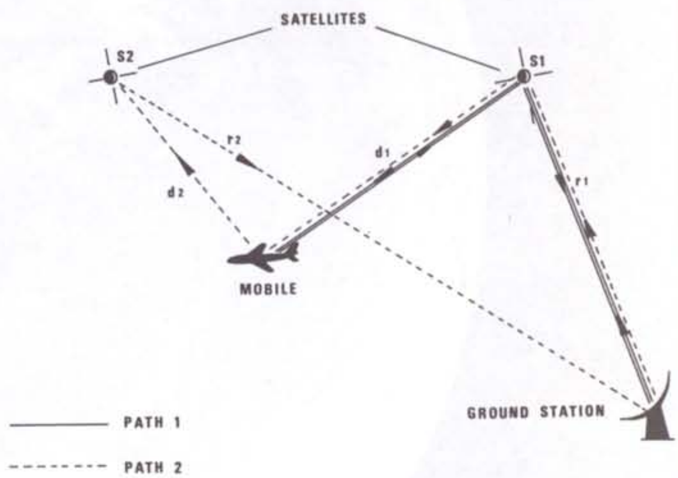


Figure 3 – Surveillance and positioning system

A further cause of possible error is incorrect knowledge of the positions of the satellites, as is also lack of precision in determining aircraft altitude.

The cumulative effect of these different errors varies according to the position of the mobile unit. All things being equal, a mobile situated close to the equator will be comparatively poorly 'localised' or pin-pointed, while one in a mid-latitude zone can be located very accurately. This phenomenon is connected with the geometry of the system, and the spacing of the two satellites in the geostationary orbit also has an influence. Localisation accuracy for a mobile at a latitude of 40°, for example, with a 40° spacing between the satellites is twice as good as with a 20° spacing.

Assuming that the latitudes and longitudes of the two satellites are known to within 100 m (1 σ) and their altitudes to within 50 m (1 σ), the positioning error for an aircraft, the altitude of which is known to within 100 m, will be less than 1 nautical mile for latitudes in excess of 40°, and 2 nautical miles for latitudes between 20° and 40° in the most favourable case (Fig. 4).

GENERAL CHARACTERISTICS OF THE SYSTEM

Coverage

One satellite will be stationed at 15° W, and the other at 40° W, giving an angular separation of 25°. This represents a

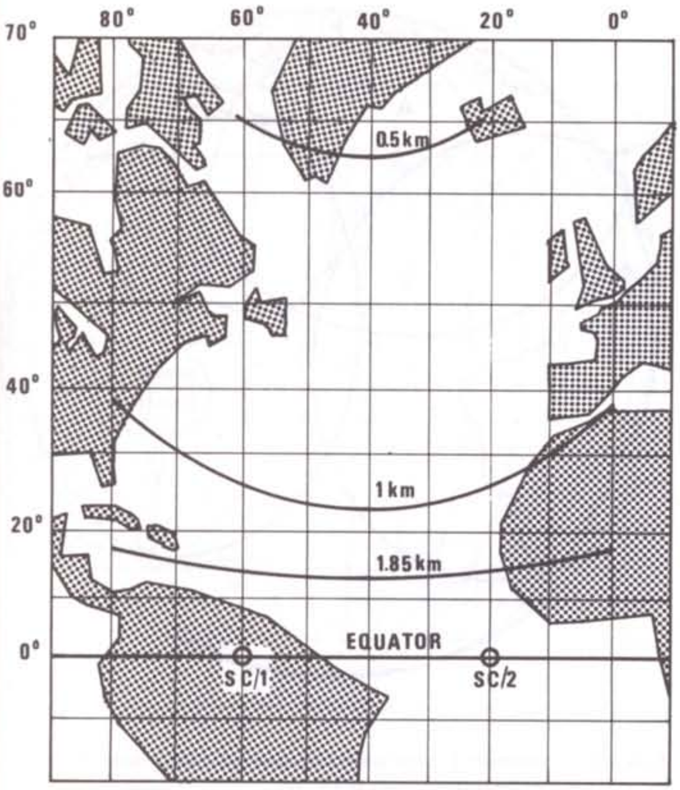


Figure 4 — Location errors over the Atlantic for two-satellite ranging system

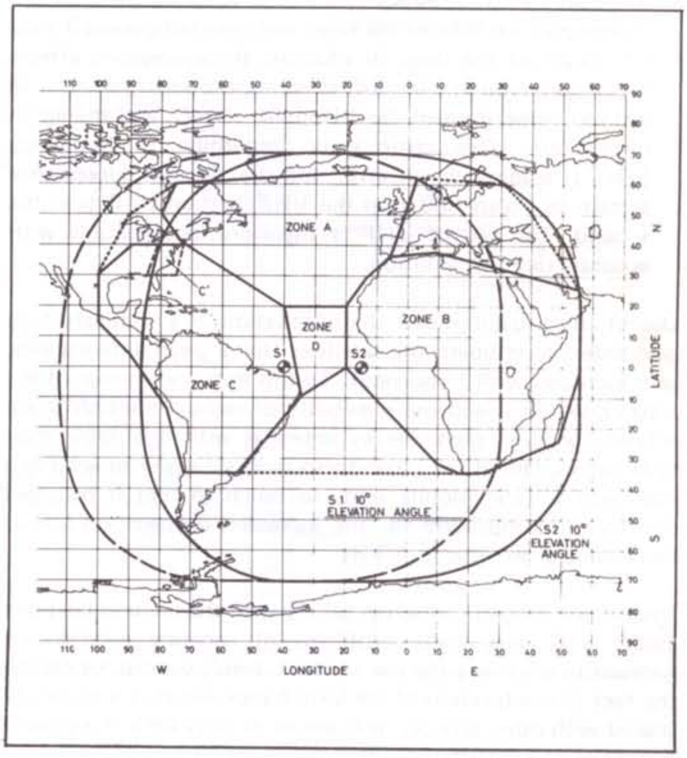


Figure 5 — Atlantic coverage, showing sectors of differing interest

compromise between a configuration giving good localisation accuracy, for which a high angular separation (40–50°) is preferable, and the need to have widespread satellite coverage.

The coverage zone has been divided into three main sectors, corresponding to zones of differing interest from an aeronautical point of view (Fig. 5).

- Zone A covers the North Atlantic routes, and carries the heaviest traffic.
- Zone B covers Europe and West Africa.
- Zone C covers the East Coast of North America, the neighbouring ocean zones, and South America.

As will be seen later, this division of coverage is of considerable interest from the point of view of satellite design.

Link Frequencies

The choice of frequencies to be used for links between satellites and aircraft has produced a wealth of literature and has led to much heated argument in recent years. In 1971, the World Radio Communications Administrative Conference assigned a 15 MHz band to the aeronautical service, a 7.5 MHz band to the marine service, with a further 1 MHz common to the two services, exclusively for links between satellites and mobiles at 1.5–1.6 GHz (L-band). While the marine community has already accepted this decision, with all projects for marine links by satellite using this band, argument continues in the aeronautical field between supporters of the L- and VHF-bands. It may therefore be appropriate at this point just to summarise the different parameters that influence this choice of frequency:

- Loss of propagation in free space for a stationary satellite with an elevation of 10° is 166.9 dB at 130 MHz (VHF), but 188.2 dB at 1.5 GHz (L-band).
- Ionospheric scintillation and attenuation are, however, more severe in the VHF-band than the L-band. For VHF, the reduction in levels received is less than 3–4 dB for 99% and

less than 14 dB for 99,9% of the time, while for the L-band it is negligible for 99% of the time, and does not exceed 0.1 dB for 99.9% of the time. In addition, the ionosphere affects the propagation rate of electric waves, producing an error in distance measurement (and Doppler effect), and thence in localisation. This error varies according to frequency ($\alpha 1/f^2$), leading to an error for the Aerosat surveillance system of about 800 m in the VHF, and only 10 m in the L-band. The use of VHF is therefore incompatible with accurate radio-localisation.

Use of the L-band allows the installation of a relatively high gain antenna on board the satellites (for a given antenna size, gain increases with frequency). To this initial advantage of the L-band, we must add the possibility of using a multiple-beam antenna or even phased-array antennas with orientable multiple beams. Use of the L-band also makes it easier to achieve a high gain on the mobile unit, so much so that it becomes possible to compensate for the increased propagation loss in the L-band with respect to VHF.

Even if we concern ourselves purely with the communications aspect and leave aside problems of accurate localisation, necessarily involving the use of the L-band, we cannot escape the fact that saturation of the VHF bands, which are currently shared with other services, will sooner or later limit the growth capacities of a system using these frequencies.

The supporters of VHF stress that the various inconveniences of these frequencies are largely compensated for by lower equipment costs, due to the use of conventional technology – an analysis that seems to be based entirely on current prices for on-board equipment.

Types of Channel

Two categories of link must be provided:
(i) between ground and aircraft, and
(ii) between the various aeronautical telecommunications stations (ground-to-ground).

For category (i) links in the L-band, a functional distinction must be made between three types of channel:
– communications channels, which have a bandwidth of 80 kHz (at 1 dB). As already indicated, the minimum C/N_0 value to be provided here is 43 dB Hz
– surveillance channels, with the same characteristics as the communications channels, a single channel being used to transmit messages (speech or data), or a telemetry signal
– experimental channels: planned for inclusion at the request of the FAA, these wideband (10 MHz) channels will be used, inter alia, to test the precision of localisation.

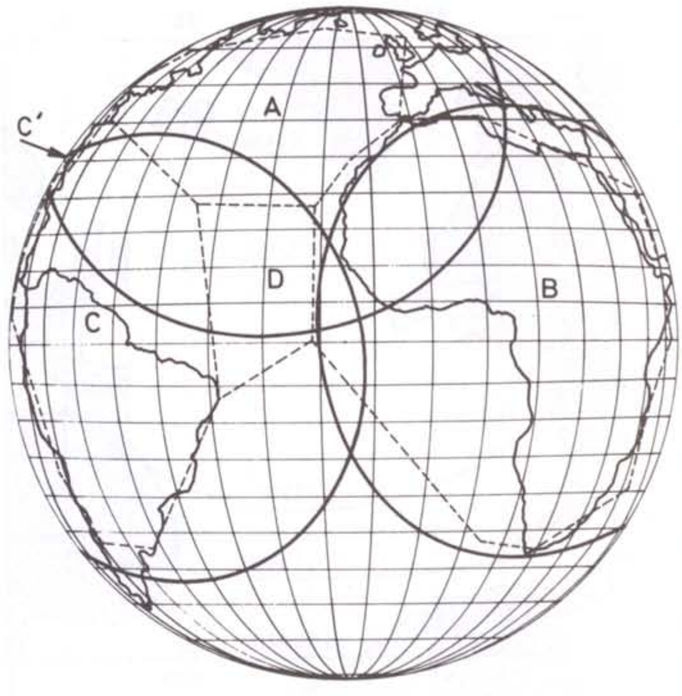


Figure 6 – Aerosat L-band transmit coverage, using three 10° × 12° ellipses (spacecraft at 15° W).

In practice, therefore, two sorts of channel will be employed, standard channels, and wideband experimental channels. The total number of standard channels under normal operation will be five per satellite for the ground-to-aircraft direction, with the possibility of having up to three in Zone A and two in Zones B and C in Figure 6, assigned from the ground by telecommand. For the return link, in the aircraft-to-ground direction, each satellite is required to supply 15 communication channels for all zones, and three surveillance channels (the return channels for the communications and surveillance functions are different: 40 kHz bandwidth for communications, and 80 kHz for surveillance). Furthermore, it is planned to be able to operate one ground-to-aircraft channel in Zone A at double power (minimum C/N_0 of 46 dB Hz).

The experimental channels must be available in the continental zone that includes the East Coast of the USA (Zones A and C' in Fig. 6), and each satellite must be capable of supplying one

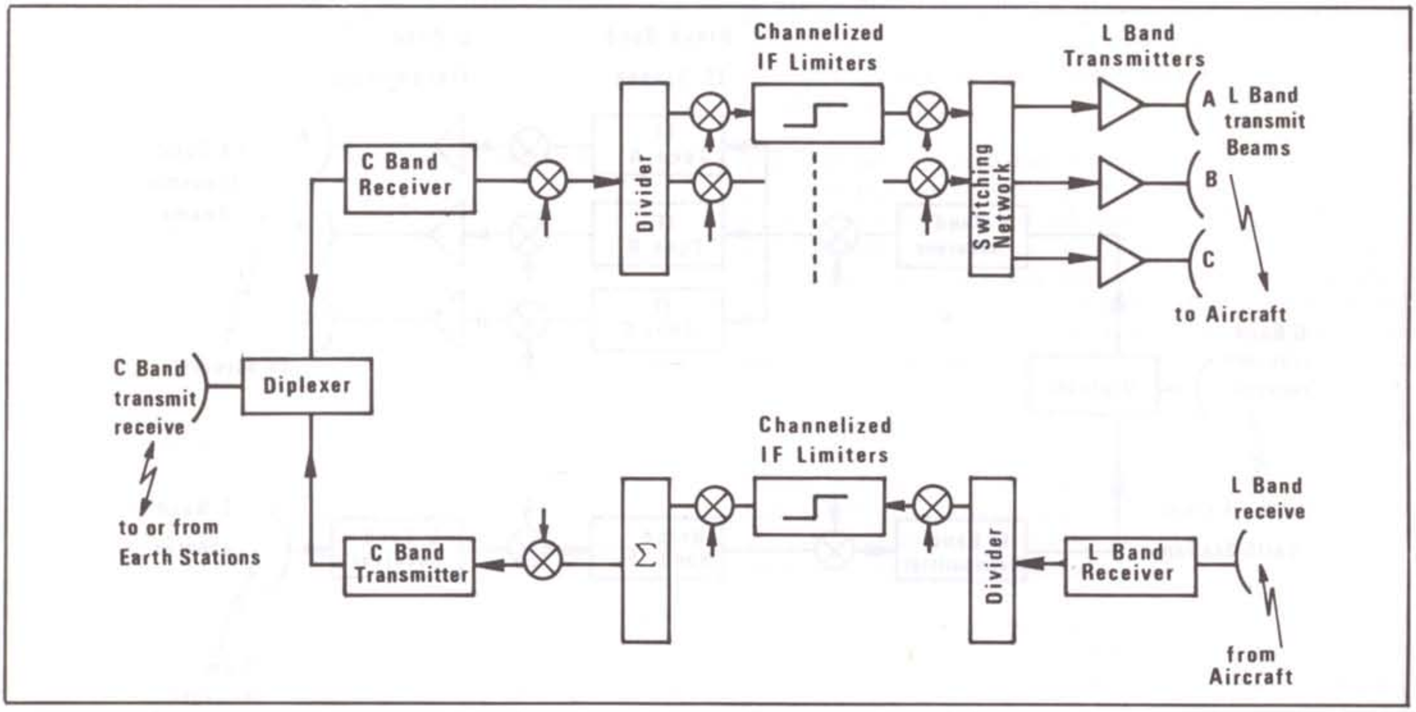


Figure 7 – Possible channelised transponder for Aerosat

experimental channel in both directions, on telecommand order.

Two VHF channels are planned for ground-to-satellite links, and four for the return link. The quality of these channels, with 25 kHz bandwidth, intended for communications or surveillance, will be identical to that of the L-band channels, and the satellites must be able to supply the VHF and L-band channels simultaneously at the beginning of life of the spacecraft.

Turning finally to the category (ii), ground-to-ground links, two C-band channels will be supplied by each satellite to provide co-ordination between ground stations.

OPERATION OF THE SYSTEM

The Aerosat system is designed to provide for the exchange of messages between a ground station and an aircraft, so that the call initiative has two possible origins.

When the initiative for the call comes from a ground station, this station knows the state of occupation of the channels, on the basis of which it prepares a call message for the aircraft in question. Generally, this message comprises the aircraft code, the code for the channel on which communication is to be established, and the type of message (speech, transmission of data, or localisation signal).

When the call originates from the aircraft, a number of possibilities exist. The aircraft can send a short call message, using a special aircraft-to-ground channel, indicating the station which it wishes to contact, its code, type of link to be established, etc. Using this information, the ground station then calls the aircraft in the same way as if the call had originated on the ground.

A second possibility is the calling of all aircraft from the ground in rotation, an aircraft wishing to contact the ground then indicating so when interrogated.

In practice, the choice between these and a number of other

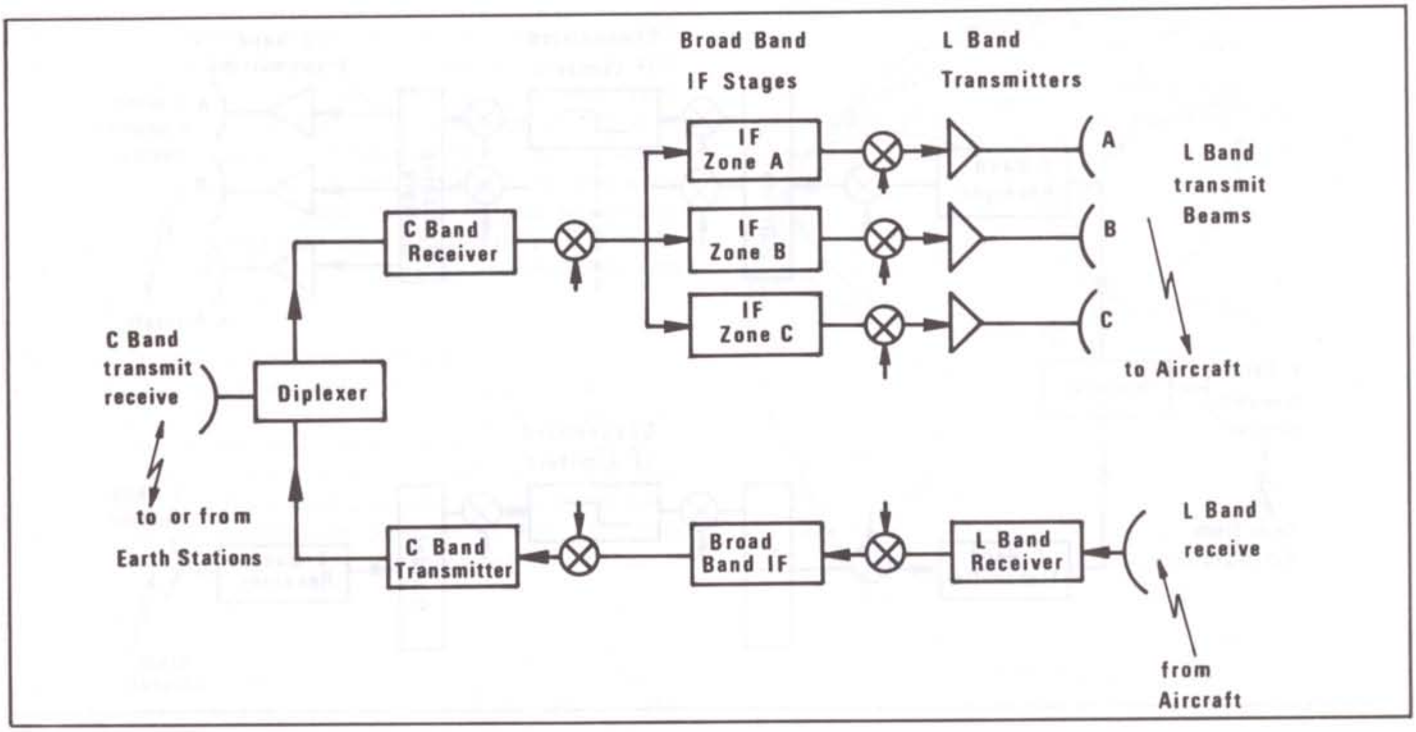


Figure 8 — Possible alternative broad-band transponder for Aerosat

possibilities depends partly on the number of aircraft involved and the degree of automation required. The Aerosat system will make it possible to evaluate the merits of the various operational possibilities.

DESIGN OF THE SATELLITE

The search for maximum communication capacity for a satellite is the fundamental element ruling the various technical choices to be made. Once the class of satellite has been fixed (launch vehicle selected), a rough idea of available on-board power can be obtained. The problem is then to distribute this available power between the largest possible number of telecommunications channels, whilst ensuring that each channel consumes a minimum of power. The most obvious way of reducing the power transmitted by the satellite is to ensure that the receiving station has a high antenna gain. The ground station can be given a high gain comparatively easily, but the mobile unit, and particularly that on an aircraft, suffers from the necessarily limited antenna dimensions, and gain is consequently low.

Under these conditions, the system is characterised by substantial imbalance between satellite-to-ground and satellite-to-aircraft links. The major part of the available power must be assigned to the latter link, thus limiting satellite capacity in practical terms. Very little can be done to increase the gain of the mobile, but the gain on board the satellite can be improved by the use of multiple beam antennas, referred to earlier, each beam covering only part of the terrestrial disc visible to the satellite.

There is, however, a limit to the progress that can be achieved in this direction also, since the weight and complexity of the system increases with the number of beams, to such an extent that the extra gain obtained is counterbalanced by a reduction in the fraction of the total satellite mass available for the power supply. In addition, increasing the number of antenna beams reduces the system's operational flexibility, as the switching circuits needed do not allow instantaneous channel-arrangement selection.

TABLE 1

Satellite data

Launch vehicle	Thor-Delta 3914
Transfer orbit payload	900 kg
Orbit	Geosynchronous/equatorial
Satellite mass	
In stationary orbit	410–430 kg
In transfer orbit (with apogee boost motor and adaptor)	850–880 kg
Power available (end of lifetime)	Approx. 800 W
Configuration	Three-axis stabilisation and deployable solar panels
Lifetime	7 years
Station-keeping	Longitudinal
Possibility for change of position	One transfer to another ocean at a rate of 20° per week
Antenna pointing accuracy	–0.5°

TABLE 2

Communications system

Satellite-to-ground link	C-band Antenna: global coverage Gain: 17 dB
Satellite-to-aircraft link	L-band VHF
satellite/aircraft	L-band Antenna: three-beam Gain: approx. 21 dB Transmitter power: 25–30 W RF per channel VHF Antenna: global coverage Gain: approx. 10 dB Transmitter power: 50–55 W RF per channel
aircraft/satellite	Antenna: global coverage L-band: gain 17 dB VHF: gain approx. 10 dB (aircraft power output: 23 dBW for L-band, 17 dBW for VHF)
Transponder	
C → L (ground-to-aircraft in L-band)	Mass (less antenna): 25 kg Power consumption: 460–480 W
VHF transmitter/receiver	Mass: 10–13 kg Power consumption: 240–250 W
L → C (return link)	Mass. 10–15 kg Power consumption: 35–40 W
Total communications payload	Mass: 50–60 kg Power consumption: 750–780 W

All in all, it transpires that a three-beam configuration provides the best operational compromise, and it is for this reason that Aerosat's coverage has been divided into the three main zones already mentioned.

With Aerosat's required operational lifetime of several years, it is evident that the system must be as simple as possible, so as to ensure a high degree of reliability. This criterion of simplicity was one of the reasons why use of an antenna with more than three beams was abandoned, and why no on-board signal-processing stages are envisaged. The transponder will merely be required to amplify and change the frequency of the received signal for re-transmission (Figs. 7 & 8).

The main technical parameters/characteristics of the Aerosat satellite are summarised in Tables 1 and 2. The majority of the figures quoted are intended only as a guide, and do not correspond to a particular study, but the satellite defined is in accordance with the technical annexes to the FAA/ESA/Canada Memorandum of Understanding.

It must not be forgotten that Aerosat is intended as an experimental system, many characteristics of which have not yet been frozen. The objective of the common evaluation programme is to study the various technical possibilities under environmental conditions. Modulation and multiplexing techniques are among the most important of the basic characteristics of the future aeronautical satellite system which have not yet been frozen, and the Aerosat system will be required to provide guidance in their selection.

SCHEDULE

The schedule for the Aerosat development programme is currently as follows:

– Calls for Tender for the spatial segment:	March 1976
– Receipt of tenders:	June 1976
– Selection of contractor:	November 1976
– Issue of contract and start of work:	Early 1977
– Development and execution phase:	Approx. 30 months
– Launch of first satellite:	Autumn 1979
– Launch of second satellite.	Mid-1980

□

Aeronautical and Maritime Communications Experiments with the ATS-6 Satellite

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Aeronautical and maritime satellite projects now form an important part of the Agency's communications satellite programmes. To assist in the definition of the mobile segments and their possible impact on satellite system utilisation, a series of experiments have been conducted by ESA using NASA's ATS-6 satellite to investigate the performance of representative voice, data transmission, and ranging systems in the presence of sea multipath interference. In addition, several joint real-time aircraft control demonstrations have been performed over the Atlantic by ESA and the US Federal Aviation Administration (FAA) and a joint ESA/US Coast Guard search-and-rescue demonstration has been conducted, this being the first using satellites.

EXPERIMENTS

The primary objectives of the ATS-6 L-band experiments were:

- to investigate fading amplitude distributions and frequency spectra as a function of elevation angle and sea state for ships and aircraft, with respect to the satellite
- to investigate the effect of sea multipath signal interference on coherent PSK (Phase-Shift Keying) data detection, tone and binary PRNS (Pseudo-Random Noise Sequence) ranging systems
- to investigate the comparative quality of a Delta-PSK and NBFM (Narrow-Band Frequency Modulation) voice transmission under the effects of sea multipath signal interference
- to assess the performance and reliability of gyro-stabilised, shipborne antennas and a simple phased-array aircraft antenna under service conditions
- to perform a series of communication experiments with a float-off SAR (Search-And-Rescue) beacon designed to alert rescue forces via satellite when a beacon-equipped ship sinks, and to use the buoy in a realistic search-and-rescue demonstration via satellite
- to perform a series of air-traffic-control demonstration tests via satellite in order to demonstrate to aeronautical authorities and airlines the feasibility of satellite communications using L-band frequencies.

The ATS-6 project group at ESTEC was responsible for: overall definition of the experiments and negotiating the experiment proposals with NASA, renting of the aircraft and ship used in the experiments, interfacing of ground-station, aircraft and ship equipment with experimenters' equipment and integration on board the mobiles, operations management of the experiments, the Position Location Aeronautical Communication Experiment (PLACE) conducted within the project group, and analysis of the multipath experiment.

TABLE 1

	Participating		*Experiments Performed & Equipment Furnished*
	Country	*Institute*	
Aeronautical Experiments	United Kingdom	Royal Aircraft Establishment (RAE)	Comet-IV aircraft (leased to ESTEC) L-band antenna system (evaluation of coverage and multipath rejection)
	France	SGAC/CNET	Dioscures TDM communication avionics (Delta-PSK voice, encoded-data and PRNS ranging system)
	ESTEC Experiment Management and Integration		L-band transmitters and receiving system, data-logging system, central timing system, PLACE experiment (NBFM voice, DECPSK data tone-ranging and multipath expt.)
Maritime Experiments	Germany	DFVLR	Vessel 'Otto Hahn' (leased to ESTEC). SAR buoy experiment
	France	CNET/CNES	Dioscures maritime terminal. Quad helix stabilised antenna system
	Norway	NTNF	Vessel 'Skiensfjord'. Phased-array antenna system and PSK data-transmission experiment
	United Kingdom	Post Office (Telecomm.)	Companded NBFM and Delta-PSK voice experiment
	ESTEC Experiment Management and Integration		Quadri-short backfire antenna system PLACE experiment

Four European countries took part in the two series of

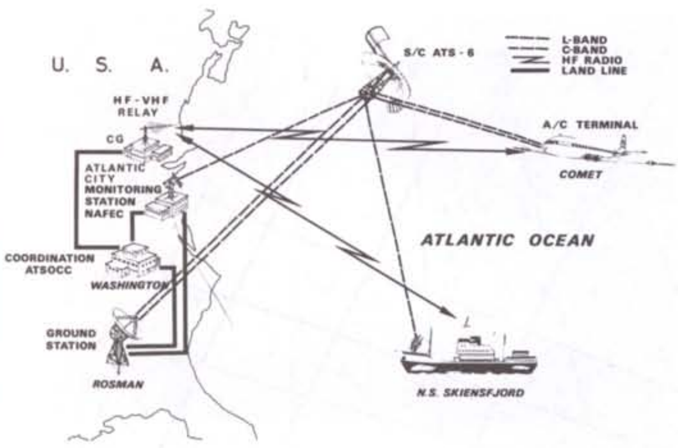

Figure 1 – Experiment configuration during the first, Atlantic City campaign.

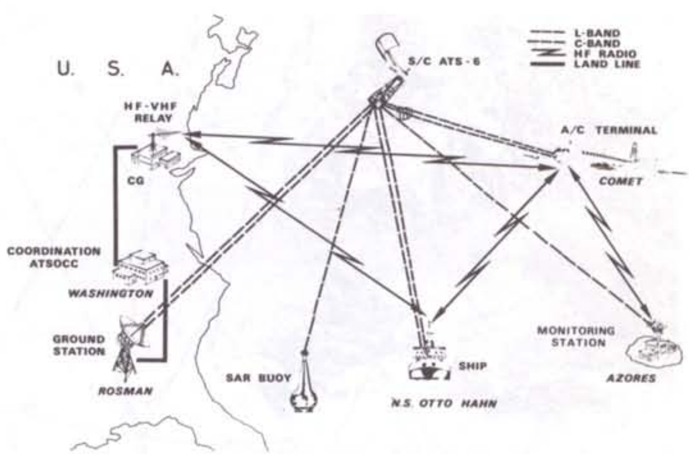

Figure 2 – Experiment configuration during the second, Azores campaign.

communication experiments (aeronautical and maritime). The participating national institutes and organisations are listed in Table 1, where the items of equipment that they loaned for the duration of the experiments are also shown.

EXPERIMENT CONFIGURATIONS AND TIMETABLES

The experiments were organised into two main campaigns, from 26 August to 2 October 1974, based at Atlantic City NJ, USA, and 21 February to 6 April 1975, based at Terceira, Azores (Portugal).

These two separate campaigns were organised to cover the high elevation angles 40° down to 18° with the Comet-IV aircraft from the FAA facility at Atlantic City and for the MV 'Skiensfjord' which crossed the Atlantic Ocean twice during the month of September 1974, and to cover the low elevation angles 15° down to 0° from the Portuguese Air Force/USAF base at Lajes during the second campaign with the Comet-IV aircraft and the NS 'Otto Hahn'. Figures 1 and 2 show the disposition of the mobile units during the two campaigns and Figure 3 shows a typical antenna coverage from ATS-6 during the Azores campaign.

During the aeronautical experiments, 138 h of data were taken in 38 flights, and for the maritime experiments 54 h of data were taken in 16 days on board the MV 'Skiensfjord' and 145 h of data in 30 days on board the NS 'Otto Hahn', each day comprising about 5 h of satellite time.

Following these two mobile experiment phases, a short final phase of experiments was conducted in late May and early June 1975 from a cliff top in SW England, with ATS-6 drifting eastward, to validate certain earlier results. This provided a unique opportunity with a daily increasing satellite elevation angle, whilst ATS-6 was being moved from its initial longitude of 94°W to 35°E for its second year of operation, with India.

RESULTS AND CONCLUSIONS

A principal reason for conducting the experiments was to examine the effect of multipath interference from the sea-scattered signal on the systems tested, all of which were candidates for future aeronautical and maritime satellite services. An excellent analogy of the multipath effect is seen in Figure 4, which shows the glistening pattern of the setting sun on the sea's surface. Clearly, the multipath effect only becomes a problem at low elevation angles, when the antenna pattern intersects the sea's surface. Modulation methods that require a signal-derived phase reference are particularly prone to detection problems when subjected to this type of interference. Unfortunately, such methods happen to provide the most efficient means of information transfer at the frequencies in question and are thus regarded as prime candidates for such radio-frequency power-limited satellites as Aerosat and Marots.

To summarise the results, TDM (Time-Division-Multiplexed) systems showed a marked improvement over analogue techniques in the critical low-elevation-angle region, mainly because

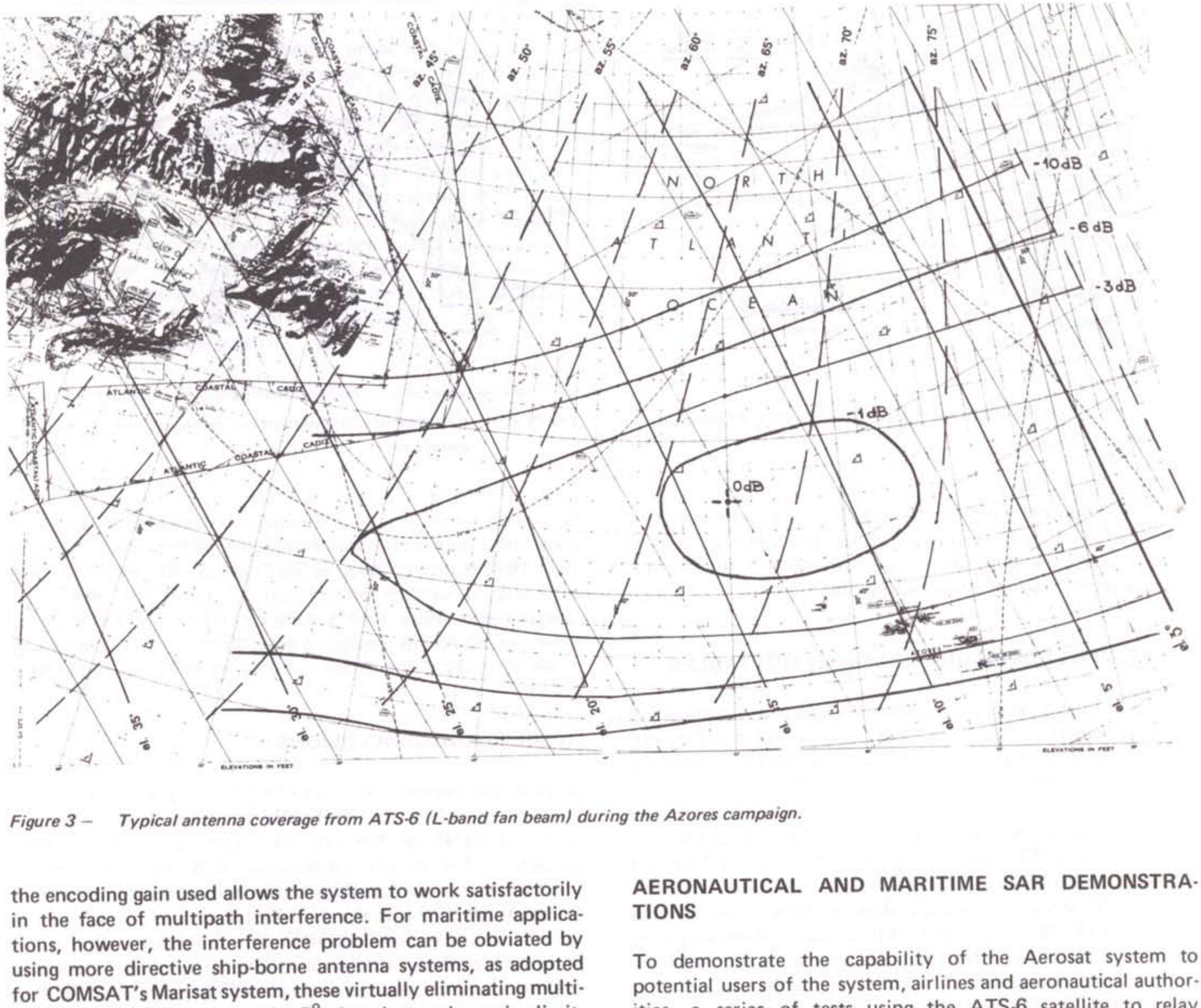

Figure 3 – Typical antenna coverage from ATS-6 (L-band fan beam) during the Azores campaign.

the encoding gain used allows the system to work satisfactorily in the face of multipath interference. For maritime applications, however, the interference problem can be obviated by using more directive ship-borne antenna systems, as adopted for COMSAT's Marisat system, these virtually eliminating multipath interference down to the 5° elevation angle service limit. For aeronautical applications, an improvement in multipath rejection is much more costly, bearing in mind the most important requirements of the aircraft antenna, a relatively low unit cost and very high reliability through a severe environment. Adoption of TDM techniques, which performed very satisfactorily with the slot-dipole array antenna evaluated on the Comet aircraft, is probably therefore a preferred solution.

AERONAUTICAL AND MARITIME SAR DEMONSTRATIONS

To demonstrate the capability of the Aerosat system to potential users of the system, airlines and aeronautical authorities, a series of tests using the ATS-6 satellite to relay operational voice and data messages were conducted (Fig. 2). The operational centre for the aeronautical demonstration was the FAA's National Aviation Facilities Experimental Center, whilst the operational centre for the SAR operation was the US Coast Guard's Headquarters in Washington DC, both centres being linked by telephone lines to NASA's Rosman ground station. In the aeronautical demonstration, voice and data messages were passed to ESA's Comet and the FAA's KC135 aircraft.

Figure 4 – An optical analogy of the multipath effect – diffuse reflection of the setting sun's rays from the sea surface.

RAE's Comet-IV aircraft

The 'Otto Hahn'

For the SAR demonstration, performed about 100 miles north of the Azores, the DFVLR buoy was placed in the water and transmitted its coded signal via ATS-6 to the Rosman ground station. The latter alerted the Coast Guard in Washington, who then used satellite links to co-ordinate the Comet aircraft and their cutter 'Gallatin' in the search for the buoy. The aircraft obtained a fix on the buoy after a two-hour search and then 'vectored' the Gallatin onto this fix, which was then refined by that vessel's direction finder. The buoy was taken out of the water about one hour after the aircraft fix, in conditions of wind force 6. This marked the successful conclusion to the first search-and-rescue operation to be initiated and conducted using satellite communications.

ACKNOWLEDGEMENTS

The authors wish to thank the staff of NASA's Goddard Space Flight Center who arranged the use of the ATS-6 satellite for these experiments, and the European experimenters who collaborated so well with ESTEC's project team to ensure a successful outcome to the campaigns.

□

SDS RECON Terminal in Morocco

Mr. Roy Gibson, Director General, signing the Visitors' Book at Mohammed V's Mausoleum during his visit to Rabat, on 25 January, on the occasion of the inauguration of the ESA Space Documentation Service's RECON terminal at the National Documentation Centre of Morocco.

M. Roy Gibson, Directeur général, signe le livre d'or du mausolée Mohammed V au cours de sa visite à Rabat, le 25 janvier, à l'occasion de l'inauguration du terminal RECON du Service de Documentation spatiale de l'Agence, installé au Centre national de Documentation du Maroc.

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 addressed to ESA Scientific and Technical Publications Branch, c/o ESTEC, Domeinweg, Noordwijk, Netherlands.

The following papers were published in Vol. 2, No. 1:

Whisker Formation on Electronic Materials, *by B.D. Dunn*

ABSTRACT

Filametary growths of single crystals, termed 'whiskers', nucleate and grow on certain electronic materials, either from vapour and liquid phases or by a process induced by residual stresses in electroplated surfaces. Whisker growth does not depend on the existence of an electric field and surfaces prone to their growth may nucleate and form whiskers as a result of exposure to a space environment.

This paper includes a detailed examination of tin whiskers which were found to have 1–4 μm diameters and lengths exceeding 2 mm. Some were found to carry currents between 22 and 32 mA before burning out. Conductive whiskers can cause extensive short-circuit damage to spacecraft electronics, particularly as miniature devices progressively employ reduced spacing between conductors. Several modes of whisker growth on spacecraft electronic materials (molybdenum, tungsten, kovar, tin) have been observed and are described. Tin, cadmium and zinc surfaces can support stress-induced whisker growth and it is recommended that these metal finishes be excluded from spacecraft design and possibly replaced by a tin-lead alloy.

RESUME

Les filaments monocristallins, ou 'trichites', qui se forment à la surface de certains matériaux utilisés en électronique, prennent naissance soit à partir d'une phase gazeuse ou liquide, soit sous l'action des contraintes résiduelles sur des surfaces à revêtement électrolytique. La croissance de trichites ne dépend pas de l'existence d'un champ électrique et peut se produire par simple exposition à l'environnement spatial.

Dans cet article, on examine en détail les trichites d'étain qui ont atteint des diamètres de 4 μm et des longueurs supérieures à 2 mm. Certaines ont même supporté des courants de 22 à 32 mA avant de fondre. Les trichites conductrices, par les courts-circuits qu'elles provoquent, peuvent causer des dommages importants à l'électronique des véhicules spatiaux, vu la miniaturisation de plus en plus poussée des composants et des espaces séparant leurs parties conductrices. On décrit plusieurs modes de croissance des trichites observées sur des matériaux utilisés dans l'électronique des véhicules spatiaux (molybdène, tungstène, kovar, étain). L'étain, le cadmium et le zinc peuvent donner naissance à des trichites par simple effet de contrainte et il est recommandé de proscrire tout revêtement métallique à base de ces métaux dans la construction des satellites pour les remplacer par un alliage du genre étain-plomb.

Rise and Set Time and Maximum Elevation of a Satellite, *by E.A. Roth*

ABSTRACT

The set-and-rise time of a near-Earth satellite is calculated analytically and the maximum elevation reached during a visibility period is determined. With the approach presented, it is not necessary to generate a detailed ephemeris, so that considerable computing time can be saved. The method is particularly appropriate if the satellite orbit is specified analytically or semi-analytically.

RESUME

On calcule par des procédés analytiques les instants d'apparition et de disparition d'un satellite en orbite terrestre basse et on détermine l'élévation maximale atteinte au cours de la période de visibilité. Cette méthode rend inutile l'établissement d'éphémérides détaillées et permet ainsi de réduire considérablement les temps de calcul. La solution est tout à fait indiquée dans le cas où l'orbite du satellite est spécifée de façon analytique ou semi-analytique.

Etablissement de modèles mathématiques pour régulateurs de puissance à modulation de largeur d'impulsion (PWM) – 1. Modèles discrets, *par R. Prajoux, J.-C. Marpinard & J. Jalade*

RESUME

On cherche à établir un modèle mathématique discret de régulateur de puissance à modulation de largeur d'impulsions (PWM), destiné à l'étude du comportement à petit signal des convertisseurs continu-continu considérés comme des systèmes électriques comportant des changements de structure. On définit d'abord le vecteur d'état discret à partir des équations d'état du système. La méthode de mise en équation correspondante permet d'obtenir soit la récurrence associée à ce vecteur d'état, soit la transmittance en z du système linéaire équivalent. Le modèle ainsi obtenu permet de calculer le gain équivalent du modulateur PWM associé à l'étage de sortie. Une méthode de calcul de l'impédance de sortie est également présentée. Enfin les résultats généraux obtenus sont appliqués au cas concret d'un régulateur élévateur.

ABSTRACT

An accurate mathematical model of a PWM power regulator is derived with a view to determining the small-signal behaviour of DC-DC converters, considered as electrical systems with varying structures within a given period. A discrete state vector is first defined from the state equations of the system. By using the appropriate method of equation derivation, one can obtain either the recurrence related to the state vector, or the z-transmittance of the equivalent linear system. Such a system

allows one to calculate the equivalent gain of the PWM modulator associated with the output stage. A method of calculating output impedance is also presented. The general results obtained are applied to the case of a boost regulator.

ESA Activities in the Field of Hydrazine Monopropellant Technology for Satellite Auxiliary Propulsion, *by H.A. Pfeffer*

ABSTRACT

Hydrazine monopropellant systems have proved to be the standard solution for auxiliary propulsion of ESA's satellites. After a review of the origins of the Agency's technology programme in this field, past and present activities are summarised.

Development activities cover: catalysts, catalytic engines, flow control valves, materials compatibility, diaphragm and surface-tension tanks, catalytic and electrothermal gas generators, electrothermal decomposition engines, and theoretical studies. The performances of European hydrazine engines are presented.

RESUME

Les systèmes de propulsion monergolique à hydrazine se sont révélés comme la formule type dans la propulsion auxiliaire des satellites de l'ASE. Après avoir passé en revue les origines du programme technologique de l'Agence, on décrit brièvement les activités passées et présentes dans ce domaine.

Les activités de développement portent sur les catalyseurs, les moteurs à catalyse, les vannes de commande de débit, la compatibilité des matériaux, les réservoirs à membrane et à tension superficielle, les générateurs de gaz à décomposition catalytique et électrothermique, les moteurs à décomposition électrothermique, et enfin les problèmes théoriques. Les performances des moteurs européens à hydrazine sont également présentées.

Méthodes d'étalonnage absolu des flux ultraviolets, *par G. Marette*

RESUME

Les diverses méthodes de mesure précise des flux absolus de sources lumineuses dans l'ultraviolet entre 50 nm et 400 nm sont passées en revue. Elles reposent soit sur des sources étalons émettant un continu ou de la lumière à des longueurs d'onde discrètes, soit sur des détecteurs étalons. Les techniques d'étalonnage absolu des flux sont comparées d'après les résultats obtenus par les divers auteurs, en tenant compte de la précision demandée par les spectroscopistes. Les avantages et inconvénients respectifs des sources et des détecteurs sont mis en évidence. Enfin on présente une nouvelle méthode combinant les avantages d'une source et d'un détecteur étalons.

ABSTRACT

Various methods for the accurate measurement of absolute flux from luminous sources in the ultraviolet from 50 nm to 400 nm are reviewed. They are based either on standard sources, which emit a continuum or light at discrete wavelengths, or on standard detectors. Techniques for absolute calibration of fluxes are compared from the results obtained by the various authors, taking into account the accuracy required by spectroscopists. The respective advantages and disadvantages of sources and detectors are described. Finally, a new method combining the advantages of a standard source and a standard detector is presented.

Requirements for Propagation Research at Frequencies above 15 GHz, *by G. Brussaard*

ABSTRACT

After indicating future requirements for use of the 20 and 30 GHz bands for satellite communication systems, the paper describes the atmospheric effects on radiowave propagation in the 15–40 GHz range. Present knowledge regarding the different phenomena is reviewed and gaps and inaccuracies in available prediction methods are indicated. Using this information as a basis, the requirements for future propagation research by the Agency are outlined.

RESUME

On détermine d'abord les exigences concernant l'utilisation des bandes de fréquence de 20 et 30 GHz pour les futurs systèmes de télécommunications par satellite, puis on décrit l'influence de l'atmosphère sur la propagation des ondes radio dans la gamme 15–40 GHz. On passe en revue l'état actuel des

connaissances sur les différents phénomènes en jeu et on indique les lacunes et imprécisions des méthodes de prévision existantes. A partir de là, on définit quelle orientation il convient de donner aux recherches de l'Agence dans le domaine de la propagation.

ESA Computer Programs for Satellite-Antenna-Pattern Prediction, *by D.J. Brain & N.E. Jensen*

ABSTRACT

Because experimental optimisation of antennas is a lengthy and expensive task, ESTEC has had a policy for several years of systematic development of computer programs for predicting spacecraft-antenna radiation patterns. As a consequence of this policy, an extensive program library now exists at ESTEC. These programs can be divided into three groups according to the techniques used: Integral Equations, Geometrical Theory of Diffraction, and Physical Optics. A choice must be made between them depending upon the particular application. To aid in such a choice, the basic limitations and approximations are described, the programs outlined, and application results presented.

The programs have been verified extensively by comparison with measurements and are now at a stage where they can be used as reliable engineering tools.

RESUME

L'optimisation d'antennes par des méthodes empiriques étant une tâche coûteuse et de longue haleine, l'ESTEC poursuit depuis plusieurs années une politique d'élaboration systématique de programmes d'ordinateur pour la prévision des diagrammes de rayonnement d'antennes de satellites. Si bien qu'il existe désormais à l'ESTEC toute une bibliothèque de programmes dans ce domaine. Ces programmes peuvent se répartir en trois groupes selon les méthodes utilisées: équations intégrales, théorie géométrique de la diffraction, optique physique. Le choix dépend de l'application envisagée. Pour éclairer ce choix, on expose ici les restrictions et approximations fondamentales de ces méthodes, on décrit les programmes correspondants et on présente les résultats d'application.

Ces programmes ont été confronté dans un grand nombre de cas avec les mesures directes et ont maintenant atteint un stade où ils peuvent être valablement utilisés comme auxilaires de conception.

Interactive Manipulation of Algebraic Expressions, *by V. Casarosa & S. Trumpy*

ABSTRACT

An interactive system for the formal manipulation of rational algebraic expressions is described. A user can define symbolic expressions containing the arithmetic operators +, –, X, ÷, * and symbolic names, and a set of special 'epi-operators' is provided for the manipulation of these expressions. The system has been implemented under APL/CMS, but can be used on any system supporting the APL language.

RESUME

*On décrit un système interactif pour la manipulation formelle des expressions algébriques rationnelles. Un usager peut définir des expressions symboliques contenant les opérateurs arithmétiques +, –, X, ÷, * et des noms symboliques. On donne également un ensemble d'opérateurs spéciaux appelés 'épi-opérateurs' pour la manipulation de ces expressions. Le système a été réalisé en APL/CMS, mais peut être mis en oeuvre dans le cadre de n'importe quel système travaillant en langage APL.*

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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 1 – Preprint).

TECHNICAL MEMORANDA

TM-163 Fuel-slosh test-rigs for GEOS and Meteosat – design, study, manufacture and testing, *by J.W. Rowley*

TECHNICAL NOTES

TN-133 Lignes directrices des activités 'Matériaux' de l'ASE, *by J. Dauphin*

SCIENTIFIC MEMORANDA

SM-83 Optimum quantisers for a Gaussian input probability density and the magnitude-error distortion measure, *by J.G. Demaret*

SCIENTIFIC REPORTS

SR-26 Perturbation of a satellite orbiter by the oblateness of the primary planet, *by E.A. Roth*

CONTRACTOR REPORTS

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CR-573 Modal survey tests on the spacecraft structure ITOS RCA 1 769 701, *by DFVLR, Germany*

CR(P)-765* Thermal vacuum accelerated life test, dismantling and examination of No. 1 MSDS low speed mechanism, *ESTL-16, by European Space Tribology Laboratory, UKAEA, UK*

CR(P)-766 Technical and economic study of a domestic or community 12 GHz band satellite broadcast receiver, Final report, *by GTE Telecommunicazioni SpA, Italy*

CR(P)-767 Array experiment electronics, *by RFE Ruimfahrtelektronik GmbH, Germany*

CR(P)-768* Design, manufacture & testing of a gas controlled heat pipe & microwave source, *by Institut für Kernenergetik, Universität Stuttgart, Germany*

CR(P)-769 A numerical technique to predict scattering from bodies of revolution (Users' guide for the computer program ROT2), *by Technical University of Lyngby, Denmark*

CR(P)-770 Study on the compression of image data onboard an applications or scientific spacecraft, Vol. 1: Description of the simulator & summary of results, *by Messerschmitt-Bolkow-Blohm GmbH, Germany*

CR(P)-771 *Idem*, Vol. 2: Mathematical deviations of compression methods

CR(P)-772 *Idem*, Vol. 3: User's manual

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CR(P)-783 Détermination de la durée de vie des accumulateurs Argent-Cadmium en orbite géostationnaire — Rapport final, *par SAFT, France*

CR(P)-784 Evaluation d'un accumulateur nickel-hydrogène à usage spatial — Rapport final, *par SAFT, France*

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TECHNICAL TRANSLATIONS

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OTHER PUBLICATIONS

ESA Report to the 19th COSPAR Meeting, Philadelphia, USA, June 1976, *by R.D. Andresen, D. Breton, J.J. Burger, A.C. Durney, D. Jones, K. Knott, F. Macchetto, A.F. Moorwood, D.E. Page, K.P. Wenzel, R.D. Willis*

ESRO SP-89

CELESTIAL OBJECTS AND SATELLITE ASTRONOMY

OBJETS CELESTES ET ASTRONOMIE PAR SATELLITE

A. Bastos

This book consists of two parts. The first, introductory, part deals with the various kinds of astronomical satellites, the sort of observations they perform and the signals they transmit to astronomers on earth. It explains how the different kinds of signal may interfere with one another and how the information sought may be masked by unwanted signals or noise. In particular, it deals with the interference that may be caused by large celestial objects such as clusters and nebulae. The second part is a catalogue of 320 such large, bright objects. Each object is identified by its equatorial, ecliptic and galactic co-ordinates; photographs of it and its immediate neighbourhood are provided and brief mention is made of any interesting peculiarities. The object of the book is to assist those engaged in the study of the data provided by astronomical satellites.

Ce livre comprend deux parties. La première partie, qui est une introduction, considère les différents types de satellites astronomiques, les observations qu'ils peuvent effectuer et les signaux susceptibles d'être transmis aux astronomes au sol. Elle explique comment un brouillage mutuel peut se produire et comment l'information peut être masquée par du bruit ou des signaux indésirables. En particulier, les interférences causées par des objets célestes de grandes dimensions tels que des nébuleuses et des amas d'étoiles sont considérées. La seconde partie est un catalogue comprenant 320 objets brillants et de grandes dimensions. Chaque objet est défini par ses coordonnées équatoriales, écliptiques et galactiques. Des photographies des objets et de leurs voisinages immédiats sont incluses et les particularités intéressantes sont brièvement mentionnées. Le livre a pour but de faciliter la tâche des personnes qui étudient les données transmises par des satellites astronomiques. □

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