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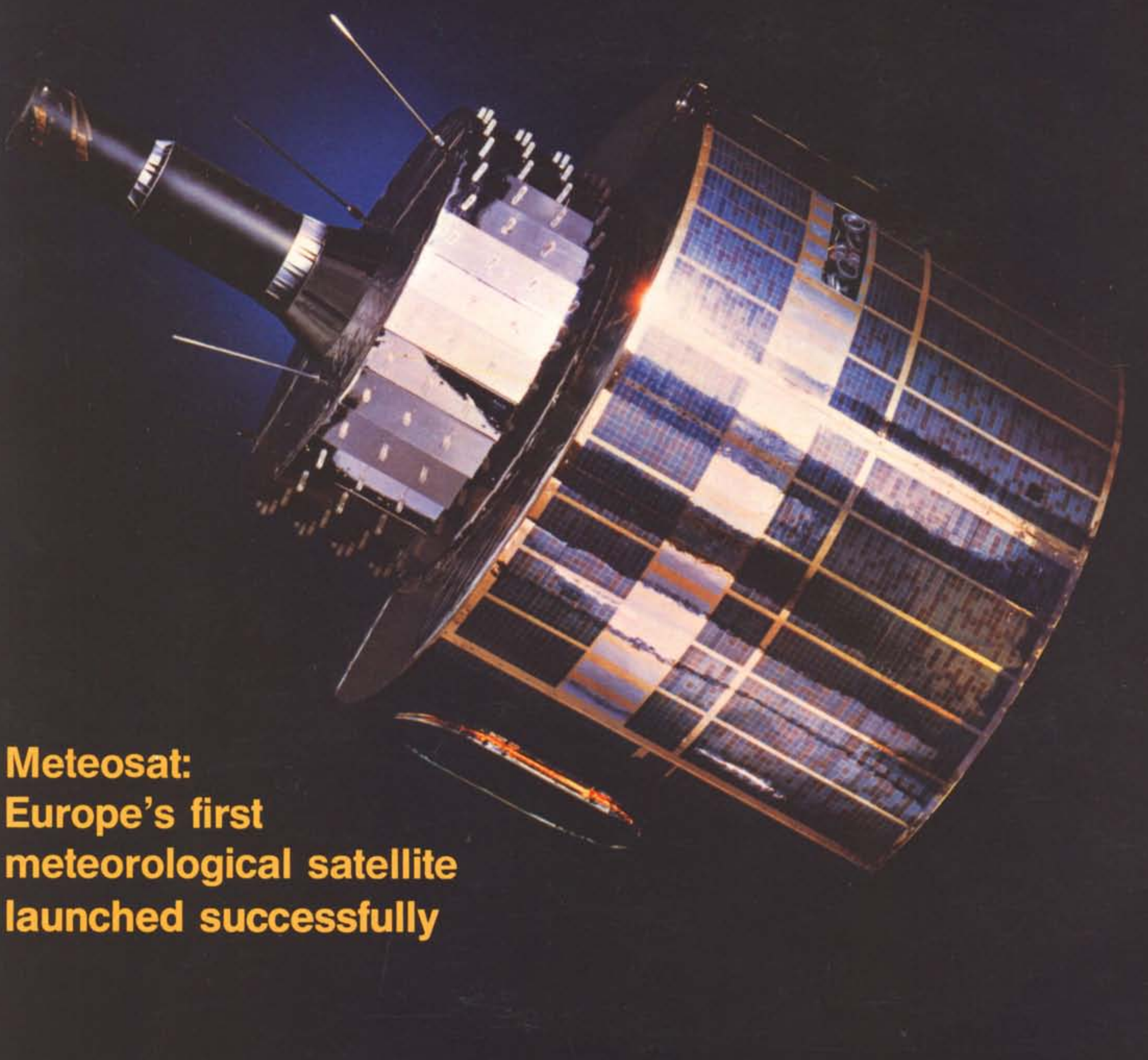

Meteosat: Europe's first meteorological satellite launched successfully

european space agency
agence spatiale européenne

no.11
december 1977

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

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

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

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

The Directorate of the Agency consists of the Director General; the Director of Planning and Future Programmes; the Director of Administration; the Director of Scientific and Meteorological Satellite Programmes; the Director of Communication Satellite Programmes; the Director of the Spacelab Programme; the Technical Inspector; the Director of ESTEC and the Director of ESOC.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

THE SPACE DOCUMENTATION SERVICE (ESRIN), Frascati, Italy.

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

Director General: Mr. R. Gibson.

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

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

(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'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

LE SERVICE DE DOCUMENTATION SPATIALE (ESRIN), Frascati, Italie.

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

Directeur général: M. R. Gibson.

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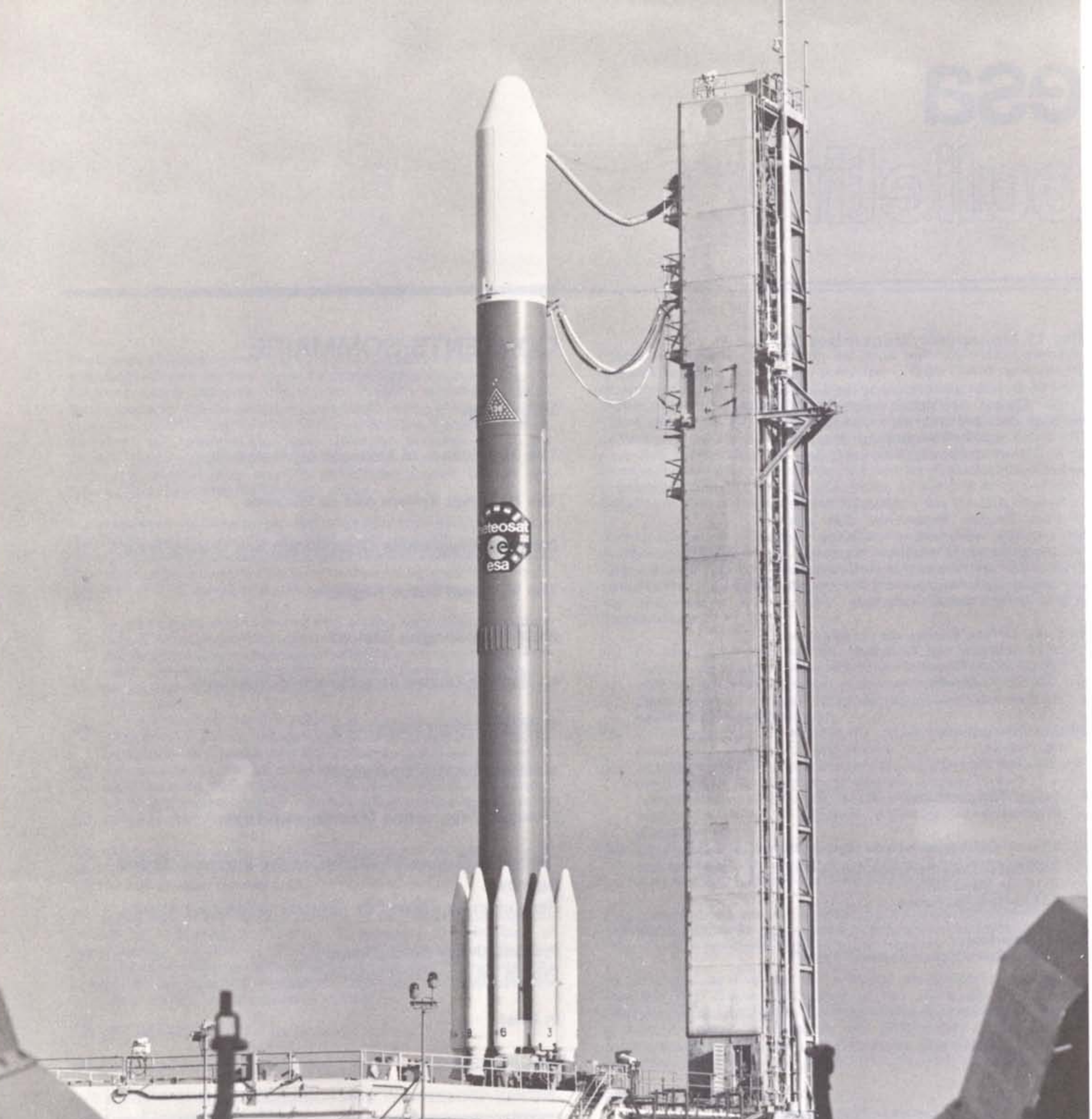
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Introduction

E.A. Trendelenburg, Director of Scientific and Meteorological Programmes, ESA

The Meteosat Programme is the European Space Agency's first meteorological satellite programme and represents the Agency's entry into the field of earth observation. The Programme was started by the French space and meteorological authorities, who performed the feasibility studies and undertook the pre-development of the satellite's radiometer. In 1972, the Meteosat Development Programme was 'Europeanised' through legal arrangements between ESA (ESRO) and CNES and between ESA and eight of its Member States (Belgium, Denmark, France, Germany, Italy, Sweden, Switzerland and the United Kingdom), which contribute financially to the programme on a Gross National Product basis.

In 1973, the main effort was concentrated on the definition of the system in accordance with the mission requirements established by the Meteorological Programme Board (PB-MET) and its Scientific and Technical Advisory Group (STAG). For the space segment Definition Phase (Phase B), contracts were awarded to two industrial consortia, COSMOS and MESH, resulting in two competitive offers for the subsequent Design and Development Phases (C/D). The Meteosat ground segment, so far the most complex of ESA's programmes, was defined by in-house effort.

Major Programme Milestones

1972	Europeanisation of programme, signing of legal arrangements
1973	Definition of space segment (in industry) and ground segment (in-house)
1974	System design, Critical Design Review, start of development, experimental campaign on data-collection-platform multipath effects
1975	Satellite structure and thermal model tests, engineering-model integration, finalisation of Meteosat Protocol
1976	Satellite engineering-model tests and prototype integration, start of ground-segment acceptance tests and ground/space compatibility tests
1977	Decision to launch Meteosat-2 in 1980, P2/F1 system performance and environmental tests, Flight-Readiness Review, Meteosat-1 launch

Le programme Météosat, premier programme de satellite météorologique de l'Agence spatiale européenne, marque son entrée dans le domaine des observations terrestres. Ce programme a été lancé par les autorités spatiales et météorologiques françaises qui ont effectué les études de faisabilité et de pré-développement du radiomètre du satellite. En 1972, le programme de développement Météosat était 'européanisé' grâce à des arrangements juridiques conclus par l'ESA (ESRO à l'époque) avec, d'une part, le CNES et, d'autre part, huit de ses Etats membres (Allemagne, Belgique, Danemark, France, Italie, Suède, Suisse et Royaume-Uni) qui contribuent au financement du programme sur la base de leur PNB.

En 1973, l'essentiel de l'effort a porté sur la définition du système, en fonction des impératifs de mission définis par le Conseil directeur du programme de satellite météorologique (PB-MET) et, son Groupe consultatif scientifique et technique (STAG). Pour la phase B du secteur spatial, des contrats ont été passés avec deux consortiums industriels, COSMOS et MESH, qui ont soumis deux offres concurrentielles pour les phases ultérieures de conception et de développement (C/D). Le secteur terrien Météosat, le plus complexe à ce jour des programmes de l'ESA, a été défini par l'Agence.

La conception et le développement du système Météosat ont démarré en 1973 par la passation avec l'Aérospatiale (Cannes) en tant que maître d'oeuvre du consortium COSMOS, du contrat principal de réalisation du satellite. Presque simultanément étaient passés avec l'industrie européenne les premiers contrats pour la conception, la réalisation et la mise en place des divers éléments du secteur terrien. Après un examen critique de la conception, qui a eu lieu à la mi-1974 et dont les résultats ont été concluants, la fabrication du modèle d'identification (P1) du satellite a été mise en route, son intégration étant réalisée en 1975 après les essais satisfaisants du modèle structurel (SM) et du modèle thermique (TM).

L'année 1975 a également vu la mise au point, par le Conseil directeur du programme, de la version définitive du 'Protocole' Météosat. Ce Protocole, qui a depuis été signé par tous les Etats membres participants (à l'exception de la Suède qui pourrait décider de se joindre aux autres ultérieurement), assigne à l'ESA la responsabilité de l'exploitation du système Météosat pendant les

Design and development of the Meteosat system started at the end of 1973 with the award of the satellite's main development to Aérospatiale (Cannes), as COSMOS Prime Contractor. Almost at the same time, the first contracts were placed with European industry for the design, development and installation of the various ground-segment elements. After a successful Critical Design Review in mid-1974, manufacture was started of the satellite engineering model (P1), integration of which was carried out in 1975 following the successful completion of structural-model (SM) and thermal-model (TM) tests.

1975 also saw the finalisation of the Meteosat 'Protocol' by the Programme Board. This Protocol, which has since been signed by all participating Member States (except Sweden, which might still join later), assigns ESA the task of operating the Meteosat system until three years after the first successful launch. During this period, ESA will not only control the satellite, but will also be responsible for the processing and archiving of the data and the extraction of meteorological parameters on behalf of the users.

In 1976, the Development Results Review was held, the satellite prototype model (P2) was integrated, the hardware of the two flight models was manufactured, the major part of the ground segment was successfully tested, and ground/space compatibility tests were started. Finally, in 1977 the system and environmental tests on both the P2 and F1 models were completed, and the results reviewed at the Qualification Results Review (QRR) in early June, and at the Flight-Readiness Review (FRR) in July.

In early 1977, the Programme Board approved the launch of Meteosat-2 as principal passenger on Ariane (L03) in May 1980. This decision, together with the signature of the Protocol, clearly demonstrates that the launch of Meteosat-1 does not represent a singular event, but the start of a European programme using geostationary satellites for the benefit of meteorology and related disciplines. This also means an increased return to Member States on the considerable investment made in the Meteosat Programme.

Principales étapes du programme

1972	*Européanisation du programme, signature des arrangements juridiques*
1973	*Définition du secteur spatial (dans l'industrie) et du secteur terrien (par l'Agence)*
1974	*Conception du système, examen critique de la conception, démarrage du développement, campagne expérimentale sur les effets de trajets multiples affectant les plates-formes de collecte de données (DCP)*
1975	*Essais des modèles structurels et thermiques du satellite, intégration du modèle d'identification, mise au point définitive du Protocole Météosat*
1976	*Essais du modèle d'identification du satellite et intégration du prototype, démarrage des essais de recette du secteur terrien et essais de compatibilité secteur terrien/secteur spatial.*
1977	*Décision de lancer Météosat sur le vol Ariane LO3 en 1980, essais de performance et d'ambiance au niveau système sur les modèles P2/F1, examen d'aptitude au vol, lancement de Météosat-1.*

trois années qui suivront le premier lancement réussi du satellite. Pendant toute cette période, la responsabilité de l'ESA couvrira, outre le contrôle du satellite, le traitement et l'archivage des données et l'extraction des paramètres météorologiques pour le compte des utilisateurs.

On a assisté en 1976 à la revue critique de développement, à l'intégration du prototype (P2) du satellite, à la fabrication des matériels des deux premiers modèles de vol ainsi qu'à la plupart des essais – réussis – du secteur terrien et aux premiers essais de compatibilité secteur terrien/secteur spatial. En 1977 enfin, se sont terminés les essais au niveau système et les essais d'ambiance des modèles P2 et F1, et les résultats de ces essais ont été examinés lors de la revue critique de qualification (QRR) au début du mois de juin et de l'examen d'aptitude au vol (FRR) en juillet.

Au début de cette année, le Conseil directeur du programme a approuvé le lancement de Météosat-2 en tant que passager principal du vol Ariane LO3 en mai 1980. Cette décision, et la signature du Protocole, montrent clairement qu'il ne faut pas voir dans le lancement de Météosat-1 un événement isolé mais la première étape d'un programme européen de satellites géostationnaires destinés à la météorologie et aux disciplines connexes. Il faut y voir également la perspective pour les Etats-membres d'un bénéfice accru, en retour des investissements considérables consentis pour le programme Météosat.

Les Etats membres de l'ESA n'ont pu encore se mettre d'accord sur un programme de satellite météorologique européen à long terme qui se fonderait sur une combinai-

Mr. B.J. Mason (UK) signing the protocol authorising ESA to exploit Meteosat, on 22 June 1976. From left to right: D. Lennertz, ESA; A. Maenhout, Belgium; G. Simmen, Switzerland; B.J. Mason, UK; P. Creola, Switzerland; L. Porpora, Italy; E.A. Trendelenburg, ESA, and M. Bourély, ESA.

M. B.J. Mason (R-U) signant le protocole autorisant l'ESA à exploiter Météosat, le 22 juin 1976. De gauche à droite: D. Lennertz, ESA; A. Maenhout, Belgique; G. Simmen, Suisse; B.J. Mason, R-U; P. Creola, Suisse; L. Porpora, Italie; E.A. Trendelenburg, ESA, et M. Bourély, ESA.

To date, the Member States of ESA have not been able to agree on a long-range European Meteorological Satellite Programme which would be based on a combination of geostationary and low-altitude missions. Such a combination would greatly enhance the observation efficiency of the system. I certainly hope that the success of Meteosat will give our present and potential future customers a new incentive to think about the future.

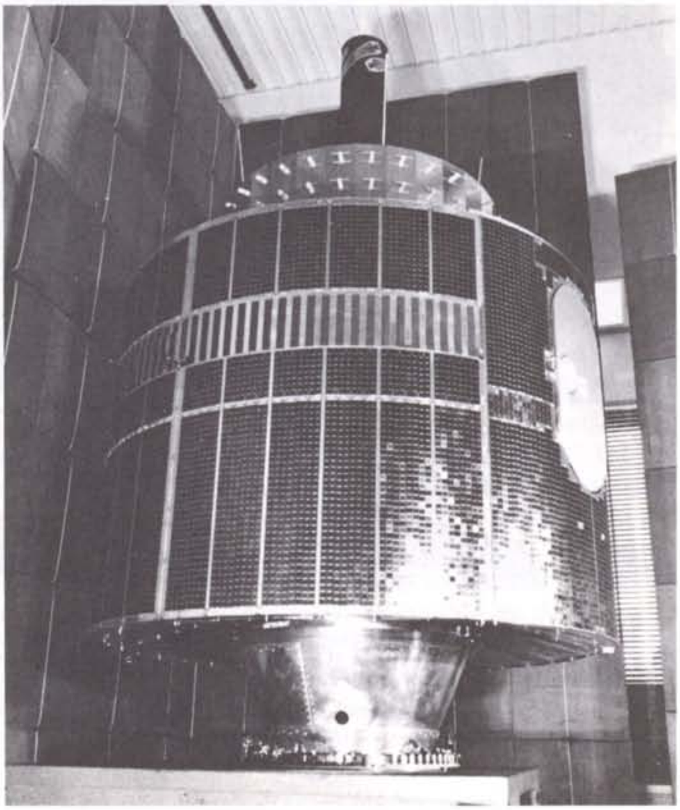
Let me finally take this opportunity to thank all those who have contributed, sometimes under difficult circumstances, to the successful completion of the hardware phase of the programme: the meteorologists in the national services, the members of the Programme Board and STAG, and in particular their chairmen (Mr. van Eesbeek, Prof. Knudsen, Dr. Stewart and Mr. Piaget); the Contractors, CNES, who originally designed the mission and whose staff have provided us with invaluable assistance in Toulouse, and finally also the ESA staff who have worked so hard, in many cases beyond the call of duty, on the project. □

son de missions géostationnaires et de missions à basse altitude. Ce type de combinaison renforcerait grandement l'efficacité d'observation du système. J'espère vivement que le succès de Météosat constituera, pour nos clients actuels comme pour nos clients potentiels, une nouvelle incitation à penser à l'avenir.

Permettez-moi enfin de saisir cette occasion pour remercier tous ceux qui ont contribué, parfois dans des conditions difficiles, à l'heureuse conclusion de la phase du programme portant sur la réalisation des matériels: météorologues des services nationaux, membres du Conseil directeur du programme et du STAG et tout particulièrement leurs présidents M. van Eesbeek, le Professeur Knudsen, le Docteur Stewart, M. Piaget, ainsi que les contractants, le CNES qui à l'origine a conçu la mission et dont le personnel nous a fourni à Toulouse une aide inappréciable et enfin le personnel de l'Agence qui s'est dépensé sans compter, souvent même au-delà de tout ce que l'on pouvait attendre, pour la réalisation du projet. □

The Significance of Meteosat for Meteorology

K.H. Stewart, Director of Research, British Meteorological Office

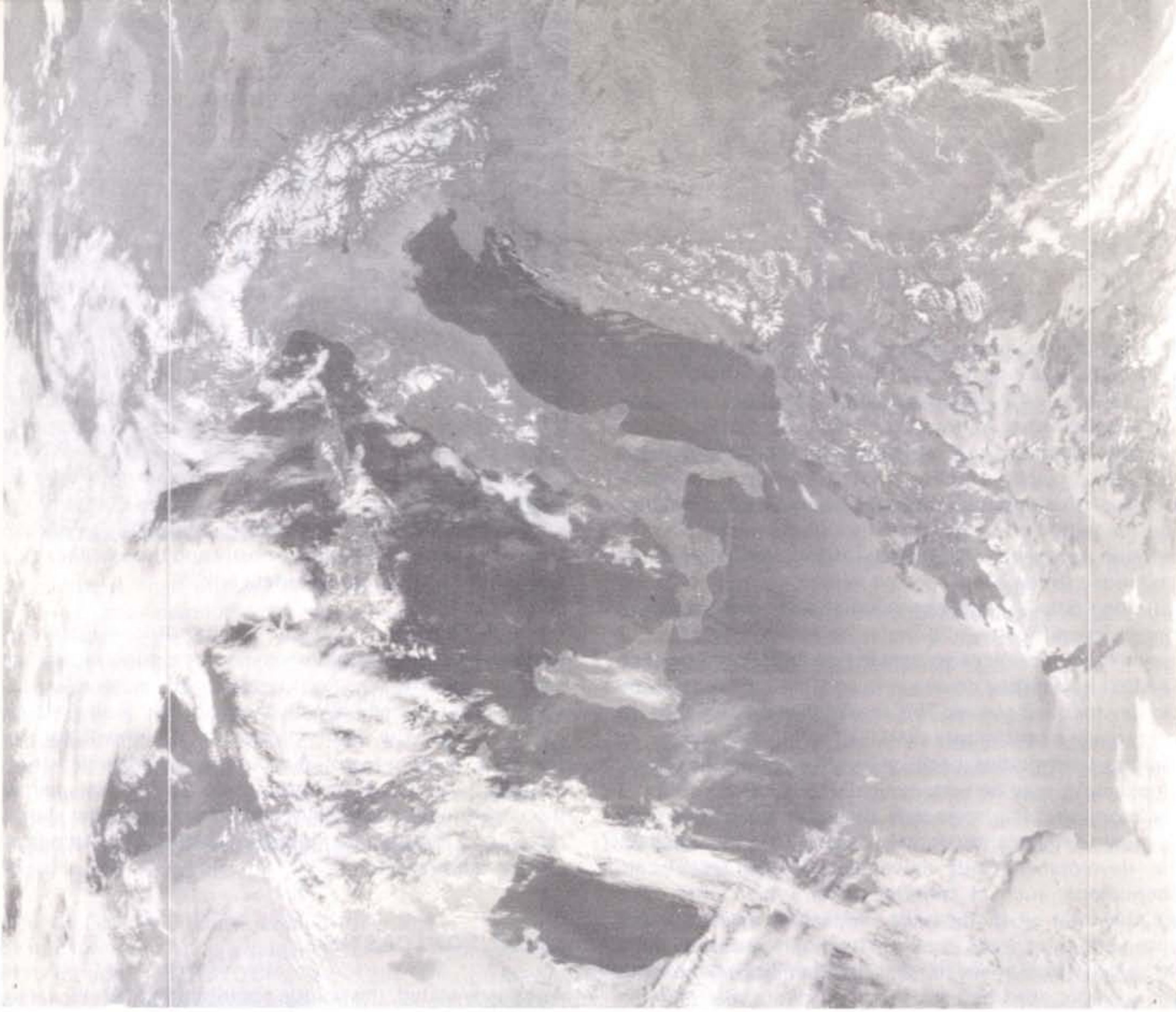


Meteorology is both a pure and an applied science. As pure scientists, meteorologists try to understand and explain the phenomena of weather and climate. As applied scientists, they use their knowledge to give advice on the effects of weather on agriculture, industry, transport and daily life. The main practical demand is for forecasts of what the weather will be like in the future – from a few hours ahead to many centuries ahead – but information on past and present weather and its effects can be very important too.

Observations provide the essential foundation for both the understanding and the prediction of weather, and the appetite of meteorologists for observations is almost insatiable. Ideally, the observations should measure the state of the atmosphere – its composition, temperature, pressure and velocity – at all heights all over the globe. The space and time resolution required depend on the phenomenon being studied and are closely interlinked, because small-scale phenomena tend to have short life cycles, and large ones long ones. Local weather forecasts for a few hours ahead require a resolution of a few kilometres in the horizontal and less than an hour in time. Forecasts for a few days ahead require a horizontal resolution of a few hundred kilometres and time resolution better than a day. For purposes of pure science it might be enough to collect such observations for a limited period only, long enough to obtain a sample of all the important phenomena of meteorology. For the applied science of forecasting, however, there is no limit to the time for which observations are required. This is because we are trying to predict the behaviour of an inherently unstable system. However well we can predict the future development of the flow patterns existing at one time, there will always be new disturbances to the pattern which grow from below the threshold of detectability and have to be taken into account in making later predictions.

Although meteorologists have always been hungry for observations, it is only in the last decade or two, with the development of large computers, that they have had the capacity to digest them in the large quantities they know to be necessary. In the last few years the capacity of computers to model the behaviour of the atmosphere, both globally and on more local scales, has far outstripped the capacity of conventional observing systems to provide data for testing, developing and using the numerical models. The problem is not that conventional methods are, in principle, incapable of providing the data required; it is simply that the cost of operating the thousands of stations needed (mostly in the oceans) would be quite prohibitive. It is no wonder, then, that meteorologists are eager to exploit to the full the possibilities of satellites in providing a world-wide observing system at reasonable cost.

Satellites have been used in meteorology for more than 15 years. The first glamour and excitement has faded, leaving the conviction that they can make an enormous



contribution to meteorology, but also the realisation that it is not a simple matter to make full use of their potential contribution. Satellites do not observe directly the quantities meteorologists most need to know and much ingenuity and effort have to be expended to plan the satellite system to best advantage and to extract the maximum of useful information from its data. The first and strongest reason European meteorologists have for welcoming Meteosat is that it enables them to play a really active part in exploring and extending the ways of using satellites in their science; of course, much work has already been done using data from American satellites, but the full understanding of the limitations and possibilities of satellite techniques that is needed to exploit them fully comes only from working in close and interactive contact with the system and its data. During the development of Meteosat, only a rather small circle of meteorologists has benefitted from this contact, but the circle widened as the day of launch approached and once the data begin to flow the challenge and the opportunity will be open to the whole community of European meteorologists.

Meteosat has been planned to complement rather than duplicate existing weather satellites. For many years the USA has provided satellites in fairly low near-polar orbits which give coverage of the whole earth once or twice per day. The observations from these satellites have improved gradually over the years and will take a big step forward in 1978 when the TIROS-N series is introduced. The satellites provide images at several different visible and infrared wavelengths and 'soundings' of the vertical distribution of temperature and humidity. The images give valuable data on conditions at the earth's surface – the distribution of snow and ice and of sea-surface temperature – as well as showing the cloud patterns and

Dr Kenneth Stewart joined the British Meteorological Office in 1949 and worked mainly on problems of fog and visibility. More recently he has been associated with the development of rocket and satellite instruments to measure ozone, molecular oxygen and stratospheric temperature. From 1972 to 1977 he was Chairman of the Meteosat Programme Board's Scientific and Technical Advisory Group (STAG).

thus determining in a qualitative way the main features of the weather systems. The sounding data, in principle, give comprehensive quantitative information about the state of the atmosphere. Although it is only the temperature and humidity that are measured, the pressure can be inferred at all levels (provided it is known at one reference level, such as the earth's surface) through the hydrostatic relation and the wind can be inferred through its relationship to pressure gradient. In practice, there are still serious limitations to the accuracy and vertical resolution of the sounding data. Apart from this technical and, we hope, temporary difficulty, the polar satellites fall short of providing comprehensive data in two important respects. The first is that their coverage is only intermittent – twice per day for most places. This means that the satellites do not provide a satisfactory sample of weather observations for long-term studies, because weather in the afternoons, for example, may be systematically different from that in the mornings. It also means that they do not provide adequate data for short-term forecasts; if we are to predict the development and movement of the small-scale phenomena, such as thunderstorms, which often give weather its most dramatic impact, we must have observations at least once an hour. The second, more technical, inadequacy is that the familiar relationship between pressure gradient and wind is too weak near the equator to allow us to infer wind from the temperature-sounding data. Air movements within the tropics play a vital part in the evolution of global weather and we therefore need some other method of measuring wind there.

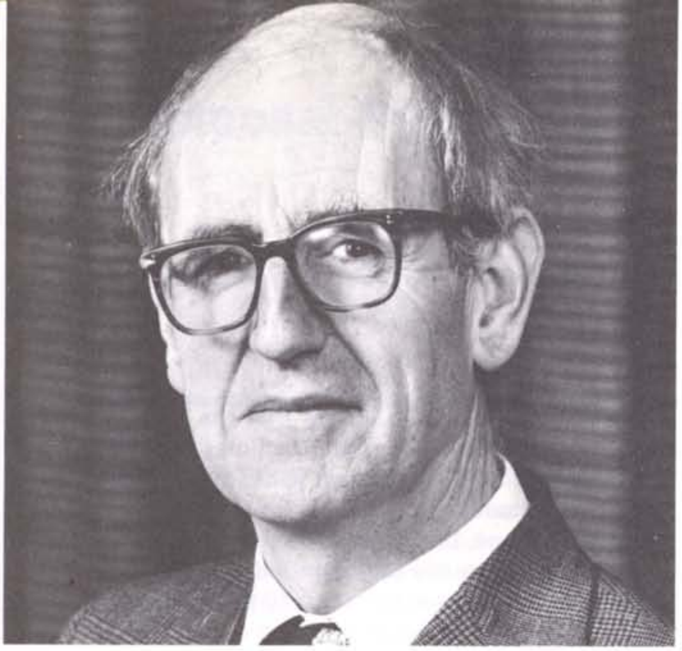
These two deficiencies of the polar satellite system can largely be made good by the use of geostationary satellites. These can provide quasi-continuous coverage of the whole area within their field of view, which is what is needed for short-range forecasts, and the wind-measuring problem can then also be solved by tracking the motion of clouds over an hour or two and assuming that they move with the wind. The method only works, of course, where clouds are present, and care has to be taken to avoid clouds of types which might not move with the wind, but experience has shown that reasonably adequate sets of data can be obtained. Four or five geostationary satellites are needed to cover all longitudes and these are being provided by a natural geographical division of responsibility, with the European Meteosat located at 0° longitude.

Although the system of polar and geostationary satellites can cover the whole earth adequately, there are several important quantities which cannot yet be measured properly by remote sensors on satellites, atmospheric pressure at the surface, rainfall amounts, and river flow being the notable examples. It is not very difficult to devise automatic stations to measure these quantities in remote or inaccessible areas, but the transmission of data from them is often difficult or costly and the satellites can play a very useful role as a data link.

As a geostationary satellite in the African-European sector, then, the role of Meteosat is not to supersede other satellites or the existing network of meteorological stations, but to complement them so that, if all systems play their part, the global observing system will, for the first time, give meteorologists a truly world-wide set of the data they need. The contributions of Meteosat may be discussed more specifically under four headings: short-range local forecasting, global forecasting, climatological studies, and research.

LOCAL FORECASTING

As already stated, the unique contribution of Meteosat to local forecasting lies in the quasi-continuous coverage it provides. Images of the clouds will be available every half hour. Images by visible light will only be available in daylight hours, of course, but those at infrared wavelengths (10-12 μm) will be available day and night and are valuable because they indicate the temperature of the cloud tops (or of the sea surface, in clear conditions) as well as showing the distribution of clouds. Analysis of the vast amount of detail in these images in relation to local conditions is beyond the power of any central station, so that use will be made of Meteosat's capacity to relay information to broadcast the images to local forecasting stations. In preparation, the images are put into a readily usable form at the central station by adding latitude/longitude grids and other information. On receipt, the images will be examined by the forecasters; they will look first to see how well the latest images confirm the ideas they have already formed about the development of the weather from other evidence, then for signs of any new or unexpected developments, particularly in areas not well covered by ordinary



observations, then in more detail at features of special interest to their own locality – the spread of fog from the sea to land, for example, or the movement of shower clouds. It is in the field of local forecasting that there is probably most to learn, most room for ingenuity, and most likelihood of surprises. We know that under some conditions the new information will be of great value; under other conditions it is not yet obvious how the information can be used, but we can hope that experience will teach us. One of the most important uses will certainly be in giving warnings of dangerous happenings such as heavy rainfall or floods.

Meteosat can help here not only with its images, but also by its capacity to act as a data relay for warning messages from ground stations (DCPs, see p.39). One powerful technique whose use is being planned in several countries is that of making a succession of images into a motion picture of the cloud development; this can give an immediate appreciation of features that may not be obvious from a sequence of still photographs. Another technique that will be used is to combine Meteosat images with those obtained from ground-based radars; these will show the actively raining parts of clouds within the general cloud structure.

GLOBAL FORECASTING

The unique contribution of Meteosat to global forecasting (and it must be remembered that if we are to forecast for any one region for more than a few days ahead, the forecast must necessarily consider the globe as a whole) is the provision of information on winds in the tropical belt. This is one of the most exacting applications of satellite data, demanding great precision in finding the position of the clouds (and therefore in finding the position and orientation of the satellite) and following the motion from one image to the next. The necessary data processing will be done at the central station and the results disseminated by the usual meteorological channels. Other important contributions to large-scale forecasting will be the use of the cloud patterns to delineate weather features and the use of the infrared images to give data on sea-surface temperature. In addition to providing images in the visible and infrared 'windows' at wavelengths of about 0.7 and 11 μm, Meteosat will give images at about 6.3 μm, a region of emission and absorption by water vapour. This is a new feature, not included in the geostationary satellites of the USA. The 'water vapour' images should give valuable information on the distribution of water vapour in the upper troposphere (6-8 km above the earth) and may also allow winds to be estimated even when no clouds are visible, by tracking invisible clouds of vapour. The analysis of the images to produce simplified maps of the distribution of cloud, water-vapour and sea-surface temperature will be carried out at the central station, and the products will be distributed both by land line and via the satellite itself.

The data-relay powers of Meteosat will be brought into play in two ways in the large-scale forecasting field: first by relaying weather information from remote automatic stations (DCPs), for example in Greenland or on ships at sea, and secondly by relaying images obtained from the American geostationary satellite GOES-1 and showing conditions in the western Atlantic and Caribbean otherwise invisible from Meteosat.

These contributions from Meteosat will be vital to the success of the important international project known as the First GARP Global Experiment (FGGE), which has been planned to obtain the maximum possible global coverage of meteorological data during 1979 and to use the data in numerical experiments designed to explore future possibilities and requirements for the prediction of weather. The FGG Experiment relies heavily on satellite data as well as the conventional observing network, but various supplementary 'special observing systems' will also be used.

CLIMATOLOGY

The role of Meteosat in climatological studies will be primarily to provide statistics on cloud coverage within its field of view; most importance is attached to ocean areas where data are scarce. Climate is determined chiefly by the balance between the radiation received from the sun and that re-radiated by the earth. Clouds have a considerable effect on this re-radiated energy and a comprehensive picture of their distribution and its changes will greatly help our understanding of climate. Although much information has already been obtained from polar-orbiting satellites, it is seriously incomplete because the observations are made only at a few, more or less fixed, times per day. The continuous coverage of the geostationary satellite will allow much more satisfactory estimates of true daily averages to be obtained. As well as giving data on the presence or absence of cloud, the central station will process the data to give estimates of the net 'radiation balance' for each area seen from Meteosat. Other climatological uses of Meteosat may well appear in the future; its use to measure snow cover and to estimate aerosol content are possible examples.

RESEARCH

The boundary between research and applications in meteorology is not a distinct one; a forecaster may be described as a researcher who is never allowed the time to complete his research. All of the applications of Meteosat data just described have their research aspects too. The most important is probably the contribution Meteosat will make to the data set of the FGGE. The possession, for the first time, of a truly comprehensive set of data on the world's weather will make possible a great variety of research projects on large-scale atmospheric processes, particularly the fundamental processes that transfer energy from low to high latitudes. On a more local scale, Meteosat will be used to clarify the factors governing African weather – those controlling rain in semi-arid regions being particularly important –, to study the local storms that affect the Mediterranean region and to investigate the effects of hills and coastlines on cloud development, these representing but a few of the possible projects.

No doubt many small research projects will be undertaken using the images received at local forecasting stations, but the major projects will require access to larger amounts of data and it is here that the comprehensive archiving and data-processing facilities provided at the central station will be of great value. Most research will probably be done by requesting the appropriate data sets from the archives, but for projects requiring access to and manipulation of really large amounts of data, it may be possible for the researcher actually to work at the central station, using its computers during the off-peak period.

CONCLUSION

This article has tried to show how Meteosat fits into the general scheme of observations for meteorology and what the significance of its contribution in various specific fields will be. In the long run, the Meteosat project may prove even more important as a prototype of the techniques and organisation that will be needed if meteorology is to make full use of modern technology in the future. Meteorology inevitably uses vast amounts of data, and the problems of collecting the data, processing them to reduce their bulk without destroying their value, and then distributing them to the point of use are formidable – particularly when it is remembered that they have to be dealt with continuously and in real time. The Meteosat satellite provides an advanced means of acquiring data, but it was soon realised that it would lose much of its value unless supported by adequate data-handling facilities. These have been provided and the basic scheme for their use worked out, but the total system – the satellite as an observing platform, the computers on the ground, and the satellite as a data relay station – has enormous flexibility and possibilities of development and adaptation to meet new needs or take advantage of unforeseen opportunities. It will be the task of those who use Meteosat to develop its possibilities to the full and to learn from it the lessons that will lead to a still better system in the future.

To end on a personal note, the experience I have been privileged to have of the far-sightedness of the original French designers of Meteosat, the skill and professionalism of the European teams that have carried the project forward, and the co-operativeness and enthusiasm of the meteorologists who have planned how to use the satellite leave no doubt that the task will be done well. □

The Meteosat System and its Missions

D. Breton, Mission/System Manager, Meteorological Programmes Department, ESA

In addition to meeting the needs of the European meteorological services, the Meteosat Programme represents Europe's contribution to two programmes set up by the World Meteorological Organisation (WMO):

- **the first, a permanent undertaking, is the World Weather Watch (WWW)**
- **the second, experimental and undertaken jointly with the International Council of Scientific Unions (ICSU), is the Global Atmospheric Research Programme (GARP).**

Following launch of the first Meteosat satellite, the system will gradually reach full operational potential during the first quarter of 1978, in time for the First GARP Global Experiment (FGGE), the operational phase of which is expected to start before the end of that year.

Within this framework, the Meteosat satellite forms part of a network of five geostationary meteorological satellites distributed around the equator. The missions and performances of the five spacecraft are being co-ordinated technically and operationally under the auspices of a committee for the Co-ordination of Geostationary Meteorological Satellites (CGMS), drawn from representatives of the countries or bodies providing the satellites, and from the users. The other participants besides Europe are the USA (two satellites), the USSR and Japan. The locations and coverages of the five satellites are shown in Figure 1.

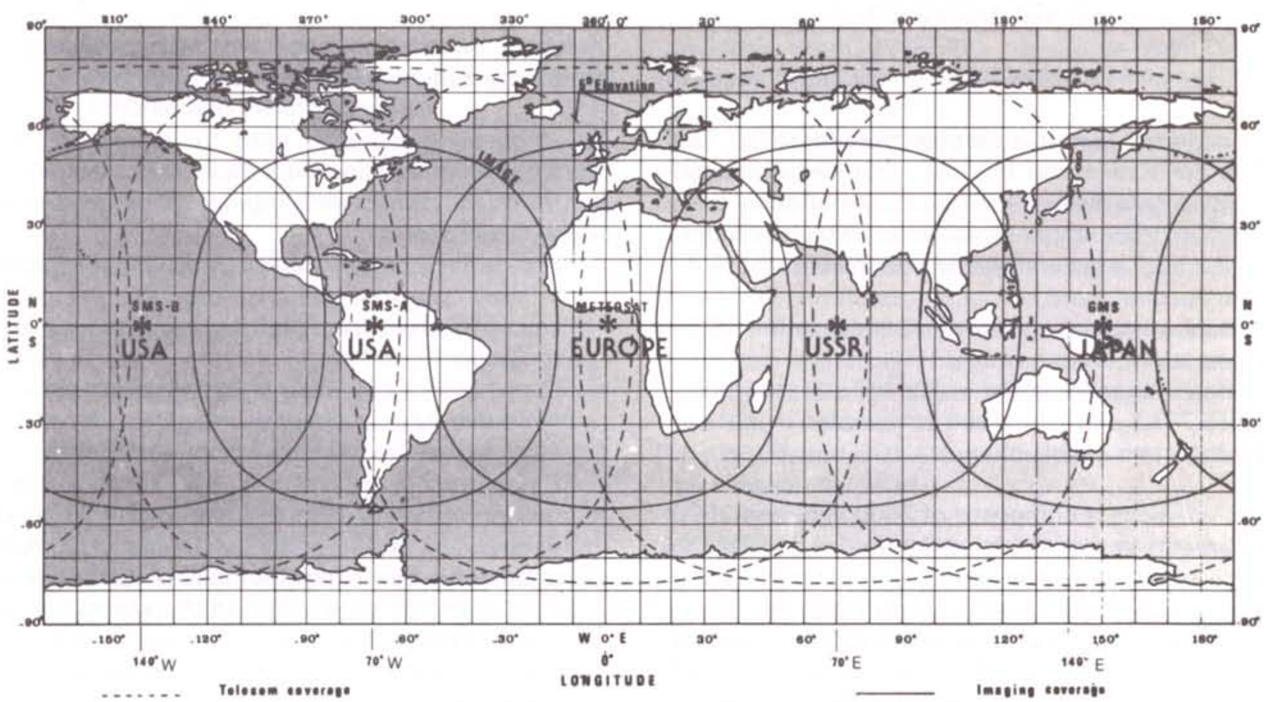


Figure 1 – Coverage of the geostationary meteorological satellites participating in the GARP experiment.

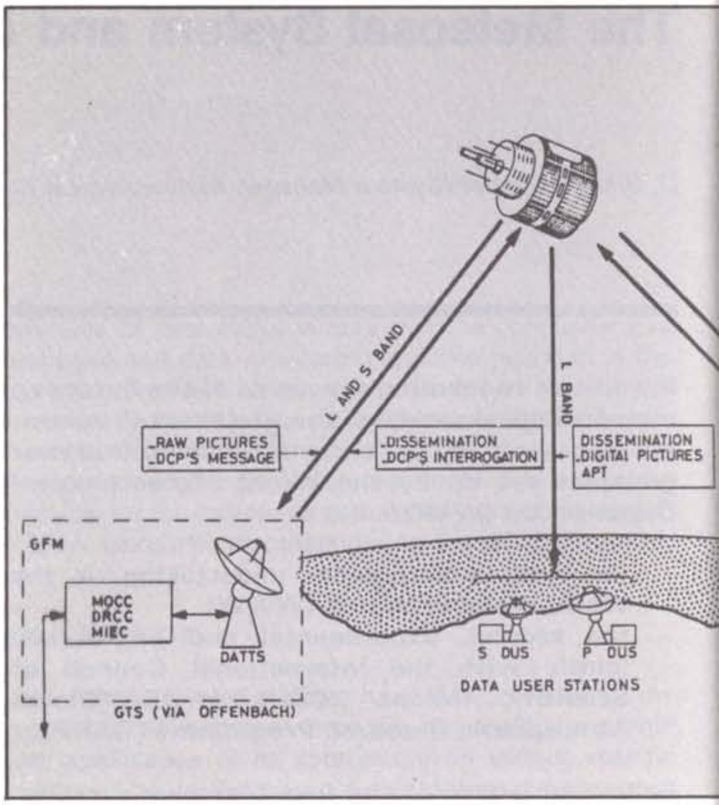


Figure 2 – The Meteosat system.

MISSION OBJECTIVES

The Meteosat system, comprising the satellite and its associated ground facilities, is shown in Figure 2, and the main products or services that it provides are the following:

(a) cloud-cover observation and analysis
(b) cloud-top and sea-surface temperature
(c) water-vapour content of the upper troposphere
(d) radiation balance
(e) wind determination
(f) dissemination of cloud-coverage pictures, and meteorological data extracted from these pictures, to remote user receiving stations
(g) collection of environmental data measured locally by remote 'in-situ' automatic or semi-automatic Data-Collection Platforms (DCPs), and possibly also by a low-orbiting satellite (not included in the Meteosat Programme).

Translated in terms of functions at system level, these objectives will be fulfilled by the three missions of earth imaging, dissemination and data collection.

MISSION 1 – EARTH IMAGING

This mission is designed to meet objectives (a) to (e). The basic data are visible and infrared radiances produced over the full earth's disc, as seen from geostationary orbit by an on-board three-channel radiometer which includes:

- two identical adjacent visible channels in the 0.4–1.1 μm spectral band
- a thermal infrared ('window') channel in the 10.5–12.5 μm band, and
- an infrared channel in the water-vapour absorption band (5.7–7.1 μm) which can be operated in place of one of the two visible channels.

Each infrared image is composed of 2500 lines and 2500 picture elements with a spatial resolution of 5 km at the subsatellite point (intersection of local vertical passing through a satellite in orbit with the earth's surface). In the visible, performance is twice as good (5000 lines and picture elements, 2.5 km resolution) when the two adjacent channels are operated, i.e. when the water-vapour channel is 'switched off'.

Radiance data are produced at the rate of one visible picture and one infrared picture of the complete earth's disc every 30 min. They are transmitted in quasi-real time, after on-board line stretching (explained later), to the Meteosat ground facility, where they are subjected to a correction process prior to the extraction of the meteorological information. The main characteristics of these images are summarised in Table 1.

The processing methods used for extracting the meteorological information from the radiance data are being progressively refined and improved; the general philosophy is as follows:

- *Sea-surface temperature* will be obtained from the infrared 'window' radiance over a segment 200 km square. Correction using the water-vapour channel is envisaged.
- *Cloud analysis* for each image segment will indicate the percentage of cloud coverage (black/white ratio after suitable enhancement).
- *Cloud-top height*, which is useful for aircraft control, will be obtained with the help of the atmospheric temperature profile, either by using standard laws or, preferably, by using the results of conventional measurements transmitted to the processing centre via the Global Telecommunications System (GTS).
- *Water-vapour content* will be obtained from the water-vapour channel. High-altitude cloud perturbations will be removed using predetermined tables.

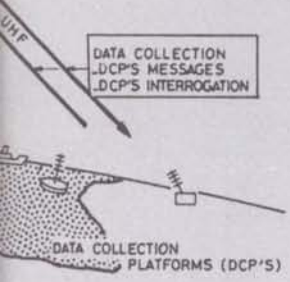


TABLE 1
Mission 1 – Earth Imaging

Spectral Bands	Visible 0.4–1.1 μm	IR (Water vapour) 5.7–7.1 μm	IR (Normal) 10.5–12.5 μm
Number of channels	2 (Simultaneous)	1 (in time-sharing with 1 vis-channel)	1 (+1 redundant)
Number of lines/pict.	5000 (2500)*	2500	2500
Number of samples/line	5000	2500	2500
Resolution (subsat. point)	2.5 km	5 km	5 km
Line duration		30 ms	
Line recurrence		600 ms	
Image-taking duration		25 min	
Image recurrence		30 min	
Transmission → DATTS		Digital 166 kbit/s (normal) 2.7 Mbit/s (back-up)	

* Case in which water-vapour channel is also transmitted.

- *Radiation balance* will be established by computation of incoming energy over the full spectrum, and subtraction of emitted-energy values. Full use will be made of the visible, infrared and water-vapour channels.
- *Wind vectors* will be extracted by using small-cloud tracers. Their displacement between two or more successive images will be calculated and correlated from the infrared and visible channels.

The useful angular coverage of the earth-imaging system is some 50° about the subsatellite point.

MISSION 2 – DISSEMINATION

This mission, designed to meet objective (f), includes the elaboration of meteorological images or data originating either from the earth-imaging mission or from external sources, and their dissemination by using the satellite as a relay or through the Global Telecommunications System.

The data produced by the Meteosat system itself include images of the earth's disc and of its cloud coverage in various formats and meteorological charts extracted from the pictures produced. The data obtained from external sources include images of the Atlantic Ocean generated by the easternmost American GOES satellite, received by the Meteorological Centre at Lannion (France) and conveniently reformatted, and meteorological charts produced by Area Forecast Centres (AFCs) and transmitted to the ground facility via the GTS.

All data will be disseminated either in a high-resolution digital form to Primary Data User Stations (PDUS), or in analogue form (WEFAX) to Secondary Data User Stations (SDUS).

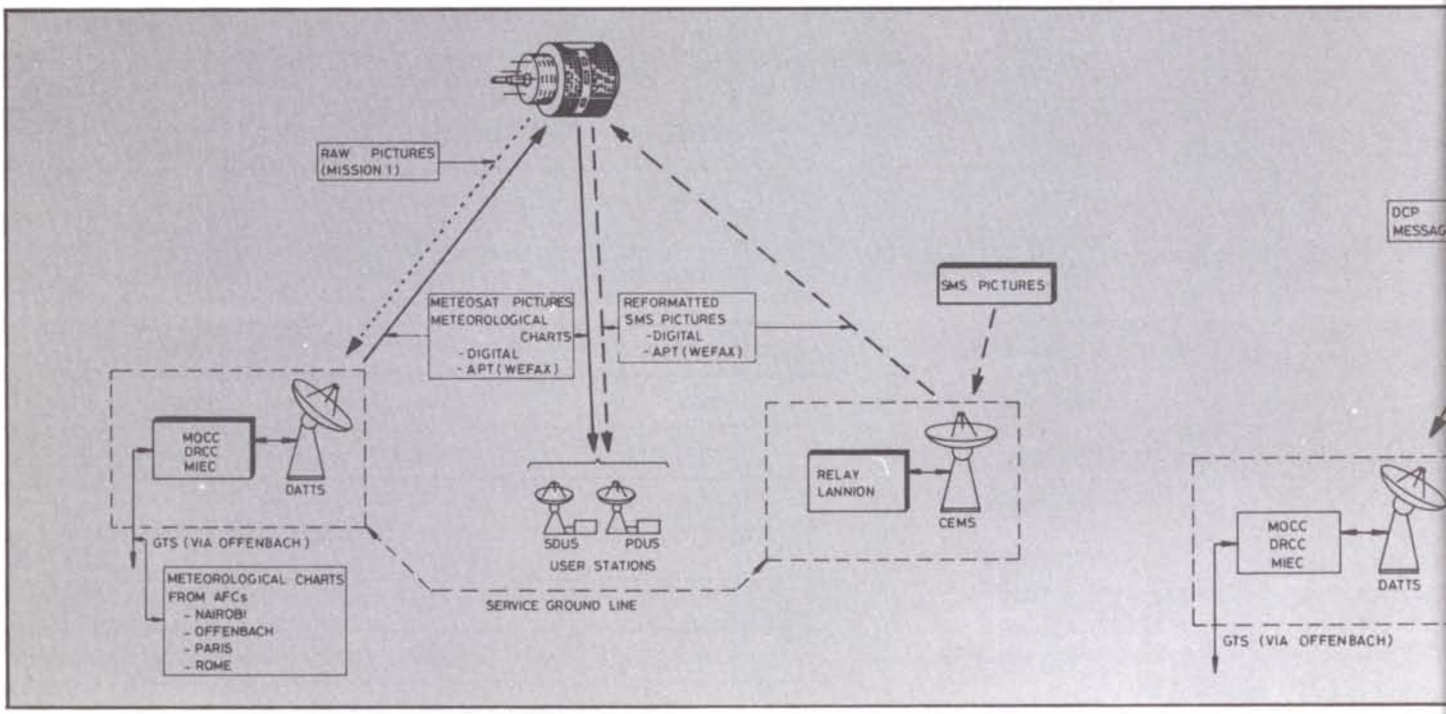
The dissemination system, shown schematically in Figure 3, relies on

- the GTS, via Offenbach, for meteorological data extracted from pictures produced by the earth-imaging mission and for data produced by the data-collection mission outlined below,
- two identical telecommunications channels via the satellite for meteorological data and pictures, either in high-resolution digital, or analogue format.

The PDUS and SDUS sites must lie within about 75° of the subsatellite point.

MISSION 3 – DATA COLLECTION

This mission, designed to meet objective (g), comprises the acquisition and pre-processing of data collected by remote DCPs and also the interrogation of these platforms, the satellite being used as a relay (Fig. 4).



The DCPs, which may be installed either at a fixed site on land, or on mobile supports such as ships, buoys or balloons, will be

- 'self-timed', transmitting their messages automatically according to a predetermined time and frequency schedule, or
- 'interrogated', transmitting their messages only upon 'request' by the Meteosat ground facility.

In addition, some may have a warning function, allowing them to transmit a short warning message automatically whenever a given measured parameter exceeds a preset threshold.

A total of 66 telecommunications channels are available for relaying the DCP messages, half being used for regional purposes, i.e. for DCPs operated exclusively via the Meteosat system, and the other half for international purposes, i.e. mainly for mobile DCPs likely to move through the coverage areas of all five satellites participating in the FGGE.

As for the Primary and Secondary Data User Stations, DCPs lying within about 75° of the subsatellite point at any given moment can be accessed by Meteosat.

MISSION SUPPORT

Although not strictly a component of the meteorological mission, mission support should be mentioned here for completeness. It includes satellite-housekeeping telemetry and telecommand, and satellite tracking.

SYSTEM CONFIGURATION AND COMPONENTS

As shown in Figure 2, the Meteosat system includes the satellite, the associated central ground facilities, and any number of remote user stations or platforms.

THE SATELLITE

The satellite itself is geostationary and spin-stabilised at 100 rpm, with its spin axis north-south. It is nominally stationed at 0° longitude, but its capability extends between 0° and 20° east longitude. Its main characteristics are summarised in Table 2.

The earth-observation package consists of a three-channel telescope radiometer instrument for imaging the earth's surface and cloud systems in the visible and infrared bands. Imaging is performed by a combination of the satellite's spin motion which provides line scanning in an east-west direction, and a tilting of the radiometer telescope, which provides a north-south scan. The radiometer has an associated synchronisation and image channel (SIC) which samples, codes and formats radiometric data, and generates reference signals for the other satellite subsystems. The SIC includes a buffer memory in which the data produced along a scan line are 'stretched' before transmission to the ground, to allow an all-important reduction in data rate.

The data-transmission and relay package, operating in the L/S and low UHF bands, provides for:

- the transmission of radiometric data to the central station (DATTS)

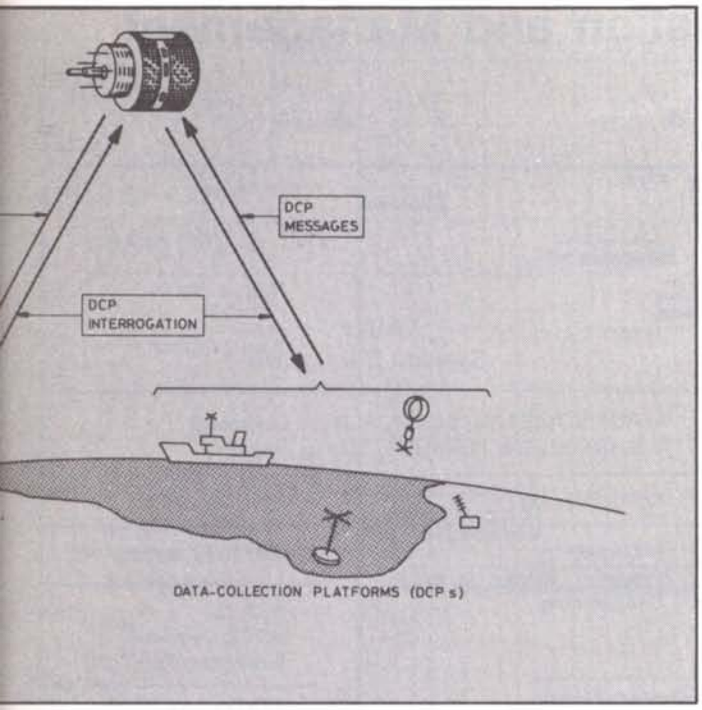


Figure 3 – Mission 2 – Data dissemination.

Figure 4 – Mission 3 – Data collection.

- the relay of data which are disseminated to the PDUS and SDUS user stations, through two independent and interchangeable channels
- the relay of data collected by the DCPs, through the maximum of 66 channels
- the relay of interrogation messages to the DCPs
- the relay of ranging signals for the determination of satellite position in geostationary orbit
- the reception/transmission of telecommand orders and telemetry data.

TABLE 2
Main Characteristics of the Satellite

Weight:	697 kg (at launch), including 345 kg for ejectable ABM and 60 kg for ABM and third-stage attach fittings
Dimensions:	210 cm diameter, 319.5 high (without ABM)
Power:	200 W, end-of-life
Lifetime:	3 years (nominal)
Reliability:	0.37 (without degradation of any mission and without making use of back-up modes)
Orbit:	geostationary, 0° longitude (nominal)
Station keeping:	±0.8° N-S, ±1° E-W (for 3 years)

THE GROUND SEGMENT

The Meteosat ground segment consists of the ground facilities at ESA's Space Operations Centre (ESOC) in Darmstadt and in the Odenwald, and the remote user stations.

The facilities in Germany include:
- a Data Acquisition Telecommand and Tracking Station (DATTS), which acquires the radiometer data, the attitude and housekeeping data, and the messages from the DCPs; it also transmits high-resolution digital data and analogue WEFAX data for dissemination, DCP interrogation signals, and telecommands
- a remote Land-Based Transponder (LBT), for satellite ranging operations
- the Meteosat Operations Control Centre (MOCC), for the control of satellite and ground-facility performances and for the co-ordination of mission performances
- a Data Referencing and Conditioning Centre (DRCC), to relate radiometer data to satellite orbital position and attitude conditions and to provide for image rectification, projection conversion, and information transformation
- a Meteorological Information Extraction Centre (MIEC), for the extraction of specific meteorological information, such as sea surface temperature, wind fields and cloud analyses, from the radiometer data.

The DATTS is located in the Odenwald and the control and processing facilities (MOCC, DRCC, MIEC) in Darmstadt. The two centres are linked by a high-capacity ground data link. The LBT is located in Kourou, French Guyana, and is operated via the satellite.

The other, remote, elements of the ground segment comprise:
- the Primary Data User Stations, for the reception and display of full-resolution image data in digital form and reception and display of APT-type transmissions in analogue form.
- the Secondary Data User Stations, for reception of APT-type transmissions; these consist of existing APT-VHF stations adapted to S-band by the addition of antenna, preamplifier and down-converter.
- The Data-Collection Platforms, for remote collection of meteorological and other environmental data on the earth's surface. □

Meteosat Programme Organisation and Management

D. Lennertz, Head of Meteorological Programmes Department, ESA

The Meteosat Legal Arrangement, which was signed in 1972 by representatives eight of the Member States and the Director General of the European Space Agency, clearly defines, inter alia, the objectives of the programme. For the Executive and its Meteorological Programmes Office (MPO), this means the design, development, construction, setting-up and operation of a system

- **the** *technical performance* **of which corresponds to the requirements of the users**
- **within a given** *time frame*, **and**
- **within a given** *financial envelope*.

In the following, I will try to show to what extent and by which means the above three programme objectives have been fulfilled at the time of the Meteosat-1 launch.

TECHNICAL PERFORMANCE OF THE SYSTEM

One of the first essential tasks of MPO's Mission/System Group was to 'translate' the users' (mission) requirements into technical performance specifications for the Meteosat system, composed of the space segment and the ground segment. The results of this 'translation' are summarised in the preceding article and the corresponding technical characteristics of both the space and ground segments are described in the contributions that follow.

As far as the Meteosat space segment is concerned, Aerospatiale (Cannes), Prime Contractor of the COSMOS industrial consortium, was able, after the Definition Phase in 1973 and only a few months after the start of the Hardware Development Phase, to present a sound satellite design for the May 1974 Critical Design Review. Since then, in the subsequent programme reviews, only minor changes have had to be introduced in order to comply fully with the satellite's technical performance specifications. On the other hand, the satellite has been designed with sufficient built-in flexibility and growth potential to allow a 'third channel'

TABLE 1
Satellite Contractors

AEROSPATIALE (F) (COSMOS) Prime Contractor
System Studies, Integration, Testing, Harness

Co-Contractors	Sub-Contractors
ETCA (B) Power Supply and Conditioning	SAFT (F) Battery
	SRA (S) AOCS Converter Subsystem Test Unit
	TERMA (DK) Distribution Box Unit
MATRA (F) Radiometer	BERTIN (F) Passive Cooler
	MSDS (GB) Image Electronics
MBB (D) Structure, Solar Array, Thermal Control, Apogee Boost Motor (ABM), Mechanical Ground Support Equipment	AEROJET (US) Apogee Boost Motor
	CONTRAVES (CH) Mechanical Ground Support Equipment ABM Adapter
	SAT (F) Solar Cells
MSDS (GB) Attitude Measurement, Attitude and Orbit Control System (AOCS), Electrical Ground Support Equipment (EGSE)	AEROSPATIALE (F) Passive Nutation Damper
	SODERN (F) Earth Sensors
SELENIA (I) Synchronisation Image Channel (SIC), Mission Support Telecommunications, Antennas S/UHF, VHF	CIR (CH) Electrical Ground Support Equipment
	CROUZET (F)
	SAT (F) Telemetry Encoder
	SIEMENS (D) Variable Power Divider
SIEMENS (D) S/UHF Transponder	MSDS (GB) S-band Preamplifier, UHF Receiver and Amplifier

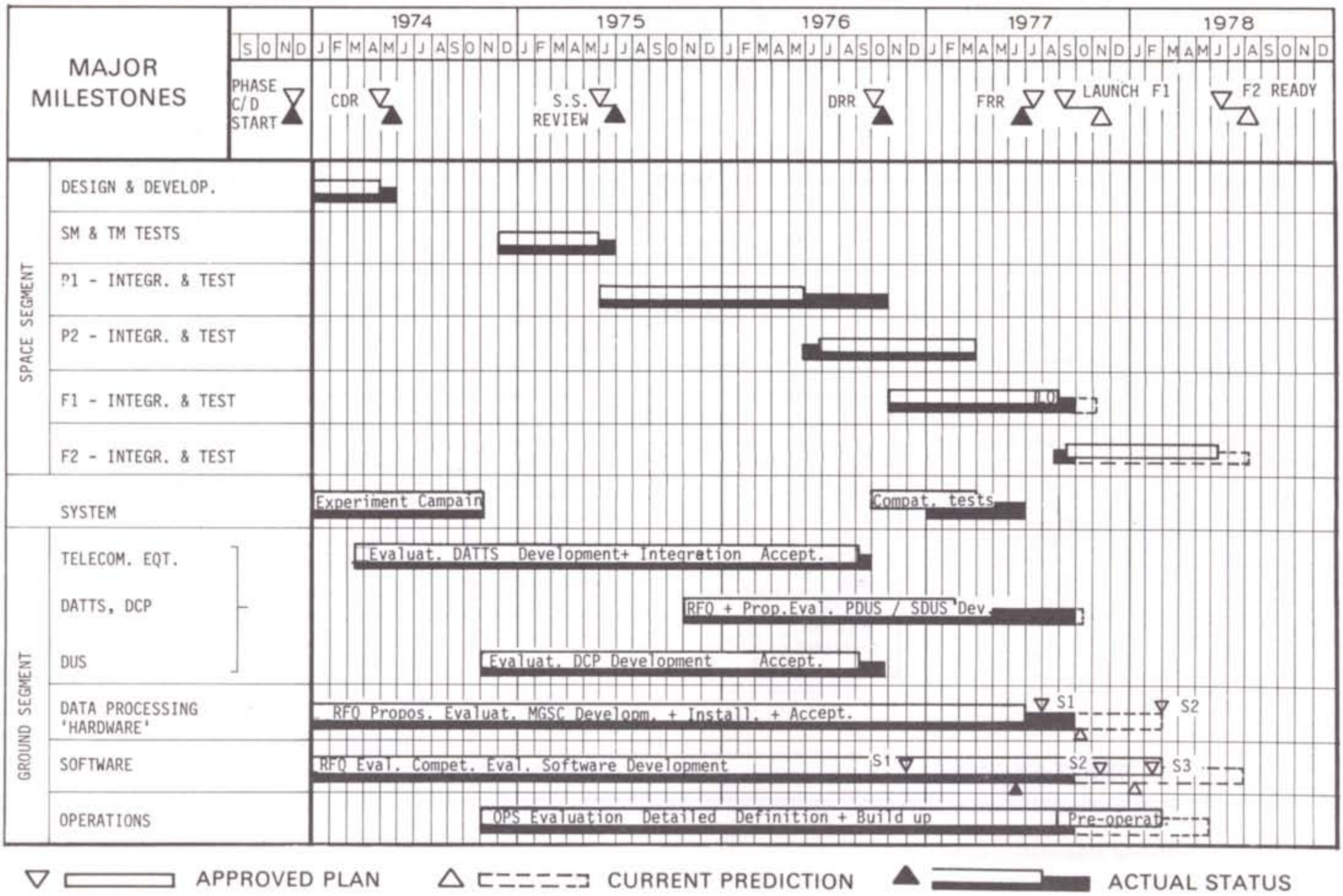


Figure 1 – Meteosat summary time schedule

for the radiometer, not originally requested by the users, to be included in 1976 relatively late in the programme.

Turning now to the ground segment, the Primary and Secondary Data User Stations (PDUS, SDUS), the Data-Collection Platform (DCP), the Data-Acquisition Telecommand and Tracking Station (DATTS) in the Odenwald, and the Meteosat Operations and Control Centre (MOCC) have passed acceptance tests with very satisfactory results. The programme's 'problem child' is, without doubt, the data-processing system, and more specifically the main-frame computer system. Although all minimum requirements for the launch of Meteosat-1 are being met (i.e. control of the satellite, archiving of all – at least raw – data, dissemination of processed images, limited extraction of meteorological parameters), it became apparent quite some time ago that the present system might not fulfil some of the original requirements, or would do so only rather late, particularly in respect of service availability for a fully operational system. It should perhaps be pointed out that:

– the Meteosat users' data-processing requirements are very ambitious, at least when compared with those of the other satellite systems that have been or are being set up for the First GARP Global Experiment (FGGE), and
– the choice of computer was extremely limited by a Member-State request that European hardware be used.

These two remarks are in no way intended as excuses, but as an explanation of why, in one area of the Meteosat system, some users' requirements will probably not be met, or at least not for some time.

PROGRAMME PLANNING

According to the 'tentative time-scale' contained in the Meteosat Legal Arrangement, it was planned in 1972 to launch Meteosat-1 at the end of 1976, in order to have a run-in system for the FGGE, which was then scheduled for the period between autumn 1977 and autumn 1978. When the World Meteorological Organisation decided in 1974 to postpone the FGGE by one year, the Programme Board agreed to delay the nominal Meteosat-1 launch

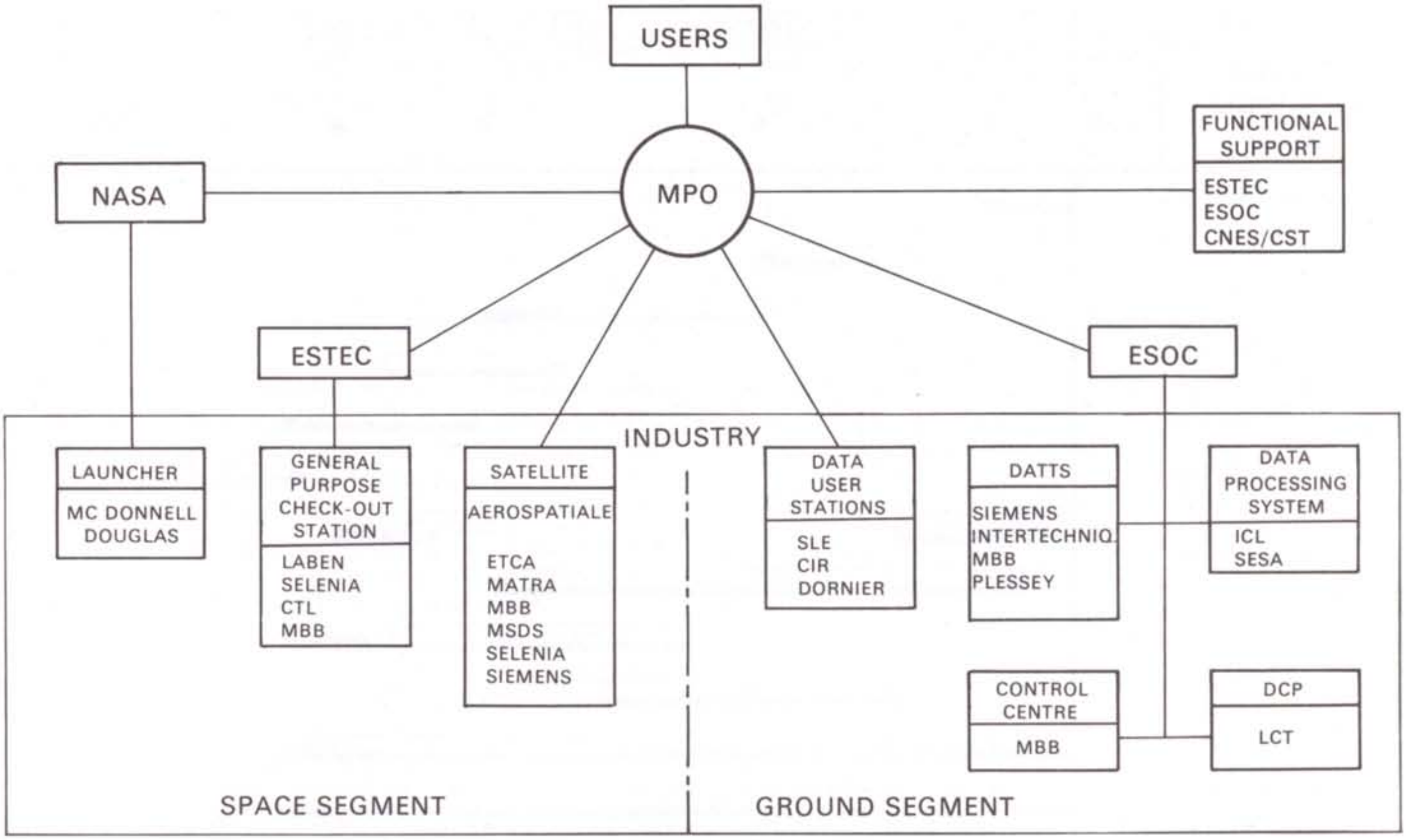


Figure 2 – Programme organisation chart

date until April 1977. A further shift in the launch date, namely until August/September 1977, was later agreed to help solve budgetary problems by stretching the payment schedule and to permit the inclusion of the third radiometer channel. Then, as a result of the OTS launcher incident in May 1977, it was decided in mid-1977 to launch Meteosat-1 in November. In any case, it is fair to say that at least from a programme-management point of view, Meteosat-1 has been launched 'on schedule'.

PROGRAMME COST

The third objective, namely to execute the programme within a given financial envelope, has also been met so far. Indeed, at the last Programme Board meeting, the Executive was able to demonstrate that there is an extremely good chance of maintaining the development cost-to-completion below the '100% ceiling' foreseen when introducing the new ESA budget structure (about 118 MAU, at mid-1971 price levels), despite the fact that since the signing of the Legal Arrangement many items have been added to the programme. Development of software for the extraction of meteorological information (~1.5 MAU), development and integration of the third radiometer channel package (~1.5 MAU), the Lannion

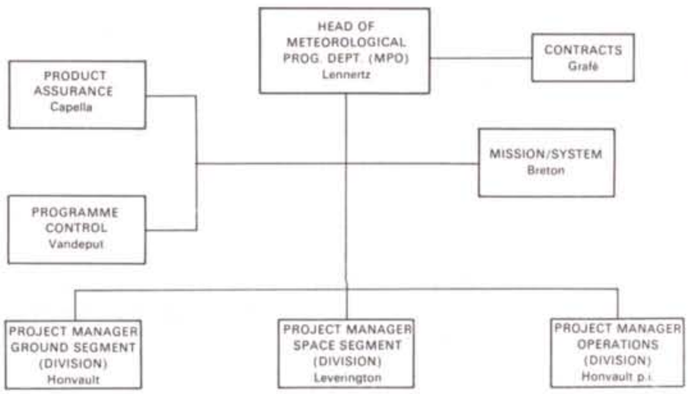


Figure 3 – Basic structure of Meteorological Programmes Office (MPO)

Geos/Meteosat relay (~0.25 MAU), and launch insurance (~1 MAU) are but four examples.

Moreover, cost comparisons show that the funding needed for the Meteosat Programme was not overestimated when the original financial envelope was defined. The present achievements, including the relatively healthy financial situation, are due mainly to sound system definition and design, strict elimination of technical 'gadgets', the minor (both in number and size) technical modifications, thorough quality, planning and

TABLE 2
Ground Equipment Contractors

		Prime Contractor	Co/Sub-Contractors
Data Acquisition Tracking and Telecommand Station (DATTS)	Antenna	SIEMENS (D)	MAN (D) CONTINENTAL MICROWAVE Ltd. (GB) LCT (F)
	Receivers	INTERTECHNIQUE (F)	EMD (F)
	Integration	MBB (D)	PLESSEY (GB) INTERTECHNIQUE (F) OSCILLOQUARTZ (CH)
	Odenwald/ Darmstadt Data Link	PLESSEY (GB)	
Data-Processing System	Hardware	ICL (GB)	CIT-ALCATEL (F) ROVSING (DK) SIEMENS (D) DATA GENERAL (US)
	Software	SESA (F)	LOGICA (GB)
METEOSAT Operations Control Centre (MOCC)		MBB (D)	
Data Users' Stations	Primary (PDUS)	SLE (F)	CIT-ALCATEL (F)
	Secondary (SDUS)	CIR (CH)	MUIRHEAD (GB)
Data-Collection Platforms (DCP)	Multifunctional DCP	LCT (F)	
	Monofunctional DCP (DCP/ship)	DORNIER (D)	

cost control, and efficient negotiation of the various contracts and their subsequent changes.

THE METEOROLOGICAL PROGRAMMES OFFICE

In accordance with ESA management practice, the Meteorological Programmes Office (MPO) was set up as a central group for the management of all programme activities (Fig. 2). It was sited in the CNES Centre Spatial de Toulouse (CST) primarily to allow a smooth transfer of knowhow from the original CNES project group, and to have direct access to the CST experts in the form of functional support. Figure 3 shows the basic MPO structure, and the members of the programme management group, which has met regularly (in principle once a week) to co-ordinate the various programme activities with the aim of achieving the right compromise between technical, planning, financial, contractual and personnel interests. Tables 1 and 2 list the industrial activities managed by MPO, either directly (satellite, users' stations), or indirectly through ESTEC (general-purpose checkout stations), ESOC (DATTS, data-processing system, MOCC, DCP), and NASA (launcher).

ACKNOWLEDGEMENTS

I should like to take this opportunity of recording my appreciation of the manner in which the Meteosat Programme has been supported by all parties concerned, whether within the Agency or externally. The fact that the Member States, through their representatives in the Programme Board, have agreed to the Meteosat exploitation programme and a second launch (on the third Ariane test flight) is particularly gratifying as it means that Meteosat will not be a 'one-shot' programme.

I should also like to express my thanks to the Scientific and Technical Advisory Group (STAG) for a clear definition of mission requirements and its support in solving our technical and operational problems.

My thanks also to CNES, its staff, and in particular the Director of CST, for their extremely valuable support, and to the Meteosat Contractors for the quality of their work. Special thanks go to my collaborators for their determination, their devotion to their tasks, and in particular for their programme-oriented spirit. □

The Meteosat Space Segment

D. Leverington, Project Manager, Meteosat Space Segment, Meteorological Programmes Department, ESA

The Meteosat spacecraft has been designed both mechanically and electrically around the radiometer and its associated electronics. The radiometer has displaced the apogee motor from its usual position inside the spacecraft and has placed a 3 Mbit/s requirement on the processing and transmission system. The addition of repeater and interrogator channels completes the picture.

MECHANICAL CONFIGURATION

Meteosat's payload is a large optical radiometer placed on the spacecraft's spin axis, in the volume normally reserved for the Apogee Boost Motor (ABM) on a geosynchronous spacecraft. Consequently, Meteosat's ABM had to be placed (Fig. 1) between the spacecraft proper and the launch vehicle, which led to a highly unstable configuration. It was therefore necessary to provide active nutation damping during the transfer orbit and to eject the apogee motor after burn. These considerations had a fundamental impact on the spacecraft's mechanical configuration.

The primary structure of the spacecraft supports the mechanical loads during all mission phases, the launch phase being the most critical. It consists essentially (Fig. 2) of:

- a central tube with an attachment ring for the ABM adapter, the radiometer being directly supported from this tube
- a main platform for the housekeeping equipment (including the attitude and orbit control tanks), and
- a secondary platform for the telecommunications units.

The secondary structure consists of body-mounted solar panels, thermal shields, an electrically despun antenna, toroïdal antenna support structure and minor brackets, etc. Conventional materials are used throughout, and the structural testing philosophy was also conventional, with acoustic-noise, static-load and sine and random vibration tests being conducted on a structural model at IABG's test facilities in Munich. Both the qualification vibration tests on the prototype spacecraft and the acceptance tests on the flight spacecraft were conducted at the CNES facilities in Toulouse.

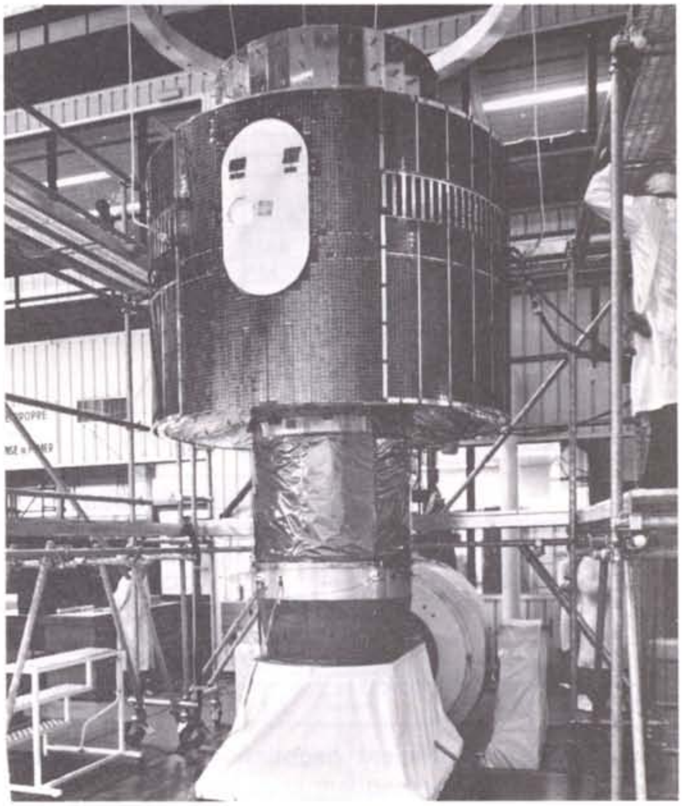


Figure 1 – Spacecraft plus ABM on shaker in Toulouse.

ENVIRONMENTAL CONTROL SYSTEM

Meteosat's environmental control system has to cope with:

- thermal control for electromagnetic radiation incident on and leaving the spacecraft
- particle radiation in so far as it degrades the solar array and thermal properties and affects the performance of some electrical components
- molecular contamination from outgassing products
- dust

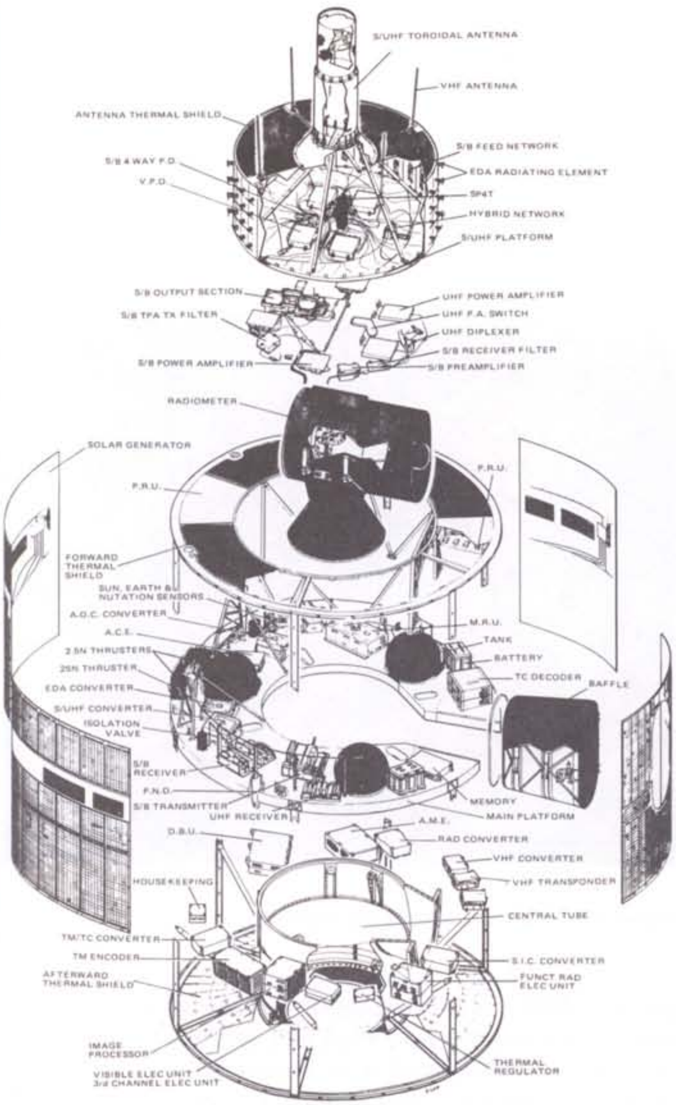


Figure 2 – Exploded view of the satellite.

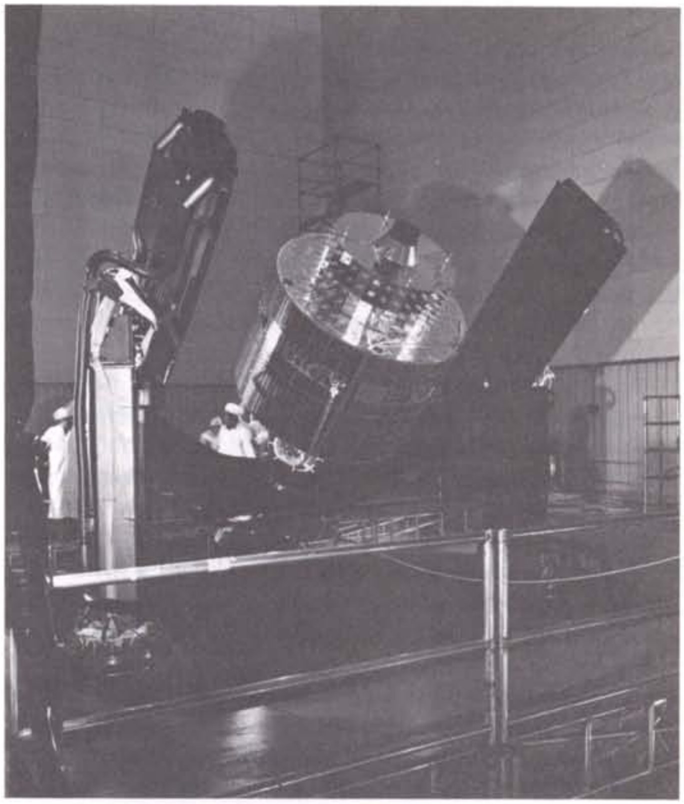


Figure 3 – Thermal model in preparation for solar vacuum test – transfer-orbit configuration.

- environmental control on the ground during spacecraft testing in both ambient and thermal-vacuum conditions
- magnetic and electromagnetic cleanliness.

THERMAL CONTROL

The classical means of temperature control for spinning satellites – namely solar cells and a control belt on the cylinder, thermal shields on the north and south surfaces, and coatings for internal equipment – have been used for Meteosat. However, as with all attitude control systems using hydrazine (which freezes below 4° C), insulation and heater protection are needed to avoid violent changes of temperature during the lengthy eclipses around equinox. Any excess power delivered by the solar generator is dissipated by external shunt resistors. Seasonal or annual changes of power have very little impact on the satellite's interior. The ABM, ejected at the end of burnout, was completely superinsulated to allow it to meet the requirements of firing up to tenth apogee in the most extreme cases of solar exposure (nominal injection at first apogee).

The radiometer, insulated conductively and radiatively from the satellite interior, possesses its own regulating system consisting of a cooler and telescope with baffle. The cooler is unique in meeting the requirements of IR detectors down to 79 K. Its growth potential permitted the addition during development of the third 'water vapour' channel and an extremely accurate regulation system (reference point 90 K) to eliminate photoconductor performance variations.

CONTAMINATION CONTROL

The chemical cleanliness control programme was set up to evaluate potential risks, and to minimise performance degradation and failure. The critical areas, established by both analytical studies and detailed experiments, are the cold faces of the radiometer (it is well known that under vacuum mass transfer takes place from hot to cold surfaces), and, to a much lesser degree, the solar cells and the thermal control coating. Risks have been minimised by careful choice of materials and by detailed configuration studies early in the programme.

The cleanliness requirements applied to the system design imposed constraints on:

- the configuration (propulsive system layout and provision of covers and baffles)
- manufacture, assembly and test procedures (control methods)
- on-ground and in-flight operations (procedures and control).

Furthermore, the very critical cold optics and cooler have been equipped with a heating system for possible decontamination operations during flight.

ON-GROUND ENVIRONMENTAL CONTROL

Climatic conditions and cleanliness were carefully controlled during Meteosat's on-gound testing. The thermal vacuum system test in particular (Fig. 3) involved major risks and a new testing method was perfected in that the spacecraft temperature was varied during solar simulation not by changing the temperature of low-temperature panels situated in the chamber, but by varying the solar constant and eclipse duration, the chamber shroud staying at low temperature.

APOGEE MOTOR

The launch vehicle injected the spacecraft into an elliptical transfer orbit from which the apogee motor was fired. This motor not only circularised the orbit, but simultaneously changed its inclination from approximately 28° to 0°.

The solid-propellant apogee motor, chosen from the well-

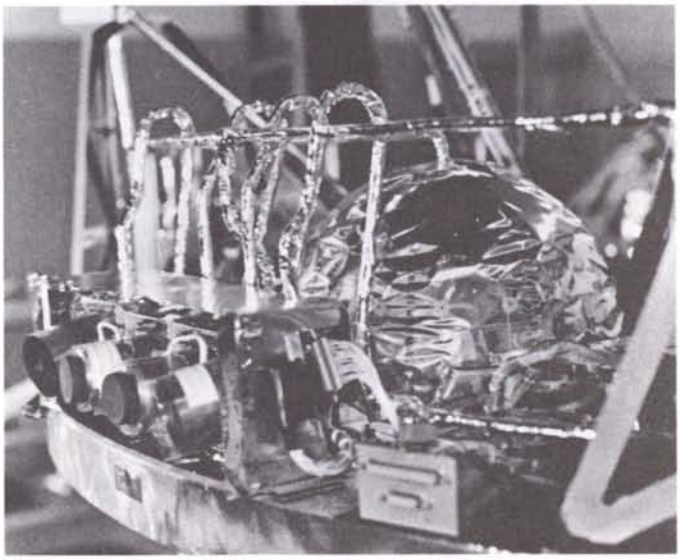


Figure 4 – Part of the hydrazine system.

proven SVM range developed by Aerojet in the USA, constituted slightly more than 50% of the total spacecraft weight at launch, and was mounted in a cylindrical adapter between the third stage of the launch vehicle and the spacecraft. As already mentioned, both the motor and its adapter were jettisoned after firing, to improve spacecraft stability.

ATTITUDE AND ORBIT MEASUREMENT AND CONTROL

Meteosat's Attitude Measurement Subsystem is responsible for the datation of the earth and sun pulses from the spacecraft's four infrared and pencil-type sensors and two pairs of sun-slit sensors, but its most critical function was the automatic control of satellite nutation during the transfer-orbit phase (nominally lasting only 5.5 h). Two redundant AND loops were automatically switched on at third-stage/satellite separation, to avoid the nutation that tends to increase exponentially in this phase, and to keep the ABM/satellite assembly spinning about the correct axis. Instability around the longitudinal axis of inertia is due principally to fuel-sloshing in the tanks.

All attitude and orbit modification operations are perfor-

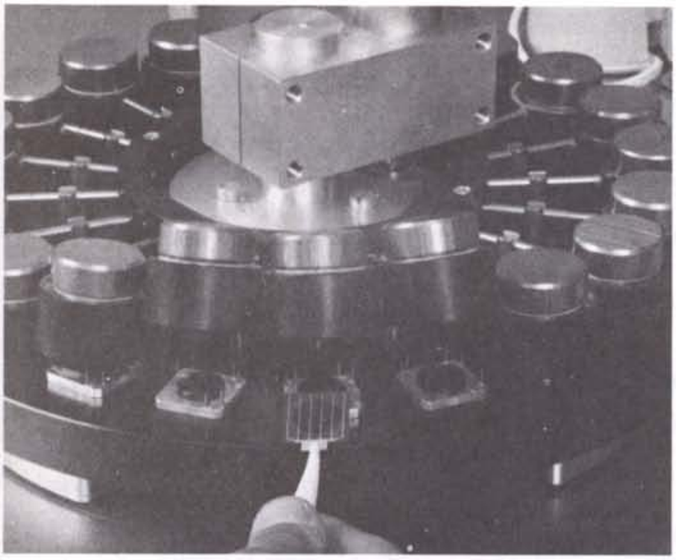


Figure 5 – Close-up of solar-cell covering with cover sheet.

med by the propulsion system of the Attitude and Orbit Control Subsystem (AOCS). As shown in Figures 2 and 4, the propulsion system has three nonredundant spherical tanks which feed two redundant sets of three thrusters (two 25 N and one 2.5 N).

The hydrazine tanks have a maximum capacity of 38 litres, easily sufficient for a five-year lifetime. The system operates with hydrazine pressurised by nitrogen under 21 atm at beginning of life and 4 to 5 atm at end of life, with an accompanying thrust reduction from about 25 N (resp. 2.5 N) BOL to 6 N (resp. 0.6 N) EOL.

The AOCS is completed by two mercury passive nutation dampers, developed specially for Meteosat, which are able to damp nutation down to 1 arc sec within a time constant of the order of 2 min.

POWER SUPPLY

The power subsystem consists of:

- a power-conditioning and distribution subsystem
- a solar generator
- harness and housekeeping, and
- a pyrotechnic system.

The power-conditioning and distribution subsystem forms the interface between the raw output power of the solar array (Figs. 1 and 5) and the regulated and switchable power for other electrical subsystems.

The constant-current characteristic of the solar generator is transformed into a constant-voltage characteristic by a sequential shunt regulator with overlapping, providing a 28 V bus for high-power loads. In eclipse, power is supplied by a nickel-cadmium battery, controlled by charge and discharge regulators.

Meteosat's solar generator is a body-mounted, cylindrical array of 16 128 2 cm × 2 cm solar cells covering 6.4 m^2 of panel surface. The basic design constraint was to provide constant power during spin despite the large cut-out needed for the radiometer. This has been achieved (spin ripple about 2%) by limiting the number of cells on the main panels to make the power drop when the sun is on the radiometer cut-out as small as possible. The generator has an end-of-life requirement of 200 W.

The Meteosat harness contains 180 connectors, 3500 cabling points, 600 shielded connections and a total of 2500 m of cable; as a result of tight shielding-requirement control, it weighs 2.5 kg less than the 16 kg originally specified. The housekeeping subsystem provides the telemetry for all nonelectrical subsystems.

Cleanliness requirements made it necessary to develop and qualify a new type of pyrotechnic cable cutter for Meteosat. This cutter, which is used for radiometer bearing relase, baffle and cooler-cover ejection, relies on the inertia of an accelerated body in a sealed tube for its cutting action. All pyrotechnics are powered by the spacecraft's battery.

MISSION-SUPPORT TELECOMMUNICATION SUBSYSTEM

The Mission-Support Telecommunication Subsystem provides the VHF telecommunication links and on-board data-handling functions (data acquisition and distribution, respectively) necessary for monitoring and control of the space system and all its subsystems (platform and payload). In addition, it provides the facilities

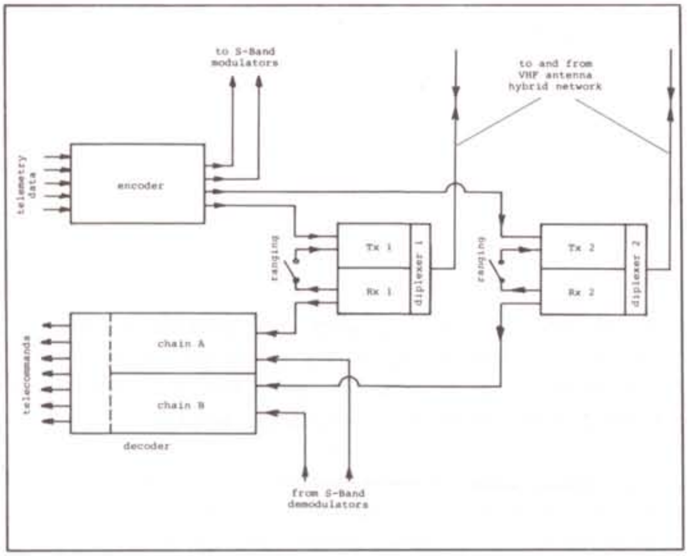


Figure 6 – VHF block diagram.

necessary to permit tracking of the satellite and to generate and distribute the on-board timing reference.

Pulse Code Modulation (PCM) is used for transmission of telemetry data via the downlink to the ground and the telemetry message is transmitted continuously.

PCM is also used in the telecommand link, which is not continuous, but only activated when required. The system is practically immune to false or spurious commands under any signal and interference conditions.

The on-board hardware provides facilities to measure the direction to, distance from, and radial speed of the satellite from the ground. It also generates a time base to which all on-board events are referred (datation). The time of execution of commands can also be given in terms of on-board time (time tagging), and this provides a very accurate time relationship for related events, such as outputs of attitude measurement sensors and operation of attitude correcting thrusters, because delays through the communication up and downlinks with the ground, which are known with only limited accuracy, are eliminated.

ON-BOARD HARDWARE

Figure 6 is a block diagram of the on-board hardware.

(a) Telemetry encoder
The telemetry encoder receives data from the various sources, digitalises them when necessary, assembles them into a serial digital PCM message, modulates this message onto a subcarrier, and transmits the resulting video (high-frequency signal) on four lines simultaneously to the redundant VHF transmitters and S-band modulators. All of these operations are controlled by the program which in turn is controlled by the time-base generator, a highly stable master oscillator and its associated driving chain. This time-base information is distributed to various users in the form of clock and synchronisation signals, notably to the image processor, the attitude-measurement subsystem, and the telecommand decoder.

(b) Telecommand decoder
The decoder receives the video on four lines simultaneously from the redundant VHF receiver and the redundant S-band receivers. A priority logic selects the valid signal.

(c) Ranging transponders
The transponder consists of a VHF transmitter and a VHF receiver to implement the telemetry RF uplink and telecommand RF downlink. The ranging transponding loop is activited by telecommand. Reception and transmission take place via the same antenna port by means of a diplexing network.

(d) Redundancies
Inside the encoder, the following four subassemblies are redundant and can be selected by telecommand:

- high-speed multiplexer
- oscillator
- programmer
- analogue/digital converter.

The transponders are redundant and the transmitters can be selected one at a time by ground command. Both receivers are on at all times and each works into a dedicated decoder chain.

MISSION-PERFORMANCE TELECOMMUNICATION SUBSYSTEM

The Mission-Performance Telecommunication Subsystem used for the operational orbit consists of a transponder operating in the S-band (1700 MHz) and UHF (400 MHz), and four antennas (Fig. 7). It provides:

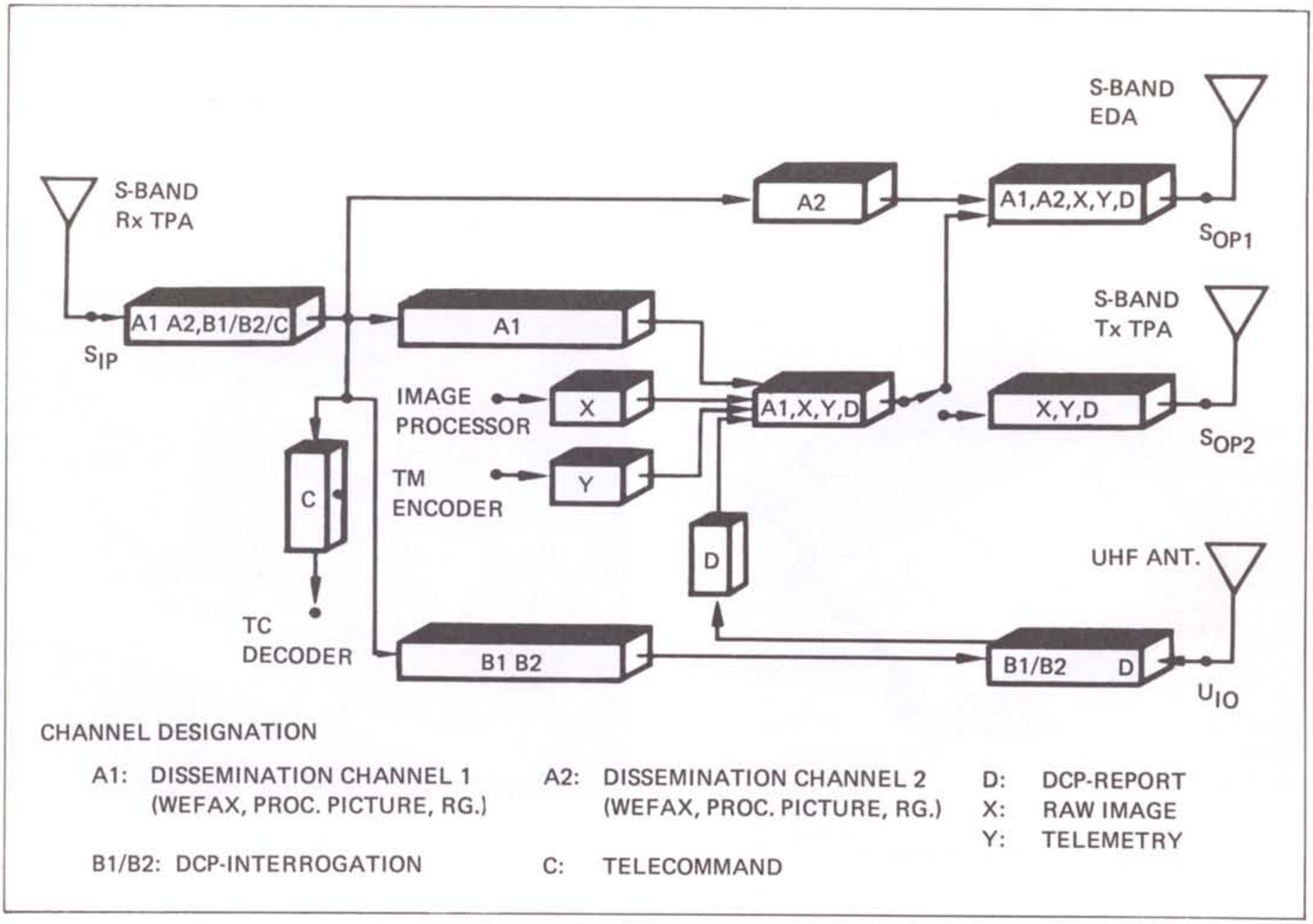


Figure 7 – Block diagram of Mission-Performance Telecommunication Subsystem.

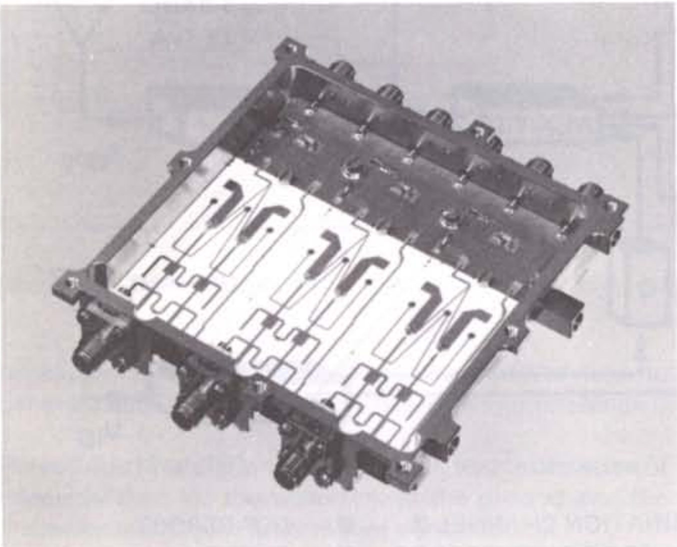
- one channel to transmit raw radiometer data to the main ground station (Mission 1) (S-band)
- two repeater channels for dissemination of processed pictures to local receiving stations (Mission 2) (S-band)
- two channels for transmission of interrogation and report signals between the main ground station and numerous data-collecting platforms (Mission 3) (UHF and S-band)
- telecommand reception and telemetry transmission (S-band).

The two repeater channels are also used to perform precision ranging. All S-band uplink signals are received via the toroïdal pattern antenna shown in Figure 2. Downlink S-band signals are transmitted via the S-band electronically despun antenna. During eclipse, the transponder is switched to the first of these two antennas and picture dissemination is not then possible. Uplink and downlink VHF signals (platform interrogation and reporting) are received and transmitted via the UHF antenna.

TRANSPONDER

Meteosat carries the first European hard-limiting, multi-carrier operated transponder. An all-solid-state, double-frequency-conversion approach is used, with an intermediate frequency around 60 MHz. The transistorised class-C amplifiers generate 20 W RF in S-band and 25 W in UHF.

In normal operation, five signals (raw image, two dissemination signals, platform reports and telemetry) have to be radiated simultaneously in the S-band between 1675 MHz and 1695.5 MHz via the despun antenna. Hard Limiting of this multicarrier signal was necessary in order to operate the power transistor amplifiers in their most efficient mode (constant envelope signal), but this results in the generation of intermodulation products. Careful frequency planning, computer analysis, transponder simulation and breadboard tests were necessary to minimise radiation of such products in the radio-astronomy band (1660–



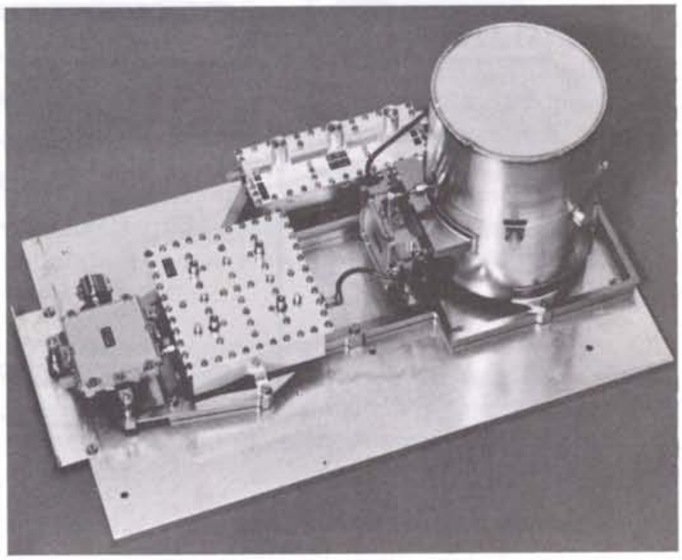


Figure 8 – (a) S-band transmitter multiplexer *(b) S-band transmitter up-converter.*

1670 MHz) and in the band used by the US satellite ITOS (1697–1698 MHz).

Interdigital and dual-mode waveguide technology is used for microwave multiplex filtering (Fig. 8a), while mixed technology (thin-film microwave integrated circuits and teflon glass) is used for converters and amplifiers (Fig. 8b).

ANTENNAS

Meteosat also carries the first European Electronically Despun Antenna (EDA) (Fig. 9). The S-band EDA is a cylindrical shell structure, 1.3 m in diameter and 54 cm high, carrying 32 columns of four dipoles equally distributed about its circumference. A beam is formed by excitation of the five columns that face the earth at any given moment. As the satellite rotates, the beam 'counter-rotates' to keep it earth-pointing. Coarse scanning, equal to the angular separation between columns, is achieved by sequential use of contiguous columns, while fine scanning is provided by progressive variation of the amplitude illumination distribution.

Three low-gain antennas, which have rotationally symmetric patterns and therefore do not require despinning, also form part of the antenna subsystem (Fig. 2):
- a conventional VHF antenna with four monopoles mounted on the top surface of the EDA
- two side-by-side S-band slotted-waveguide antennas producing a linearly polarised toroïdal pattern, mounted on top of the EDA
- a UHF antenna with a broad circularly-polarised toroïdal pattern, mounted above the slotted S-band antenna.

Meteosat is also the first European satellite programme which has used near-field testing techniques for its antennas. Normally, during satellite development complete RF system tests are conducted on an early satellite model (structural, thermal, etc.) using a qualified antenna range and only very limited checks are run during satellite integration and testing. In the case of Meteosat, it was deemed necessary to make as many checks as possible, and a unique near-field approach developed by ESA (outlined in Bulletin No. 8, pp. 48-53) was selected and a special transportable checkout station developed.

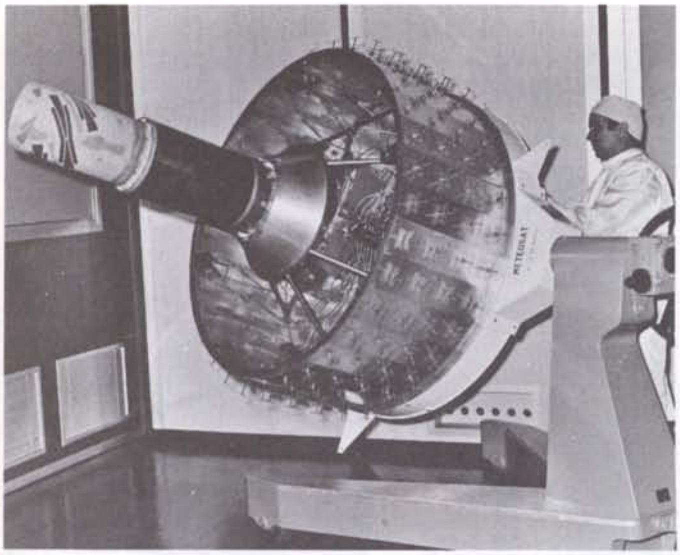


Figure 9 – Antenna subsystem.

DATA HANDLING

Meteosat requires accurate synchronisation of images, fast encoding of radiometric signals, and buffer memories to lower transmission rates by format 'stretching'. In these three areas, in which future European remote-sensing satellites could be even more demanding, Meteosat is ahead of satellites already launched by the Agency.

Two image processors and one buffer memory synchronise the image-taking and the processing of the radiometric signals. A telemetry encoder and a telecommand decoder provide the corresponding support functions.

IMAGE SYNCHRONISATION

The image synchronisation system, which organises image-taking sequences and image transmission, is characterised by a very precise spin clock, using the sun or earth as reference, and by numerous operating modes. For each revolution of the satellite, it controls:

- south-north scanning of the earth, commanding the telescope tilt within limits preset by ground command.
- east-west scanning of the earth to determine the exact position of the sampling window of the radiometer tracks
- generation of the image
- switching of the despun antenna elements.

The spin clock is controlled by a quartz oscillator (5.3 MHz) and reset by a reference pulse from a solar attitude detector. It computes an artificial image edge corresponding to the beginning of the image-taking window. This window is open for 30 ms, during which time the telescope axis scans a sector of 18° to cover a complete earth disc.

DIGITAL IMAGE CHAIN

This chain treats the signals from three nominal radiometric channels, one in the infrared band (10.5–12.5 μm) and two in the visible (0.4–1.0 μm). The water-vapour channel (5.7–7.1 μm) can be substituted for the first visible channel by telecommand.

The multiplex function samples and converts analogue signals to digital data, and it generates and stretches the image format.

Each format is emitted for 600 ms synchronously with the satellite spin. It requires a synchronisation word, auxiliary data, radiometric data and a pseudo-random filling code. The only differences between the 'stretched' and the real-time mode of transmission are the rates at 167 kbit/s and 2.7 Mbit/s and the lengths of the filling codes.

TELEMETRY AND TELECOMMAND

The telemetry encoder supplies clock signals to all users, multiplexes and processes analogue and digital signals coming from all over the satellite, and generates the telemetry format to the VHF and S-band transponder. The telecommand decoder demodulates the signals coming from the above transponders; it chooses, decodes and executes the PCM telecommand messages.

Telemetry and telecommand was at VHF for the transfer orbit and early near-synchronous orbit, but at S-band when in sight of Darmstadt. However, the VHF band can always be used in 'emergency' mode. □

Meteosat's Imaging Payload

M. Reynolds, Radiometer Manager, Space Segment Division, Meteorological Programmes Department, ESA

The Meteosat radiometer forms the subject of this separate article not because it is in any way a functionally or physically independent part of the space hardware, but because it constitutes the basis of the imaging mission and because it is the first large European optical payload of its type for meteorology (Fig. 1).

The formulation and dissemination of Meteosat's images was the subject of an article in a previous Bulletin (No. 6, August 1976) and so, to avoid duplication, the present article will be restricted to a description of the payload's more interesting functional aspects and some instrument design engineering problems encountered during the development programme.

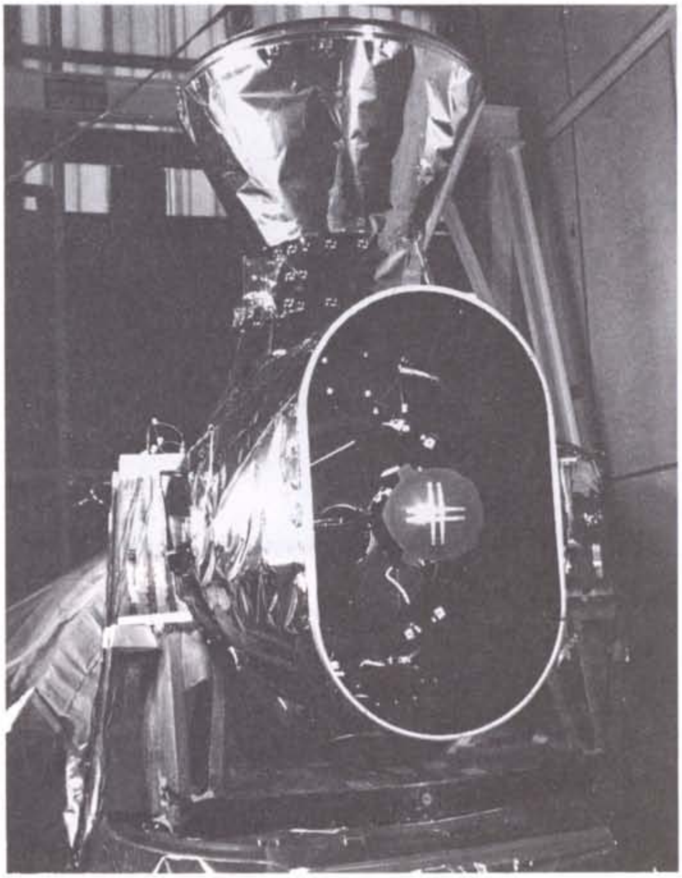


Figure 1 – The Meteosat radiometer during vibration testing in Toulouse.

DEVELOPMENTAL HISTORY

The major activities and phases that have formed part of the radiometer's development, starting with the pre-Agency work performed under CNES guidance, are summarised by the accompanying bar chart (Fig. 2). The pre-development work under CNES's responsibility provided the Agency, at the start of hardware development, with an optically functional model (M1). After being used for initial optical and thermal evaluations, this same model was equipped with a mass-representative dummy cooler and electronics and used, after minor interface modifications, as the subsystem and system-level structural model.

The use of the engineering model (P1) in the dual role of fully functional development model and thermal model was a very desirable feature not only from a cost-saving viewpoint, but also because the very large radiometer baffle opening coupled with the large optical elements demanded a functional model for thermal simulation of the interaction of telescope scanning with solar radiation. Such a model philosophy was, of course, considerably aided by the relatively advanced development status at that time.

During the development programme, two interesting functional modifications were made to the basic design between models P1 and P2. The first was to increase the telecommanded gain change rate of the visible channels from 2 : 1 to 16 : 1 (commandable in 16 steps) to allow investigation of atmospheric aerosol concentrations above low-albedo areas, e.g. sea surfaces. The second was to introduce an additional image channel in the atmospheric water-absorption band (5.7–7.1 μm). The original specification called for imaging in only the visible/near-infrared (0.4–1 μm) and the infrared (10.5–12.5 μm).

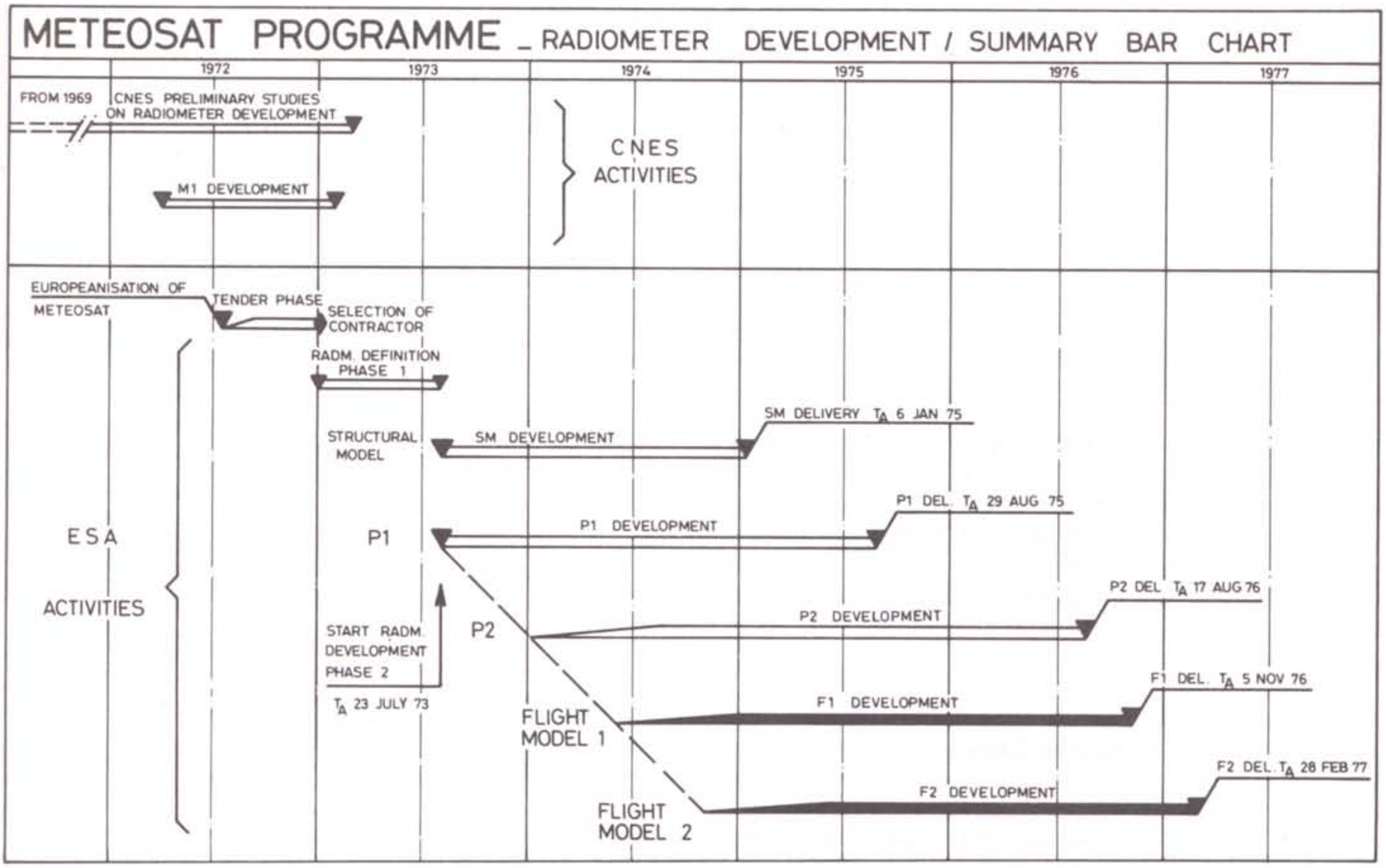


Figure 2 – Radiometer development/summary bar chart.

TECHNICAL DESCRIPTION

Physically, the radiometer consists of the main optical unit and some additional electronic packages mounted on the satellite equipment platform.

MAIN UNIT

The major outward feature distinguishing this European radiometer from similar equipment developed in the United States for the SMS and GMS satellites is the absence of a single, large scanning mirror as the first element in the optical chain. To avoid the need for such a mirror, the Meteosat design scans the primary telescope, which consists of a Ritchey-Chrétien primary and

TABLE 1
Main Physical Parameters

Telescope aperture : Primary	400 mm diameter
Telescope aperture: Secondary	140 mm diameter
Telescope focal length	3650 mm
Telescope optical material	Zerodur
Reflective coating	AG Th F4
Mass (total)	61 kg
Power requirements	28 V
Average consumption	27 W
Peak consumption	66 W (during cooler decontamination)
Cooler performance:	
– winter solstice	< 80 K
– summer solstice	< 95 K

TABLE 2
Main Performance Parameters

Parameter	Visible	10.5–12.5 μm	5.7–7.1 μm
Number of channels	2 simultaneous	1 + 1 redundant	1
Field of view	0.065 mrad	0.14 mrad	0.14 mrad
MTF (optics and detector)	> 0.5 for f ≤ 5600 cycle/rad	0.5 for f ≤ 2800 cycle/rad	0.5 for f ≤ 2800 cycle/rad
Number of lines per image of ±90°	5000	2500	2500
Detectors: Type	Si photo-diodes	Hg Cd Te	Hg Cd Te
Dimensions	250 × 250 μm	70 × 70 μm	70 × 70 μm
Electronic bandwidth	60 kHz	30 kHz	30 kHz
Radiometric performance	S/N > 200 for 25% albedo	NE(ΔT) < 0.4 K at 290 K	NE(ΔT) < 1.0 K at 260 K

secondary mirror mounted with a small 45° on-axis mirror in a 'Condé Cassegrain' arrangement. This configuration allows the telescope to be scanned about an axis which nominally lies in the satellite, and hence the earth's equatorial plane, while still maintaining the subsequent relay optics, detectors, etc. in a fixed position with respect to the satellite. The general arrangement is illustrated in Figure 3.

On exiting the telescope, the optical axis is folded by a series of small flat mirrors, to arrive either at the visible detectors or at the input to a lens relay assembly leading to the infrared detectors. Two of these flat mirrors, arranged in a right-angle configuration at the end of a linear translating mechanism, allow the optical focus to be optimised, both during ground testing and in flight, by simple telecommanding of the mechanism drive assembly.

To maintain the necessary optical quality over a wide range of temperatures and in the presence of significant thermal gradients, the mirrors are fabricated from 'Zerodur', a low-expansion material from which material excess to structural requirements was removed by ultrasonic drilling and grind processes (permitting a 65% mass reduction). To avoid mechanical stress in the telescope scanning drive mechanism and the telescope support bearings, the telescope assembly was strapped down to the main radiometer structure for transport and launch. Once in orbit, the strap was released by pyrotechnic cutters.

The environmentally induced problems of vibration,

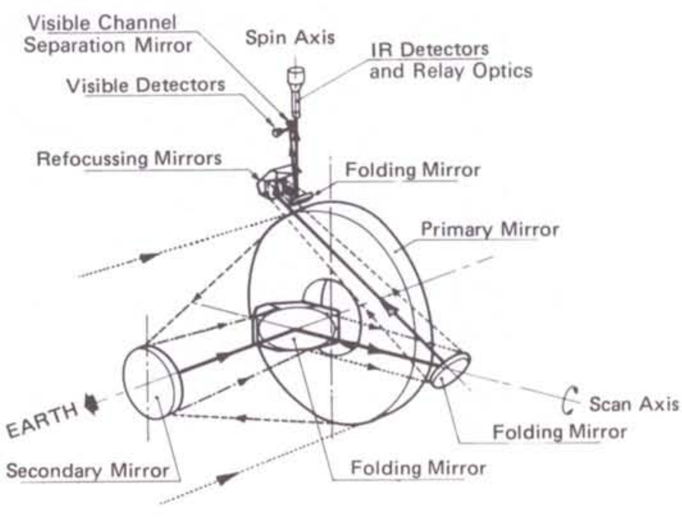


Figure 3 – Radiometer optics (schematic)

shock and acceleration during launch and differential expansion in orbit led to the development of a special primary-mirror mounting technique, relying on a system of three flexible blades linked to spherical bearings bonded to the mirror substrate. This assembly is carried in the telescope support structure, which consists of a frame-strengthened Invar cylinder and an Invar tripod to support the telescope secondary. The whole assembly is suspended on flexure pivots and can be rotated through ±10°.

In normal use, an image is generated by rotating the telescope through ±9° (selectable from the ±10°) in

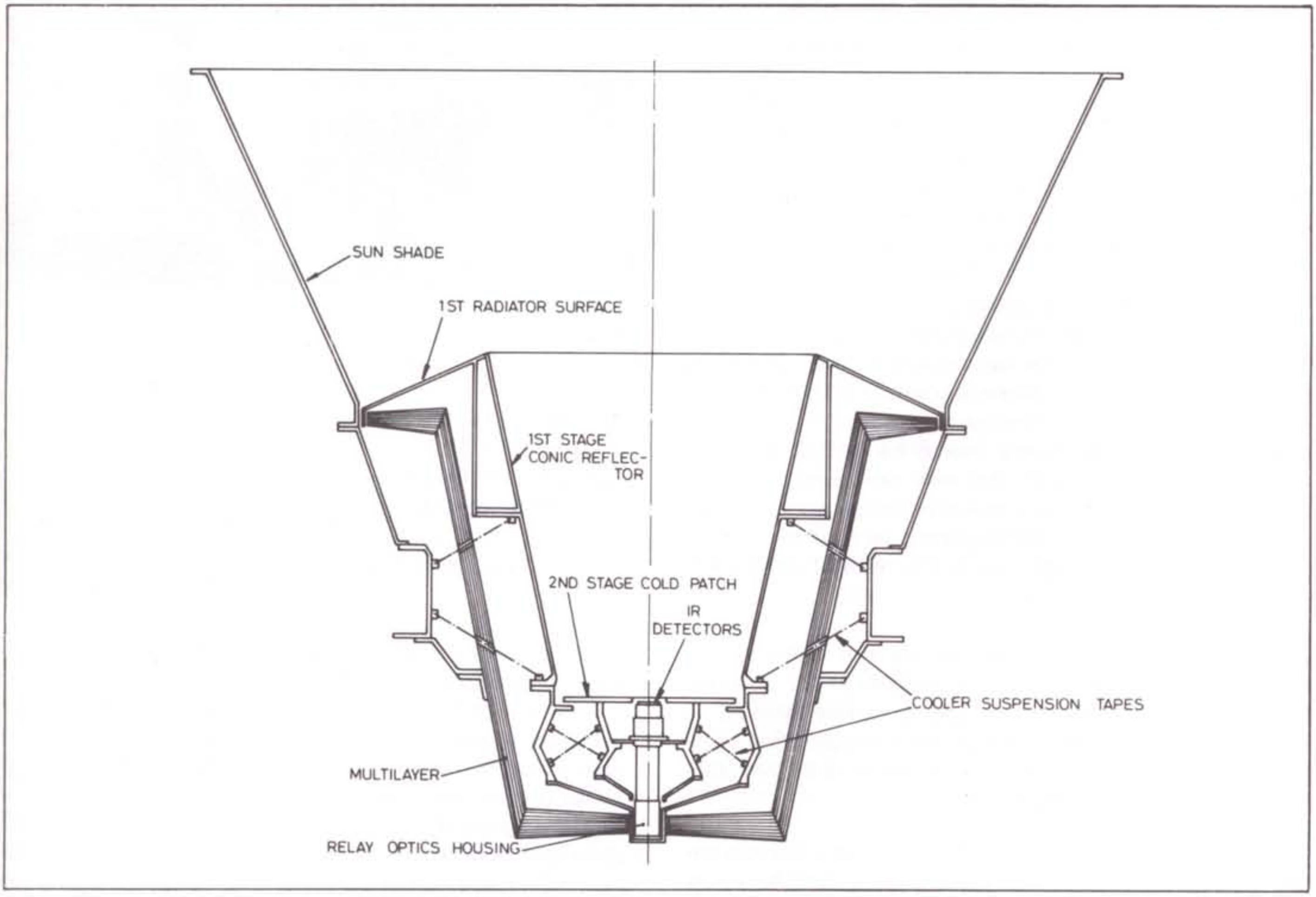


Figure 4 – Radiometer cooler (schematic)

2500 steps (1 step per spacecraft rotation). A complete image is therefore generated in 25 min with the satellite spin of 100 rpm. Scanning control is derived from the synchronisation and image channel (SIC) subsystem to ensure synchronisation with other functions linked to spin rate and phase.

The optically collected visible and infrared earth signals are converted into analogue electrical signals by the various detectors, five in all. These are divided into two subsets, two visible and three infrared.

The two visible detectors are positioned in the focal plane of the primary telescope. Their instantaneous field of view at the earth's surface (2.5 km square) is determined by their physical size, 250 μm × 250 μm sensitive area, and the telescope's focal length. Both detectors are fabricated on a single silicon chip by manufacturing techniques similar to those used for transistor manufacture. This ensures the homogeneity of detector performance needed for good image quality, as each detector generates alternate lines of the high-resolution image.

While the visible detectors function correctly at ambient temperatures, the three infrared detectors must be cooled to less than 95 K. Hence these detectors – a redundant pair for the thermal infrared and a single element for atmospheric-water-vapour imaging – are integrated into the second stage, or 'cold patch', of a passive cooling system. Each detector is 70 μm square, and by virtue of the relays and primary optics, generates an instantaneous 5 km square field of view at the subsatellite point. The detectors are cooled by what is effectively a black radiator surface mounted at one end of the spacecraft, insulated from thermal input from the latter and free to radiate to space. An equilibrium temperature is established corresponding to a balance between thermal input from insulation inefficiencies, thermal conduction from electrical leads, etc. and the thermal energy radiated to space. In practice, the view to space has to be limited to avoid energy interchange with the sun and earth. This is achieved with an internal conical reflector, cooled by its own radiator surface and protected in turn from solar radiation by a sun shield, also in the form of an internal conical reflector (Fig. 4).

As even the above precautions are not sufficient to completely remove the sun's influence on detector temperature the whole year round, active heating is employed to keep detector operating temperature constant and stabilise the otherwise temperature-variable spectral-sensitivity characteristics.

Infrared channel electronics and the infrared detectors are coupled by specially designed cables which are a compromise between the conflicting requirements of low electrical resistance and low thermal conductance encountered in the path between the electronics at ambient temperature and the detectors at operating temperature.

Another significant item of the main unit (Fig. 5) is a mechanism for in-flight infrared calibration with an associated blackbody reference source. This mechanism permits three calibration conditions: detector self-viewing, detector sun-viewing and detector blackbody viewing. During operations, the moon, space background signals and selected earth regions will also be used for calibration referencing, but these references are available through inherent system flexibility rather than any special on- board equipment.

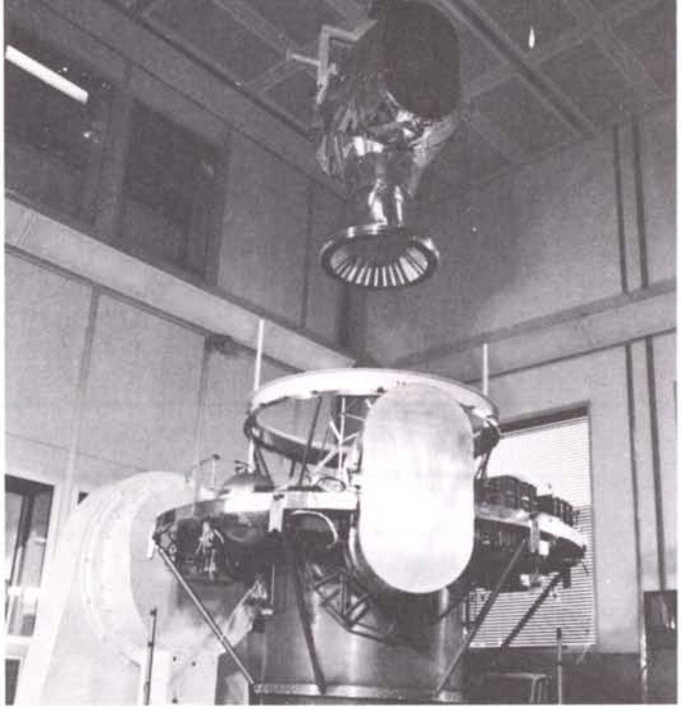


Figure 5 – Installation of the radiometer.

IMAGING ELECTRONICS

Part of the image electronics is housed in and on the main radiometer unit. The remaining items, visible and water-vapour channel amplifiers, are mounted together on the satellite equipment platform.

While the electronics of the various image channels differ in design detail, in principle each channel consists of the same general types of functional units; namely a pre-amplifier with appropriate interfacing to the respective detector, several stages of gain amplifiers, a commandable gain-change stage and signal bandwidth limiting filters. In addition, use is made of active biasing and zero-level clamping during the non-earth-viewing section of each spin, in order to maintain sensible radiometric-signal zero levels and compensate for low-frequency drift.

The output of each channel is an analogue voltage which is directly proportional to the input optical signal of the radiometer and is adjustable in amplitude (by gain change) depending on the purpose for which the images are to be used.

FUNCTIONAL ELECTRONICS

The term 'functional' is used to distinguish a collection of electronics integrated into a single box and also positioned on the satellite equipment platform. This unit's main tasks encompass power-conditioning and supply, motor-drive electronics, logic sequencing controls, amplifiers for temperature-monitoring thermistors and analogue/digital conversion of analogue encoding data from the telescope scanning mechanism, to allow identification of radiometer line scan number.

PARTICULAR DEVELOPMENT PROBLEMS

Whilst hardware development encountered the usual difficulties one might expect in such a programme, neither the space available here nor the reader's interest could be expected to accommodate a full catalogue. Only a few of the more interesting problems will be briefly recounted.

In terms of general technology, the radiometer marks the first space application of several novel techniques, the telescope fabrication and telescope mounting having already been mentioned in this context. In addition, the detectors themselves represent a new field for Europe, especially the infrared units. The water-vapour channel detector is particularly interesting as it is the first known application of cadmium/mercury telluride technology to this region of the spectrum.

In terms of programme impact and importance, the most difficult development problem was undoubtedly the mechanical suspension of the cooler. A very careful compromise between thermal and mechanical requirements had to be struck and the final solution relies on glass-fibre filaments arranged in parallel to form tapes. The cooler is integrated with these tapes in tension, six to support the first stage from the cooler outer structure and six to support the second stage from the first. This approach proved adequate during early thermal and static mechanical tests, but the first attempts at vibration testing ended in support failure in a matter of seconds. Early attempts to solve the problem were frustrated because the visual evidence suggested that the attachment interfaces of the tapes were at fault, but it was eventually found that the fibre failed in a manner analogous to metal fatigue, when subjected to repeated bending beyond a critical angle.

The cooler was also the root of a second problem area that had considerable programme impact, in that it nominally functions in radiative thermal equilibrium. Any change in the surface characteristics of the radiating elements would change the equilibrium temperature and so for this and similar reasons associated with the radiometer optics, a very sophisticated programme of chemical and particle contamination control had to be introduced which had repercussions at all levels of design, manufacture, integration and test.

As well as the problems of chemical and particle cleanliness, the radiometer has provided other engaging requirements for innovation. The measurement and checking of optical performances posed an interesting problem, as the Meteosat instrument is effectively focussed at 36 000 km. Collimators were needed to reduce this distance to a few metres and, as they had to have better optical performance than the radiometer for obvious reasons, they represented important cost items.

Calibration of the infrared image channels demanded good thermal simulation of space for cooler operation. An existing vacuum facility dating from the ESRO TD satellite project and sufficiently large to accommodate the radiometer, test collimator and optical test sources, was adapted for this purpose by the inclusion of a helium-cooled screen.

A major problem at system level was real-time evaluation of the image data to allow use of an automatic checkout system. Although not exactly the same, this problem is very comparable to the computer image-processing problems to be encountered in satellite operations.

CONCLUSIONS

While I cannot claim to have given a complete exposé on the Meteosat radiometer, I hope to have conveyed at least a general idea of Europe's newly demonstrated ability to develop and manufacture large optical instruments for space application. The article would not be complete without an acknowledgement to the many contributors to the radiometer's design and development, in particular to the various European industrial groups, headed by SNIAS as Prime Contractor for Meteosat and Engins MATRA as their co-contractors specifically for the radiometer, but also to CNES who initiated the radiometer's development and subsequently provided invaluable technical assistance with many problems as well as with the less interesting but equally important evaluation, control and monitoring tasks. □

Le Secteur Terrien du programme Météosat

C. Honvault, Chef de Projet Segment Sol, Bureau du Programme Météosat, ESA

Les caractères géostationnaire et pré-opérationnel du satellite Météosat ont nécessité le développement et l'installation d'un secteur terrien très important, caractérisé par

- **un niveau de complexité élevé dû à la masse considérable d'informations à acquérir et à traiter en temps réel (166 kbit/s) 24 heures sur 24.**
- **une redondance très poussée des équipements de façon à satisfaire au mieux les exigences des utilisateurs concernant:**
  - **le pourcentage d'images non exploitables (<5%)**
  - **la diffusion des informations sur le réseau opérationnel météorologique à des instants fixes chaque jour.**

FONCTIONS PRINCIPALES

Les fonctions principales assurées par le secteur terrien sont les suivantes:

- la localisation, la commande et le contrôle permanents du satellite en orbite;
- l'acquisition des images;
- les corrections géométrique et radiométrique des images;
- l'extraction des paramètres météorologiques conformes aux demandes des utilisateurs, et leur diffusion sur le réseau météorologique via Offenbach;
- la dissémination des images corrigées aux stations utilisatrices via le satellite;
- l'acquisition, le traitement et la diffusion des informations émises par les plates-formes de collecte de données.

LES INSTALLATIONS

Le secteur terrien de Météosat comprend des installations très diverses (Fig. 1) qui peuvent être classées en deux grandes catégories:

- installations nécessaires à la réalisation des fonctions énoncées ci-avant (installations centrales en Allemagne, relais de diffusion des images des satellites géostationnaires américains GOES situé à Lannion et transpondeur-sol pour la localisation du satellite (LBT));
- installations nécessaires aux utilisateurs pour l'exploitation du système Météosat, telles que
  - les stations primaire et secondaire d'utilisation des données (PDUS et SDUS)
  - les plates-formes de collecte de données.

Pour ces équipements, l'Agence n'a développé que des prototypes fonctionnels destinés aux tests du système global et aux démonstrations.

LES INSTALLATIONS CENTRALES

Compte tenu de la haute cadence de transmissions (166 kbit/s) des informations, aussi bien du satellite vers le sol (images brutes), que du sol vers le satellite pour la dissémination des images haute résolution, il a été nécessaire de limiter la distance entre la station de réception et le Centre de Traitement des Données, pour des raisons techniques et économiques. Ceci a amené en 1973 le choix de la solution Darmstadt-Odenwald.

Odenwald, région radioélectriquement calme où est installée la station de réception (1675–1695 MHz) et de transmission (2097–2101/5 MHz)

Darmstadt, où se trouve l'ESOC et le Centre de Traitement des Données Météosat.

Les deux sites sont reliés par une liaison coaxiale à large bande (1,2 MHz), sur laquelle transitent aussi les données du satellite scientifique Geos utilisant des installations aux fonctions identiques sur les deux mêmes sites.

Odenwald

La station (Fig. 2), qui assure la réception des données (images, contrôle de fonctionnement du satellite, messages des plates-formes de collecte de données, signaux de localisation), la transmission des ordres de télécommande, des images et informations à disséminer vers les utilisateurs, des interrogations des plates-formes de collecte de données, des signaux de localisation, se trouve près de Michelstadt à environ 50 km de Darmstadt.

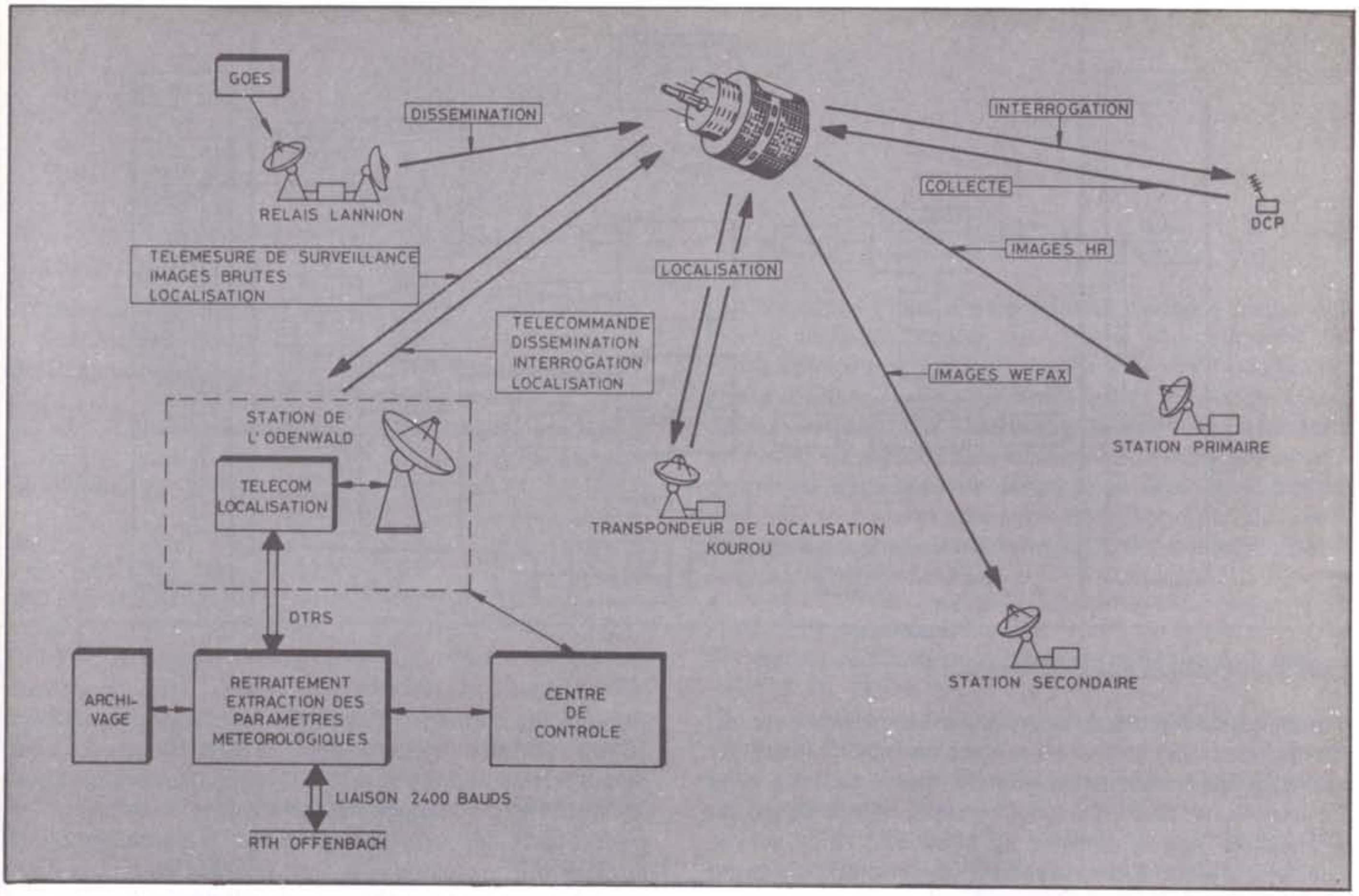


Figure 1 – Secteur terrien de Météosat.

Figure 2 – Vue de la station de Michelstadt (Odenwald).

Sa caractéristique principale est d'être gérée entièrement à partir du Centre de Contrôle Météosat à Darmstadt, ce qui signifie

- la transmission des informations de fonctionnement de la station à Darmstadt, ces informations sont prises en compte par un mini-calculateur qui assure leur présentation sur un écran de visualisation sous une forme appropriée aux opérateurs;
- en cas de panne, la commutation automatique d'un équipement sur l'autre, tous les équipements essentiels étant doublés pour assurer le maximum de redondance.

Les seules interventions humaines dans la station sont celles liées à la maintenance, soit préventive, soit corrective. Ce choix a résulté d'une étude de coût comparatif avec la solution classique (opérateurs en station).

Eu égard au caractère pré-opérationnel du programme et à son extension possible vers un programme opérationnel constitué par d'autres modèles de vol de Météosat ultérieurement, la solution retenue devrait s'avérer moins onéreuse à long terme.

Kourou (Guyane française)
La localisation du satellite est basée sur le principe de la trilatération dans lequel trois stations mesurent le temps de propagation aller et retour entre le satellite et chaque station avec une très grande précision. En fait, compte tenu des règles de mécanique céleste, deux stations (éventuellement une) sont suffisantes: Darmstadt et un

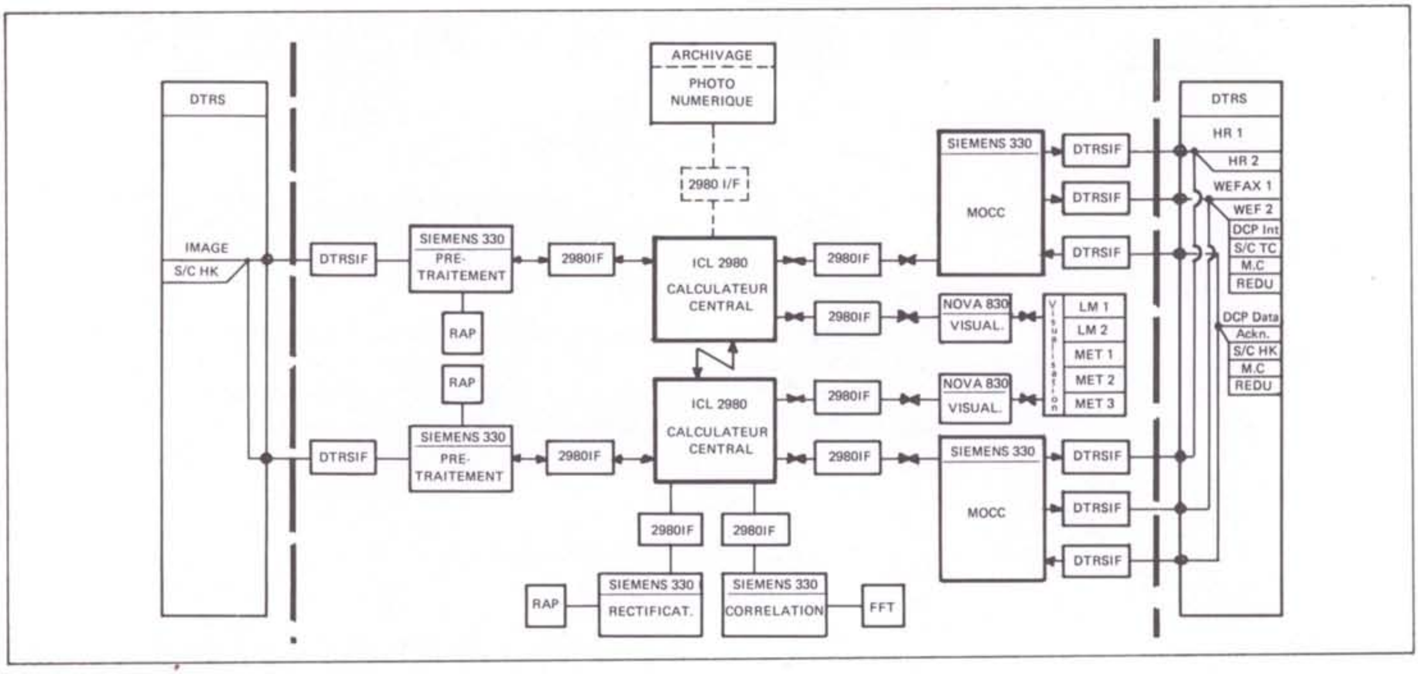


Figure 3 – Centre de traitement Météosat.

transpondeur installé à Kourou. Le fonctionnement du transpondeur est entièrement automatique. Il reçoit et analyse en permanence le signal disséminé par le satellite sur le premier canal. Dès qu'il y reconnaît le signal de localisation, il le retransmet sur le second canal vers le satellite qui à son tour le réémet en direction de la station de l'Odenwald.

Lannion

Afin de faire bénéficier l'Europe des images prises par le satellite géostationnaire GOES sur l'extrême ouest de l'Atlantique, un relais a été installé à Lannion (France) au Centre de Météorologie Spatiale. Compte tenu de sa situation à l'extrême ouest de la France, cette station est capable d'acquérir le satellite GOES situé à la longitude 70° ouest. Après réception et conversion au format compatible avec celui des images transmises à partir de la station de l'Odenwald, les images sont retransmises vers le satellite Météosat qui assure leur diffusion vers les stations utilisatrices primaire et secondaire situées dans sa zone de couverture.

Darmstadt

Le satellite Météosat transmettra une image de la terre pendant 25 minutes toutes les demi-heures, 24 heures sur 24, pendant toute sa durée de vie. Les informations météorologiques extraites de ces images doivent en particulier être transmises aux centres météorologiques chargés d'élaborer les prévisions du temps. Un des critères de jugement de l'efficacité du système est la rapide disponibilité de ces informations. Ceci nécessite donc un traitement des images en temps réel et une disponibilité du système très grande.

Chaque jeu d'images (visible + infrarouge) représente $(5000 \times 5000 \times 6) + (2500 \times 2500 \times 8)$ bits à traiter chaque demi-heure, soit $400\,10^6$ bit/h. Ceci explique que le système de traitement installé est l'un des plus performants existant actuellement sur le marché pour des applications en temps réel. Son concept de base est un moyen terme entre une version centralisée (très grosse machine assurant tous les traitements) et un réseau de mini-ordinateurs assurant des fonctions spécialisées:

La solution retenue (Fig. 3) est basée sur deux gros calculateurs du type ICL 2980 associés à des mini-ordinateurs assurant quelques fonctions spécialisées. Ainsi,

- l'acquisition et le pré-traitement nécessaires à la mise en forme acceptable par les ICL 2980 sont assurés par un Siemens 330 (en fait deux, l'un étant en redondance active de l'autre) associé à
- 2 calculateurs spécialisés (array-processors) construits par la firme Christian Rovsing (Danemark);
- la gestion du satellite et de sa charge utile est assurée par un autre Siemens 330 (lui-même redondant);
- le sous-système de visualisation d'images, aussi bien pour l'extraction des amers que pour le contrôle de qualité des traitements effectués est géré par deux calculateurs Nova 830 reliés aux calculateurs centraux ICL 2980.

Il en est de même pour d'autres fonctions telles que l'archivage, la corrélation, la rectification, la dissémination des images via le satellite et des paramètres météorologiques par ligne terrestre vers le centre météorologique d'Offenbach à 40 km de Darmstadt.

Les deux calculateurs centraux assurent principalement la gestion des traitements effectués, l'élaboration du modèle de déformation servant à la correction géométrique des images (ce système est décrit dans un autre article de ce Bulletin), l'insertion des grilles sur les images corrigées à disséminer, ainsi que l'extraction des paramètres météorologiques.

L'EXTRACTION DES PARAMETRES METEOROLOGIQUES

En 1972, un groupe d'experts météorologistes européens s'est réuni pour définir les objectifs à assigner aux missions du système Météosat. Il a été décidé en particulier que l'extraction des paramètres se ferait à une échelle globale pour des analyses synoptiques effectuées par des centres météorologiques nationaux, et fournirait les données sous forme numérique.

Les paramètres extraits des images sont les suivants:

La *vitesse* et la *direction des vents* au-dessus des mers dans une zone correspondant à un angle géocentrique de 50° autour du point sous-satellite, avec une précision de 3 m/s sur la vitesse, à trois niveaux d'altitude. Ces informations seront disséminées 4 fois par jour (à 02, 08, 14, 20 h GMT), chaque message utilisant les mesures effectuées pendant les 6 heures précédentes.

La méthode de mesure est basée sur la mesure du déplacement des nuages bien identifiables, utilisés comme traceurs, entre deux ou trois (ou plus) images successives. La vitesse correspond à $\Delta X/\Delta T$. Cette mesure du déplacement peut être réalisée soit

- automatiquement (détermination des pics de corrélation d'un traceur dans des fenêtres prédéterminées), soit
- manuellement par des opérateurs de consoles interactives dialoguant avec le calculateur et disposant d'un écran de visualisation d'images.

Les *autres paramètres* tels que
- la température de surface de la mer
- le bilan radiatif
- le contenu de vapeur d'eau
- la néphanalyse (en température et couverture)

sont extraits à l'aide d'un programme appelé 'traitement météorologique intégré' sur chaque segment d'image élémentaire de 32 × 32 pixels IR ou 64 × 64 pixels VIS, correspondant sur la terre à des zones d'environ 160 × 160 km au point sous-satellite évidemment variables avec la latitude de mesure. Ces segments sont générés dans le centre de traitement de façon à ce que leurs centres occupent toujours la même position géographique. Seuls les segments situés dans la zône de 50° autour du point sous-satellite sont utilisés.

A partir des données d'entrée:
- signaux calibrés du radiomètre dans les trois canaux VIS, IR, WV
- un modèle d'atmosphère pour corrections
- le modèle de déformation de la terre extrait de l'image
- des tables de données astronomiques et météorologiques mises à jour périodiquement

on génère les produits intermédiaires suivants:
- les pics dans les histogrammes et les réflecteurs significatifs (mer, nuages)
- les résultats
- les flux émis
- le contenu de vapeur d'eau.

Après contrôle de la qualité à l'aide des consoles interactives, les paramètres météorologiques sont extraits en accord avec le programme journalier, c'est-à-dire:
- température de la mer et contenu de vapeur d'eau, 2 fois par jour;
- néphanalyse, 4 fois par jour;
- bilan radiatif, 1 fois par jour.

SYSTEME INTERACTIF

Le contrôle de qualité des données intermédiaires, des produits de sortie, l'extraction manuelle des vents, se font à l'aide de consoles disposant de trois écrans de visualisation. Sur l'un deux, il est possible de faire apparaître des images, ou extraits d'images sélectionnés par les opérateurs, prises par Météosat (Fig. 4). Ces consoles, reliées aux calculateurs centraux ICL 2980 par l'intermédiaire de deux calculateurs Nova 830, permettent de faire appel aux données-images stockées sur les périphériques des unités principales. Compte-tenu de leurs nombreuses possibilités: zoom de certaines zones d'images, mémorisation et rafraîchissement rapide de l'écran jusqu'à 6 images IR et VIS, changement rapide sur l'écran (1 à 4 secondes suivant la source utilisée), manipulation de couleurs, superposition etc., elles représentent un outil de travail très perfectionné, qui n'a actuellement pas son équivalent dans le domaine de la météorologie spatiale. Elles doivent permettre éventuellement l'accès aux unités centrales pour des travaux de recherche et d'optimisation du logiciel, en parallèle avec les opérations normales du système.

L'ARCHIVAGE DES DONNEES

Météosat constitue un outil très utile non seulement pour les météorologistes chargés de la prévision du temps, mais aussi pour une meilleure compréhension et une meilleure connaissance statistique des phénomènes. D'autre part, il est certain que les logiciels qui sont développés pour ce premier satellite pré-opérationnel évolueront au cours de la durée de vie de ce dernier vers une meilleure utilisation des ressources en matériel disponible, pour tenir compte des résultats des premiers mois d'exploitation.

Pour répondre à ces besoins, il a été jugé indispensable de stocker le maximum d'informations possibles. Essentiellement, les données archivées seront de deux types: les images (sous forme numérique ou photographique) et les produits météorologiques.

Les *images* numériques ayant subi un prétraitement standard (en particulier une calibration) seront archivées sur des bandes magnétiques de longueur 9200 pieds avec une densité 22 kbit/pouce.

Les images photographiques sont archivées sous la forme d'un négatif, chaque format comprenant deux paires d'images dans les trois domaines de détection. Chaque jour est produit un film regroupant les 24 formats.

Les *produits* suivants sont disponibles aux utilisateurs:
- copie des informations numériques sélectionnées (image complète) dans tous les canaux, dans un seul canal, ou partie d'image, sur bande à haute densité (une journée par bande) ou sur bande compatible calculateur (une image par bande);

Figure 4 – Une image visualisée sur console interactive.

- copie (positif ou négatif) des images photographiques;
- diapositives 35 mm (en noir et blanc);
- film 16 mm obtenus à partir des films journaliers mentionnés ci-dessus.

LE CENTRE DE CONTROLE DES OPERATIONS METEOSAT

Toutes les opérations liées au système Météosat ont été regroupées dans une seule salle attenante au centre de traitement des données (Fig. 5). On y trouve donc:

- des consoles de contrôle et de commande du satellite
- des consoles de contrôle et de commande de la mission telles que balayage limité du radiomètre, modifications du programme de dissémination, etc.
- une console de contrôle et commande à distance de la station située dans l'Odenwald
- les 2 consoles d'extraction des amers
- les 3 consoles météorologiques permettant aux opérateurs de dialoguer de façon interactive avec le centre de traitement.

LES STATIONS D'UTILISATEURS

De façon à recevoir les informations disséminées par la station de l'Odenwald, les utilisateurs doivent s'équiper de stations pouvant être de deux types, correspondant à des performances et à des besoins différents:
- les *stations primaires*, (Fig. 6) capables d'acquérir les

Figure 5 – Centre de traitement Météosat.

Figure 6 – Station primaire d'utilisation des données.

signaux numériques à 166 kbit/s correspondant aux images haute résolution;
- les *stations secondaires*, capables d'acquérir les signaux transmis sous forme analogique au format WEFAX standard et compatible avec les satellites à défilement.

Un exemplaire de chacune de ces stations est installé au voisinage des installations centrales en Allemagne. Elles sont intégrées dans des conteneurs transportables de façon à permettre des démonstrations sur d'autres sites.

LES PLATES-FORMES DE COLLECTE DE DONNEES (DCP)

Pour tester les liaisons station centrale/satellite/plateforme et vice versa, l'Agence a été amenée à développer un prototype de plate-forme de collecte de données représentant, les différents types compatibles avec le système Météosat, c'est-à- dire fonctionnant
- en émission seulement, et synchrones à l'aide d'une horloge interne
- en émission sur réception d'un signal d'interrogation
- en mode alerte lorsqu'un paramètre dépasse un seuil prédéterminé.

COMPATIBILITE DU SECTEUR TERRIEN AVEC LE SATELLITE

Indépendamment des tests de sous-systèmes et de système propres au secteur terrien, un programme important d'essais de compatibilité entre ce secteur et le satellite a été mis sur pied de façon à éliminer le plus possible avant le lancement toutes les sources d'incompatibilité, en cas de besoin. Un tel programme, tant au niveau radiocommunications qu'au niveau logiciel, a été mené de février à octobre 1977 principalement à l'aide d'un modèle prototype du satellite installé dans la station de l'Odenwald. Ce programme a aussi permis l'entraînement, au cours des simulations, des opérateurs qui seront chargés ultérieurement des opérations du satellite en orbite. Cet entraînement est complété par l'utilisation du secteur terrien.

COUT DE DEVELOPPEMENT DU SECTEUR TERRIEN

Le montant global des contrats passés à l'industrie pour le développement des équipements, à plus de 95% européens, est de l'ordre de 35 millions d'unités de compte. Il est certain que cet investissement important n'est justifiable et rentable que dans la mesure où un programme opérationnel de météorologie spatiale, basé sur le lancement d'autres modèles de Météosat, améliorés si nécessaire, est mis sur pied dans les années à venir. Le coût d'opération d'un tel système (satellite + secteur terrien) est de l'ordre de 6 MUC par an.

CONCLUSION

Le développement d'un tel secteur terrien est vraiment un défi dans lequel même les Etats-Unis, pour cette application particulière, ne se sont pas lancés. Il est encore impossible de dire, et même de prévoir, à cause des incertitudes sur les performances des calculateurs centraux du système de traitement, si tous les objectifs pourront être atteints. La méthode utilisée, consistant en l'addition pas à pas de tâches nouvelles au logiciel de base existant au moment du lancement, devrait cependant permettre au système Météosat de remplir sa mission pendant la première année du GARP (Programme de Recherches sur l'Atmosphère globale). □

Meteosat Image Processing

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The development of earth-observation space systems has led to a new way of thinking as far as the use of satellite-transmitted data is concerned. The spacecraft and its instruments are but one link in the observational chain and the image data that they generate contain a wealth of quantitative information. In many cases, the quality of the remote-sensing products derived will largely depend on the accuracy with which instrument errors are removed. Moreover, meteorological observation is increasingly utilising more than one satellite for the same purpose, which implies a need to compare data from different satellites, and even more so that from satellites with information collected by conventional ground means.

Space-induced constraints are forcing designers to make trade-offs between space and ground systems. In many cases, the 'instrument' is shared between space and ground, and in Meteosat's case the ground processing can be considered the 'tail' of the optical device. This concept has already been discussed in ESA Bulletin No. 6, and we will restrict ourselves here to a presentation of the particular techniques used to correct Meteosat images.

THE AIMS OF IMAGE PROCESSING

Basically, a raw Meteosat image can be likened to the work of a painter using a thick brush (optical and electronic pulse responses) and false colours (amplitude calibration) in an attempt to reproduce a given landscape (scanning, orbit, attitude). For many instrumental and orbital reasons, a given image element, or 'pixel', may not be sited at its geometrically correct place in the painting and the shade of the paint may not be exactly representative of the radiance value in the scene. These discrepancies must be corrected before the painting provided by the satellite's instruments can be used for *quantitative* meteorological applications.

For wind-extraction processing, for example, which relies on the movement of small cloud tracers across two or three successive images, an accuracy of 3 m/s is specified, which means that the maximum acceptable distortion is less than 1 pixel.

A further constraint is introduced by the need to distribute geometrically-corrected products in real time. As the use of ground control points for such an operation would obviously lead to unacceptable delays, the corrections for the next incoming image have to be predicted from the last one, on a continuous-learning basis.

Meteosat's image processing has to deal with each of the above problems and it can not compensate perfectly for all of them. What it can do is to ensure that the processed images can be used with confidence by the world meteorological community.

PRESENTATION OF THE SYSTEM (Fig. 1)

The main functions performed are:
- *Image conditioning*, the aim of which is to restore the real amplitude value of a given pixel (compensation of optical and electrical properties of the instrument).
- *Image referencing*, which establishes the relationship between image co-ordinates and ground latitude/longitude locations, the result of which is a mathematical description of the deformation.
- *Gridding and rectification*, two functions related, respectively, to the introduction of deformatted grids onto the distorted image (gridding) and, for one format (B), removal of the distortion by pixel displacement (rectification).
- *Formatting and dissemination*. The last operation to be performed is the generation, according to a planned schedule, of the necessary image formats and their broadcasting to the users, as described elsewhere in this Bulletin.

Although the last two functions require a large processing capacity, they are rather conventional in nature and will not be discussed further here.

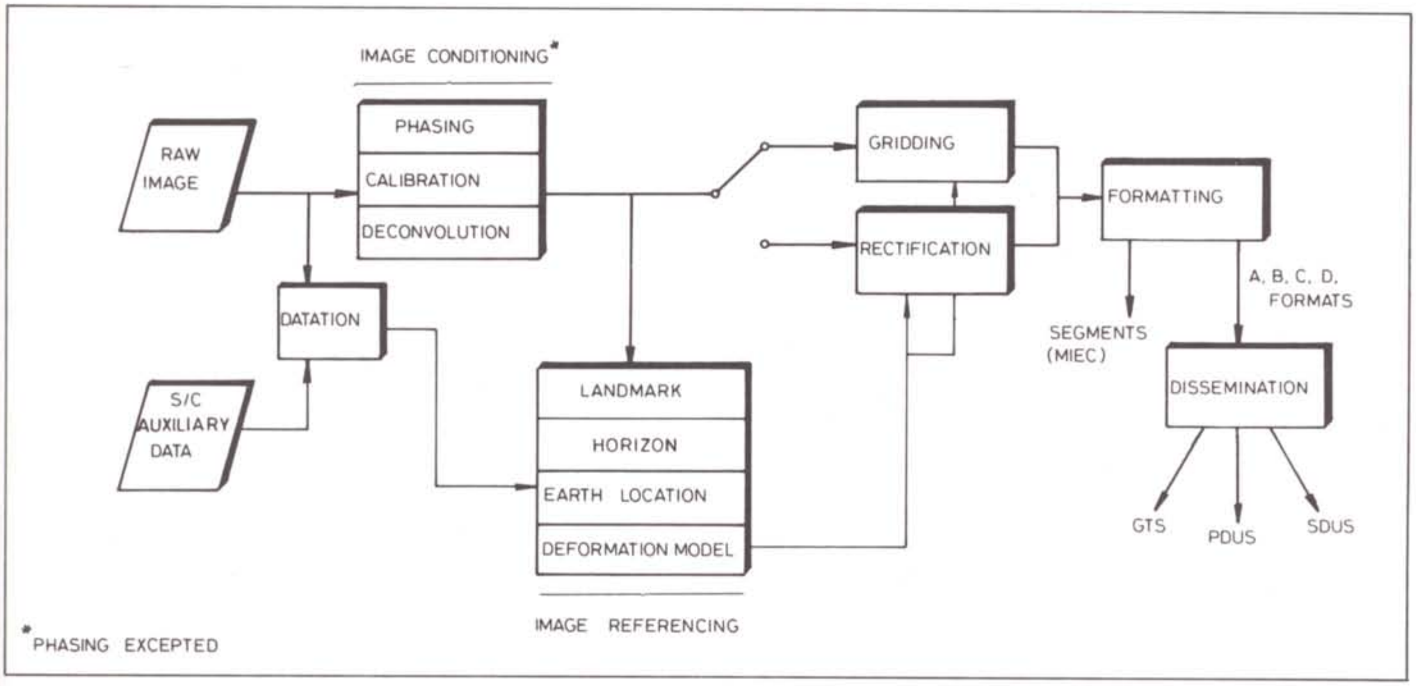


Figure 1 – General image-processing scheme.

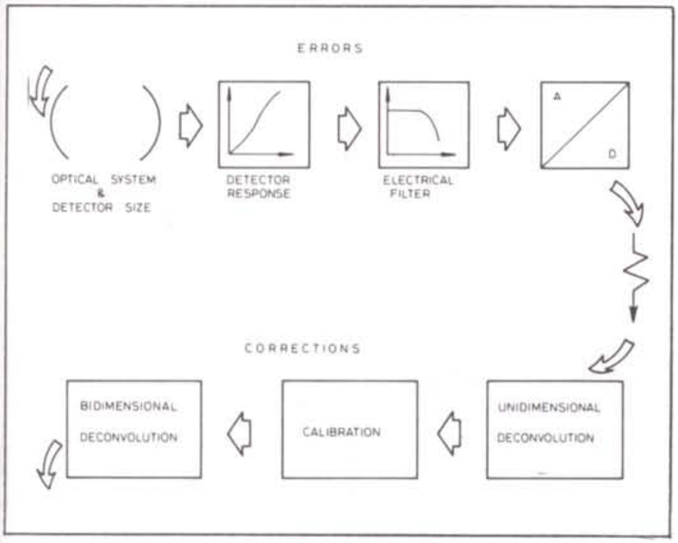


Figure 2 – Amplitude-processing scheme.

IMAGE CONDITIONING (AMPLITUDE PROCESSING)

As we have said, the signals received by the Meteosat Ground Computer System (MGCS) are not exactly representative of the landscape signal, but if we assume that most of the distortions are small and remain linear (i.e. reversible), we can compensate for them. In the course of the imaging 'chain', changes can be introduced by:

- optical response (optical system never perfect)
- detector response
- electrical filter transfer functions
- sampling and analogue/digital conversion (essentially nonlinear and irreversible).

Any corrections must be applied in reverse order to that in which the unwanted changes have occurred (Fig. 2).

In Meteosat's case, the degree to which the electrical and optical errors can be compensated is constrained by the accuracy of the optical radiometer's transfer function and by signal-to-noise ratio considerations. Moreover, the quality of the optics is also related to the width of a Modulation Transfer Function, or MTF (Fig. 3), which can be considered the optical counterpart of the well-known bandwidth factor in electronics. The more extended the MTF, the sharper is the response – in other words the more accurate is the picture. It has been shown that image resolution can be improved by measuring MTF and applying a corresponding linear transformation at each point utilising the neighbouring image pixels. This operation, called 'deconvolution' (Fig. 4), allows Meteosat to provide quantitative measurements even for very small tracers (<5 pixels). As optical effects are basically two-dimensional, bi-dimensional deconvolution has to be applied.

As far as image calibration is concerned, there is little difficulty in performing the compensation, which is a pure multiplication (some precautions must be taken to avoid disturbing the statistical content of the image), but rather

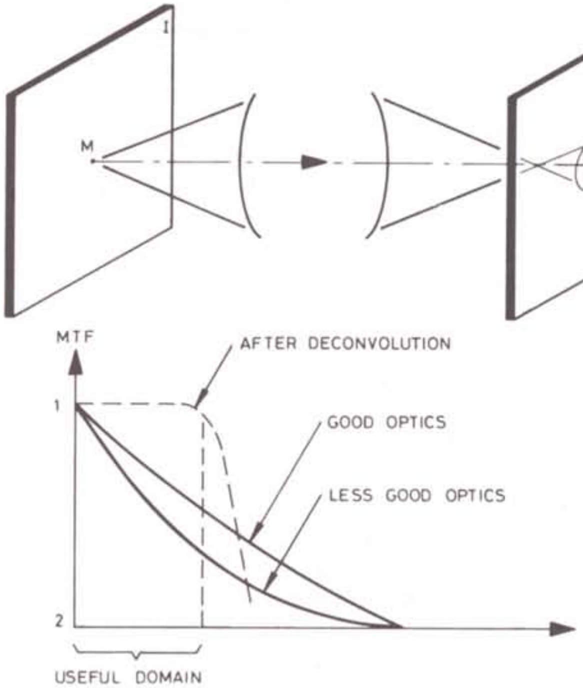


Figure 3 – Modulation transfer function.

more in determining the factors to be applied. Several 'tools' are available for this determination, namely

- amplifier gain setting (in order to put the signal in the useful range of the digitiser)
- measurement in space and in front of a blackbody at a known temperature
- measurement of solar radiance attenuated by a predetermined factor, and
- use of the moon as reference body.

Each presents particular advantages and drawbacks, and they must be used in combination to achieve the greatest benefit.

IMAGE REFERENCING

Another important function of Meteosat's image processing is to reconstitute true geographical co-ordinates as closely as possible in the image, particularly for accurate wind-vector extraction. The problem is basically one of

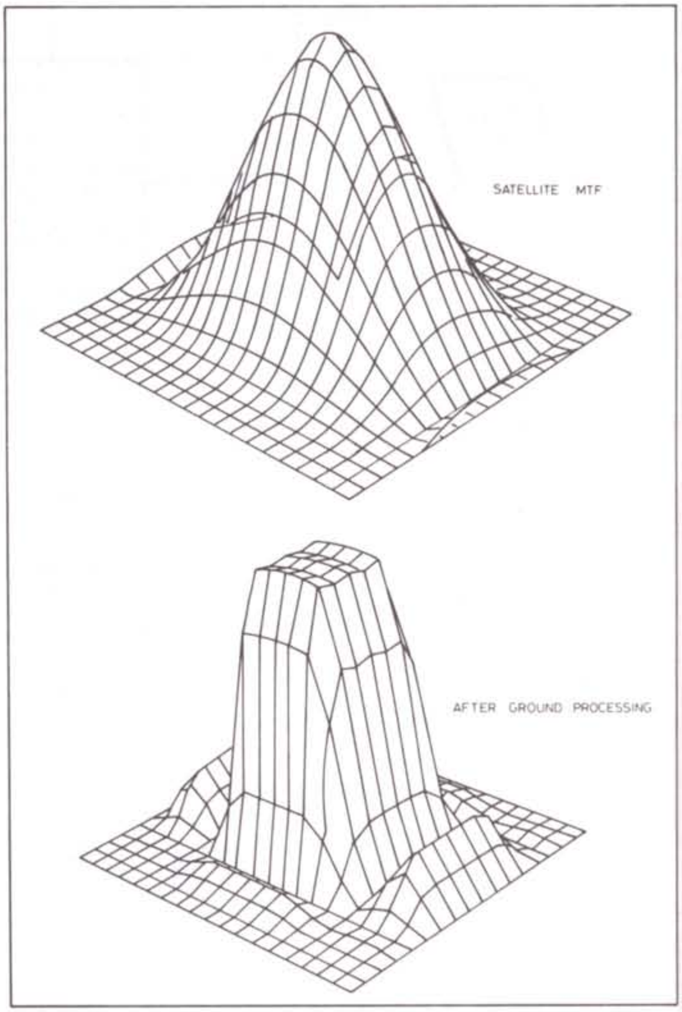


Figure 4 – Meteosat Modulation Transfer Function (infrared channel).

establishing a correspondence function between image plan and earth's surface (Fig. 5). The method that has been chosen for restitution of Meteosat's images relies on knowledge of the dynamic properties of the satellite, which define the scanning law, the free parameters of which are finally adjusted with the help of an observation equation (landmark and horizon extraction).

A very simple example can be used to illustrate the concept. If we assume that an observer must try to

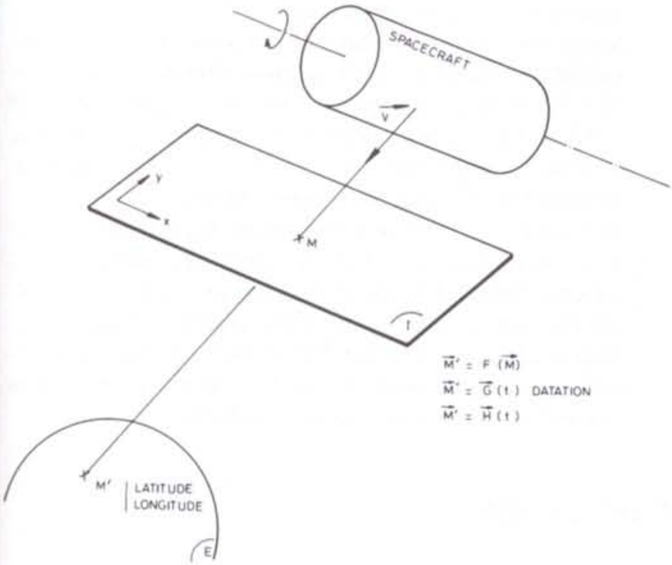


Figure 5 – Correspondence between image plan and the earth's surface.

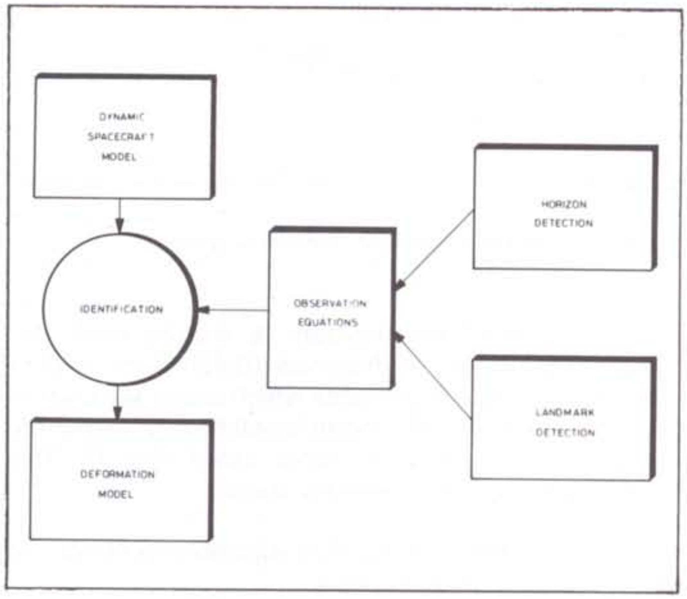


Figure 6 – Image referencing.

determine the motion of a pendulum, a first approach could be to measure the pendulum's angular position as many times as possible as a function of time, the large number of measurements being necessary to ensure an acceptable accuracy for the sinusoïdal restitution. On the other hand, if the observer were a physicist, he might consider the pendulum as a mechanical body obeying the well-known law $\theta'' + \omega^2\theta =$ constant. In this case, only three parameters have to be identified – the phase, the frequency and the amplitude of the movement – and these three measurements are theoretically sufficient not only to determine the system accurately, but also to predict its future motion.

This simple illustration shows how advantageous such a modelisation can be, and this same principle is employed for Meteosat in the sense that the pendulum is replaced by the rotating spacecraft and measurement is achieved by considering crossings of the radiometer optical axis by identified ground control points (landmark and horizon). The equations employed are of course much more complex than in the case of the pendulum (Fig. 6).

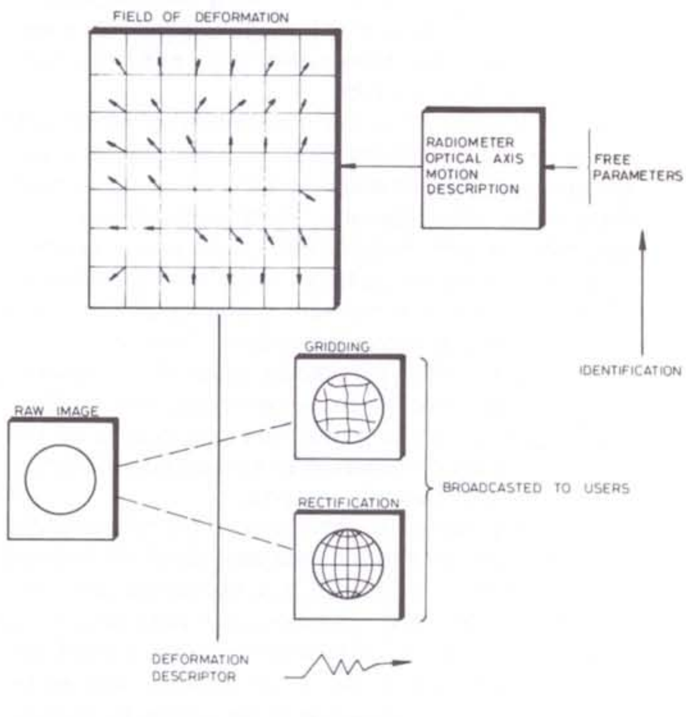


Figure 7 – Utilisation of deformation model.

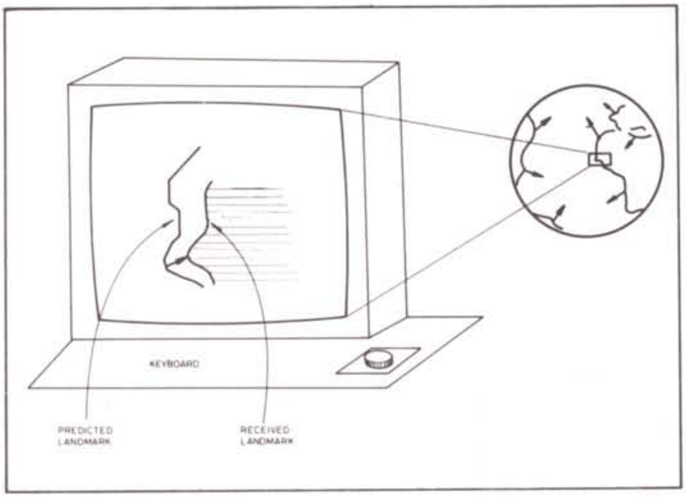


Figure 8 – Landmark extraction – interactive system.

After parametric identification, a mathematical description of the actual distortion (deformation model) over several images is available which allows the grids to be superimposed on the image in real time, or allows the image to be rectified in some cases (Fig. 7). This calculation is updated for every image.

In addition to the earth-location subsystem, a number of other functions are performed:

- *Real-time correction (line synchronisation)*, to align each image line-start geometrically.
- *Datation*. The spacecraft's dynamics form the basis for the image referencing, in that a time-dependent description of the scanned image is used. All pixels must therefore be time-referenced, and this constitutes the datation task.
- *Landmark detection*. From a collection of about 100 landmarks, a certain number are selected for comparison with infrared and visible images received from the satellite. Conceptually, landmark restitution is an automatic system, but as a refinement two interactive landmark extraction systems have been provided to allow the differences between predicted and received landmark locations to be monitored (Fig. 8).
- *Horizon extraction*. This model gives the geometric correspondence between the reference image and the real image. It is computed from the results of the earth-location computation, in a prediction mode, i.e. before the real image is sampled.
- *Deformation model computation*. This model gives the geometric correspondence between the reference image and the real image. It is computed from the results of the earth location computation, in a prediction mode, i.e. before the real image is sampled.
- *Grid computation*. Grids for all images have to be computed and associated with the image data before dissemination and archiving.
- *Segmentation and storage*. Incoming images are stored in segments, each segment being made up of 32×32 infrared pixels, 64×64 visible pixels and 32×32 water-vapour pixels and constituting the basic product transmitted to the Meteorological Information Extraction Centre (MIEC).
- *Rectification*. This encompasses transformation of the image data structure to ideal geometrical conditions. Only 20% of all images are to be rectified, mainly those constituting European coverage.
- *Registration*. As the satellite detectors are not coincident, images must be shifted slightly to ensure correct pixel-to-pixel correspondence.

CONCLUSION

Although by no means complete, this brief description will, it is hoped, have clarified the image-processing methodology used for Meteosat. The driving concept is one of being in a position to provide the users with images of known and controlled quality.

The efforts that have been expended on Meteosat image processing over a period of more than five years have led to considerable progress in the area of displays, algorithms, specialised and interactive processors, image enhancement and, generally speaking, to a better knowledge of the interests and limitations of digital image processing. More specifically, a new concept has been born; namely that of considering an image not only as a picture, but also as a matrix of measurements that must be properly referenced in amplitude and geometry.

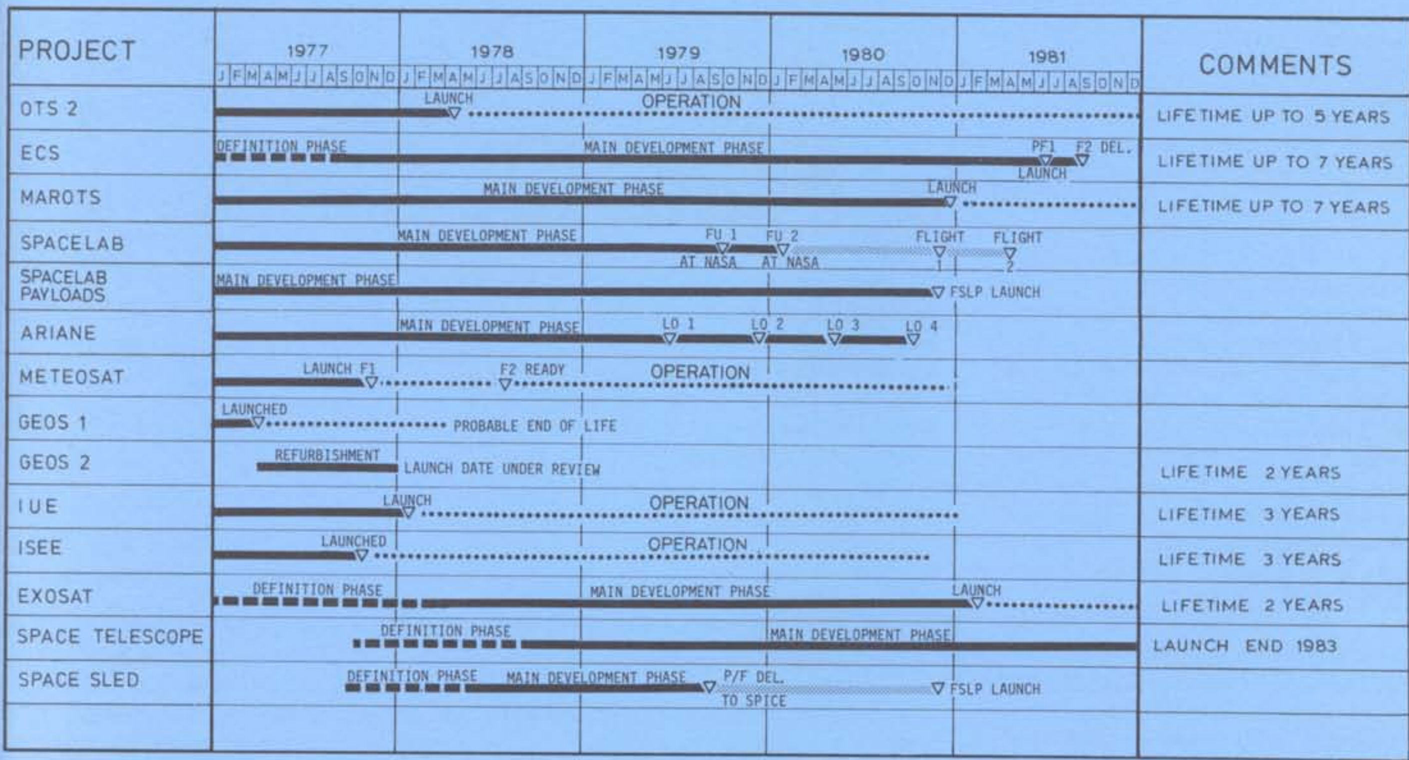
It is perhaps worthwhile mentioning that the quality of correction, the number of images treated, and the real-time nature of the system (particularly in 'predicting' image distortion) make the Meteosat system unique, not only in Europe, but very probably throughout the world, at least as far as civil applications are concerned.

The results that have been achieved to date can be applied not only in forthcoming ESA meteorological programmes, but more generally in the development of other future spaceborne image-taking systems. □

Projets under Development

Projets en cours de réalisation

THE ESA DEVELOPMENT AND OPERATION PROGRAMME (November 1977)



OTS

The Failure Review Board investigating the OTS-1 launcher explosion has not yet concluded its investigation. Examination of recovered hardware continues and several possible causes of failure are being pursued.

Meanwhile, the preparation of OTS-2 is well under way. The integration and testing programme should be completed by the end of February 1978, ready for an April 1978 launch.

ECS

In July 1977, approval was given for the commencement of ECS Phase C/D by the MESH/AEG-Telefunken group, led by Hawker Siddeley Dynamics covering the period September- November 1977, during which procurement of long-lead parts and development of schedule-critical items is being initiated.

It is expected that during November the Joint Communications Satellite Programme Board and ESA Council will extend the approval to the whole of Phase C/D as part of a new overall satellite communications programme.

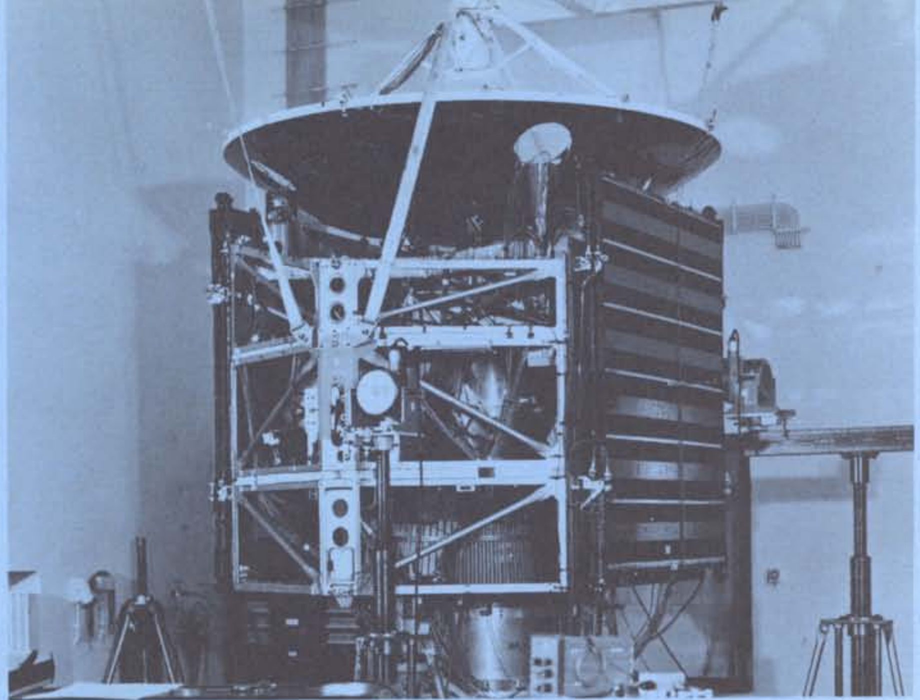
MAROTS

Discussions between the Marisat Consortium, the European PTTs and ESA concerning the possibility of using Marots satellites to provide a world-wide system from 1981 onwards have taken place over the last few months. European industry was requested to tender in respect of this during September 1977 and the

OTS

La Commission chargée d'enquêter sur l'explosion du lanceur d'OTS 1 n'a pas encore achevé ses travaux. L'examen du matériel récupéré se poursuit et les différentes causes possibles de l'échec continuent d'être étudiées.

Simultanément, la préparation d'OTS 2 est en bonne voie. Le programme d'intégration et d'essai devrait être achevé pour la fin de février 1978 en vue d'un lancement en avril 1978.



Marots structural model under test at DFVLR, Göttingen.

Modèle de structure de Marots en cours d'essais à la DFVLR, Göttingen.

ECS

Approbation a été donnée en juillet 1977 au démarrage de la phase C/D d'ECS, confiée au Groupe MESH/AEG-Telefunken, avec Hawker Siddeley Dynamics comme chef de file; cette phase couvre la période septembre-novembre 1977, pendant laquelle l'approvisionnement des pièces à long délai de livraison et le développement des éléments critiques pour le calendrier doivent être mis en route.

On s'attend que le Conseil directeur commun des programmes de satellites de communications et le Conseil de l'ESA donnent au mois de novembre leur approbation à l'ensemble de la phase C/D, considérée comme élément du nouveau programme d'ensemble de télécommunications par satellites.

MAROTS

Des discussions ont eu lieu ces derniers mois entre le consortium MARISAT, les Administrations européennes des PTT et l'ESA au sujet de la possibilité d'utiliser des satellites Marots pour assurer une couverture mondiale à partir de 1981. Les industriels européens ont été invités à présenter des offres à ce sujet en septembre 1977; leurs réponses sont à l'étude. Les travaux couverts par les contrats Marots existants se sont poursuivis. Le modèle d'identification de la charge utile doit être livré en décembre 1977 afin d'être intégré avec le précédent modèle de qualification du module de service d'OTS pour essais au niveau système.

AEROSAT

A la réunion de septembre du Conseil d'Aérosat, la Délégation américaine a annoncé que, faute de moyens de financement suffisants, il était impossible de continuer le programme Aérosat dans les conditions prévues. Il a donc été décidé de laisser s'éteindre l'option relative au contrat du satellite. De nouvelles mesures sont à l'étude, notamment une proposition américaine tendant à créer un Comité chargé d'examiner une restructuration éventuelle du programme. Ce point sera étudié à la réunion du Conseil d'Aérosat qui doit se tenir en décembre.

SPACELAB

Le contrat industriel entre l'Agence et Dornier System pour le développement d'un système de pointage d'instruments (IPS) destiné au Spacelab a été signé le 16 juin 1977. Ce contrat engage la firme Dornier à livrer l'IPS en juin 1980. L'IPS assurera la précision et la stabilité de pointage des instruments du Spacelab, en particulier pour les expériences d'astronomie et d'observation de la Terre. Il est prévu de l'embarquer pour la première fois sur le deuxième vol du Spacelab, fin 1980. Le principal sous-traitant de Dornier est MBB; SODERN fournira le détecteur. Le montant total du contrat à prix forfaitaire est de 54,2 millions de Deutsche Mark.

Un examen des interfaces équipements (Crew Station Review) – auquel participaient des représentants de l'Agence, d'ERNO et de la NASA – a été effectué sur la maquette en dur du Spacelab. Il y a eu très peu de demandes de modification des matériels mais certaines lacunes ont été décelées dans le logiciel. Des mesures sont en cours pour porter remède à cet état de chose.

responses are under evaluation. Meanwhile, the existing Marots contracts have continued. The engineering model payload is due to be delivered in December 1977, after which it will be integrated with the former OTS service-module qualification model for system level testing.

AEROSAT

At the September meeting of the Aerosat council, the US delegation stated that because of inadequate funding it was impossible to proceed with the Aerosat programme as contemplated. The option for the satellite contract has therefore been allowed to expire. Future courses of action are now being considered including a US proposal for the establishment of a committee to examine the possibility of re-structuring the programme. This will be discussed at the December meeting of the Aerosat council.

SPACELAB

The industrial contract between the Agency and Dornier System for the development of an Instrument Pointing System for Spacelab was signed on 16 June 1977. The contract commits Dornier to deliver the IPS in June 1980. The system will provide pointing accuracy and stability for Spacelab's instruments, and in particular for astronomical and earth-observation experiments. Its first flight is scheduled for the second Spacelab mission in late 1980. The major subcontractor is MBB; Sodern will furnish the sensor. The total value of the fixed-price contract is 54.2 million German Marks.

A Crew Station Review, involving ESA, ERNO and NASA, was successfully performed on the Spacelab Hard Mockup. This review resulted in very few suggestions for hardware changes, but some deficiencies in software were highlighted. Corrective actions are under way.

The programme of Co-contractor Critical Design Reviews (CDR) has begun and will lead to the design release for the flight-unit manufacture. Subsystems are being reviewed at the co-contractors' sites. A final system CDR review scheduled for February 1978 will conclude the design reviews.

The ASSESS-II Spacelab-simulation mission has been successfully carried out. Ten flights were performed in the period 16–25 May 1977. All equipment performed to the complete satisfaction of the principal investigators and valuable scientific data was collected. The mission demonstrated that a multiple experiment payload can be satisfactorily operated by a small number of payload specialists. A more detailed report on the mission and in particular on the lessons learned from it is in preparation.

ESA has started the procedure for selecting the payload specialists to participate on the First Spacelab Flight which will take place in 1980. It has been agreed that three payload-specialist candidates will be chosen from the applicants. Beginning in July 1978, these three will receive full payload- specialist training and a prime candidate and two reserves will be nominated some time before the flight. ESA, NASA and the national agencies are involved in the overall procedure.

It should be recalled that during the First Spacelab Flight, the joint ESA/NASA payload will be operated in orbit by one ESA and one NASA payload specialist. Operations will be performed around the clock and each payload specialist will carry the re-sponsibility for the entire payload during a twelve-hour shift period.

ARIANE

Hardware manufacture under way for LO1 flight test

In less than two years – on 15 June 1979 to be precise – the first flight of the Ariane launcher will take place. Manufacture of the hardware for this first LO1 launcher began during the first quarter of 1977, and assembly of the three stages is scheduled for completion for the beginning of launcher integration in November 1978. The status of the programme, which is running on schedule, can be summed up as follows:

- all the structures have been developed and most of the qualification tests have been completed
- engine development has been completed and the qualification tests are in progress
- the long-duration tests for the engines have been completed
- the propulsion-bay system tests at stage level are under way
- the electrical mock-up tests have started
- the dynamic mock-up tests are now complete and analysis of the data obtained confirms the calculational models of the first modes.
- so far no technical problem has emerged which might lead to a slip in schedule.

In the area of propulsion, a major step has been achieved regarding the first stage, with the highly successful cluster firing tests of the propulsion system, totalling 402 s during 10 tests on 4 bays. For the second stage, the 'battleship' test series was continued very satisfactorily with the GM1/1 test lasting 137 s by integrating the flight configuration equipment.

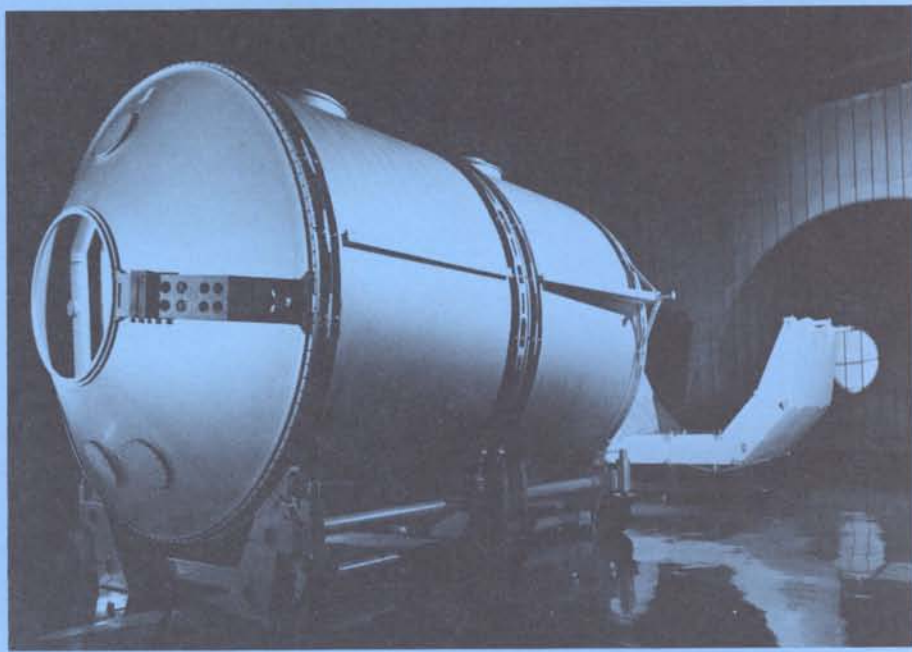
For the second stage, a series of three consecutive firings took place, integrating the pressurisation system, the servo motors and the flight-configuration roll-control system. The results were excellent.

For the third stage, chamber qualification tests are complete and show a specific impulse of 444 s, i.e. 10 s better than specified. This is a remarkable result.

In addition, the propulsion-bay tests started in early May on stand PF42, reproducing the sequence of preparations for the stage at the Guiana Space Centre (CSG). The synchronised sequence was validated. The first firing test was carried out on 21 July.

Maquette en dur de module pressurisé de Spacelab dans le hall d'integration chez ERNO.

Hard mock-up of Spacelab pressurised module in ERNO's integration hall.



Le programme des examens critiques de la conception chez les co-contractants a commencé; lorsqu'il sera terminé, le feu vert sera donné pour la fabrication de l'unité de vol. Les sous-systèmes sont passés en revue chez les co-contractants et un examen final au niveau système est prévu pour février 1978. Il marquera la fin des examens de la conception.

La mission ASSESS II, simulant une mission Spacelab, a été couronnée de succès. Au cours de la période du 16 au 25 mai 1977, dix vols ont été simulés. Tous les équipements ont fonctionné à la pleine satisfaction des responsables principaux et des données scientifiques intéressantes ont été recueillies. La mission a prouvé qu'une charge utile multi-expériences peut être exploitée par un petit nombre de spécialistes.

L'ESA a commencé la procédure de sélection des spécialistes charge utile désireux de participer au premier vol du Spacelab qui aura lieu en 1980. Il a été décidé que trois candidats seront retenus. A partir de juillet 1978 ils recevront une formation complète de spécialiste charge utile et l'on désignera, quelque temps avant le vol, le titulaire et ses deux remplaçants éventuels. Les organismes nationaux, l'ESA et la NASA participeront à l'ensemble de la procédure de sélection.

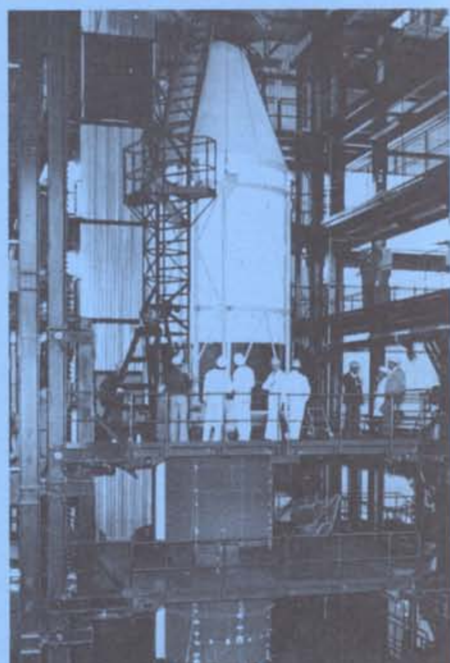
On se rappellera que lors du premier vol du Spacelab, la charge utile commune ESA/NASA sera exploitée en orbite par deux spécialistes charge utile, l'un de l'ESA et l'autre de la NASA. Les opérations seront menées 24 h sur 24 et chaque spécialiste aura la responsabilité de la charge utile toute entière pendant ses douze heures de 'quart'.

ARIANE

Fabrication des matériels pour le vol d'essai LO1

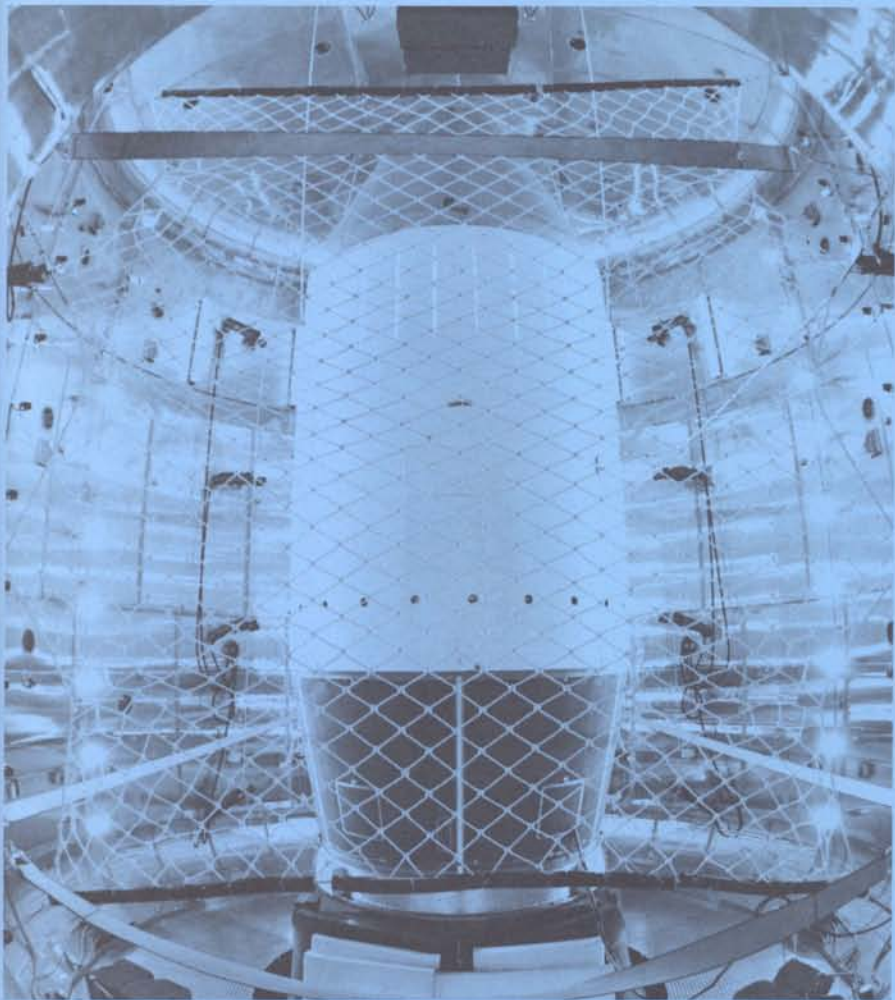
C'est dans moins de deux ans – exactement le 15 juin 1979 – qu'aura lieu le premier vol d'essai du lanceur Ariane. La fabrication des matériels pour le lanceur LO1 a commencé au cours du premier trimestre 1977, et l'assemblage des trois étages doit être terminé pour le début de l'intégration du lanceur en novembre 1978. L'avancement du programme qui se déroule selon le planning peut être résumé comme suit:

- *la réalisation de toutes les structures ainsi que la majeure partie des essais de qualification sont terminées;*
- *la réalisation des moteurs est terminée et les essais de qualification sont en cours;*
- *les essais de longue durée des moteurs sont terminés;*
- *les essais de baie de propulsion sont en cours;*
- *la réalisation de tous les équipements électriques est terminée et leur qualification est bien avancée;*
- *les essais maquette électrique ont commencé;*
- *les essais de la maquette dynamique sont terminés et les*



Essais de la maquette dynamique en configuration 2ème étage, 3ème étage et coiffe au Site d'Integration Lanceur.

Dynamic mock-up in '2nd/3rd stages and fairings' configuration under test at the Launcher Integration Site.



Ariane fairings installed in ESTEC's Dynamic Test Chamber (with the catching system in the foreground).

Coiffe d'Ariane installée dans la Chambre d'Essais Dynamiques de l'ESTEC (avec filet de sécurité au premier plan).

The first flight-configuration cryogenic stage has just been set up on stand PF43 and the filling tests have started.

The 15th vacuum ignition test of an HM7 engine on the PF41 stand was carried out, lasting the nominal 570 s.

First full-scale fairing separation test performed
Ariane's fairings are designed to protect the vehicle's payloads against aerodynamic heating and other harmful environmental effects during ascent, within a useful payload volume of about 50 m³. Their general layout is as follows: an aft cone with an interface diameter to the equipment bay of 2.6 m opens to 3.2 m maximum diameter and is followed by a cylindrical section 4 m high that terminates in a front cone section with a spherical nose. The overall height of the fairings is 8.6 m.

Ariane fairings provide radio transparency by several means. The aft cone consists of a glass fibre – Kevlar sandwich structure. In all metallic parts, i.e. cylinder and front cone, access doors or cutouts with RFT-characteristics can be accommodated. Standard payload connectors on a support of variable length, to cope with a large variety of satellite size and connector accommodation, are available. A second device can be provided for dual-launch purposes. Fairings can now be delivered with an acoustic blanket for those payloads susceptible to lift-off and aerodynamic noise.

Fairing separation will take place at an altitude of some 110-140 km, determined by the payload requirements and the trajectory flown. A parallel separation mode similar in principle to the separation system used many times for Thor-Delta fairings will be employed.

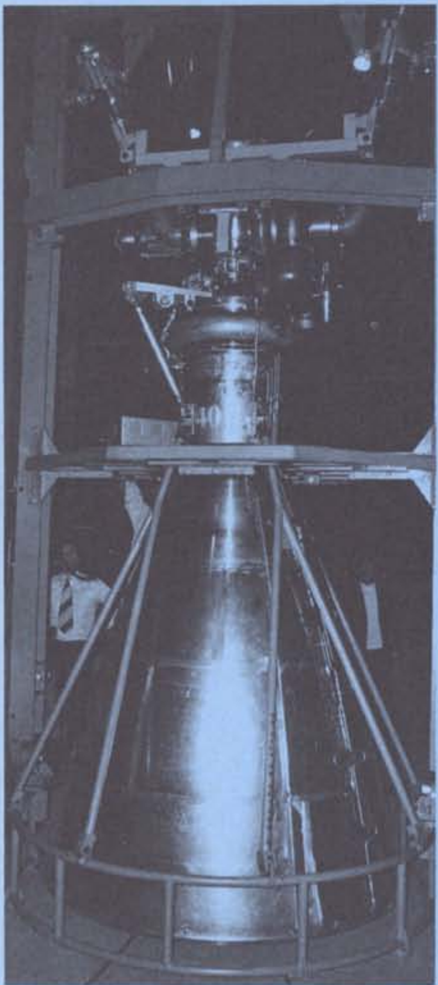
To simulate mode and altitude of fairing separation, ground tests under vacuum are needed and therefore ESTEC's large Dynamic Test Chamber (DTC) was chosen for the Ariane tests.

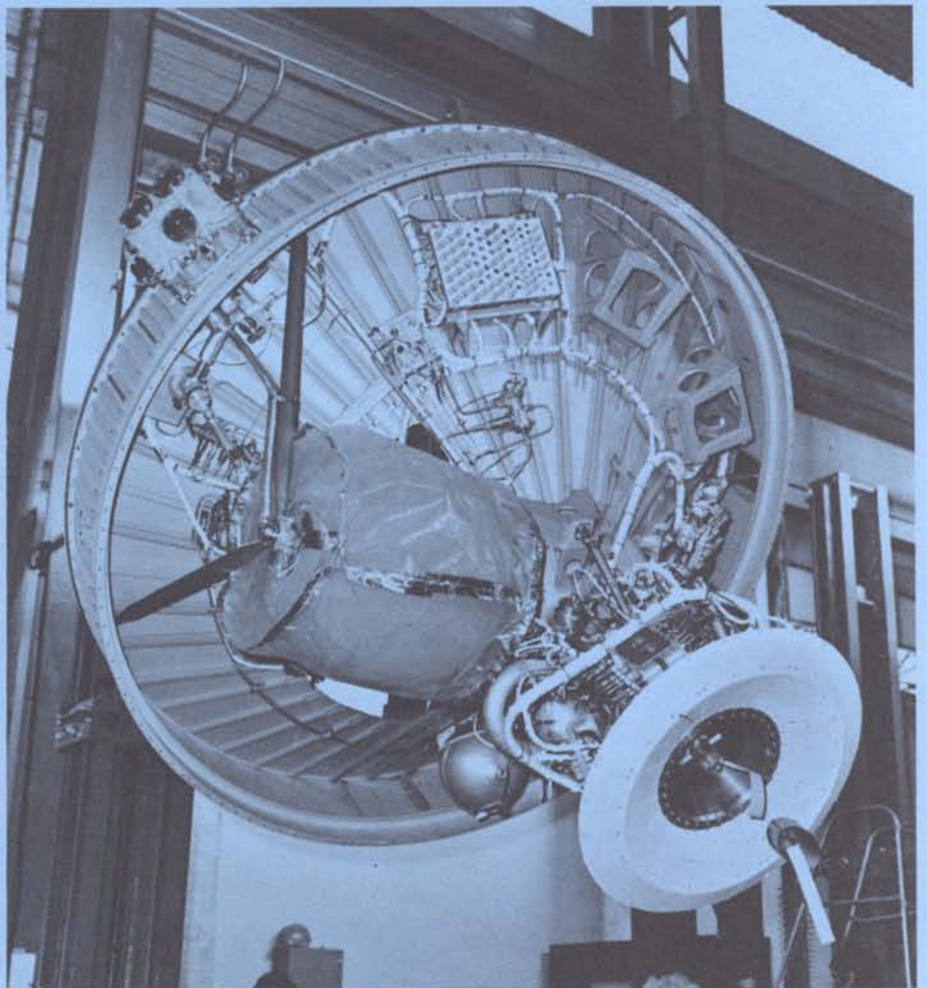
After a series of separation tests at component and panel level to develop the vertical and horizontal separation systems, followed by a series of three separation tests using a fairing aft cone only, and after detailed dynamic analysis, development activities have now converged towards full-scale separation tests. The main objectives are to study separation behaviour, to validate test procedures, to learn how to handle a complex structured measurement system and to run through a process of complete data evaluation.

The first of these took place on 18 June in the DTC. The fairings separated successfully and all separation systems functioned correctly.

A number of lessons were learnt. Preparation and execution was found to be good. The clearance around the launcher was found to be better than predicted, although detailed analysis of trajectories and correlation with mathematical models is still going on.

The structure failed locally and modifications are already being made to avoid further failures, particularly rivet failures. The fairings are already undergoing a refurbishing process in preparation for a second test at the end of October. This test will be the first of a series of two qualification tests using the same fairing model (SM1).





Le moteur Viking IV dans son outillage de transport.

Viking IV engine in its shipment fixture.

Première baie de propulsion H8 assemblée.

First H8 propulsion system assembled.

exploitations permettent de confirmer les modèles de calcul des premiers modes;

- *à présent aucun problème technique n'est apparu qui pourrait mettre le calendrier en cause.*

Dans le domaine de la propulsion, une étape importante a été franchie sur le premier étage avec l'achèvement très satisfaisant des essais de groupement de l'ensemble propulsif totalisant 402 s pendant 10 essais avec 4 baies.

Pour le deuxième étage, la série d'essais 'battleship' a été poursuivie dans des conditions très satisfaisantes avec l'essai GM1/1 d'une durée de fonctionnement de 137 s en intégrant les équipements en configurations vol.

Pour le troisième étage, les essais de qualification de la chambre sont terminés et font apparaître une impulsion spécifique de 444 s, soit 10 s de plus que spécifié, ce qui est un résultat remarquable.

Par ailleurs, les essais de la baie de propulsion ont commencé début mai sur le banc PF42 reproduisant la chronologie de la préparation de l'étage au CSG. La séquence synchronisée a été validée. Le premier essai à feu a été effectué le 21 juillet.

Le premier étage cryogénique en configuration de vol vient d'être déposé sur le banc PF43 et les essais de remplissage ont commencé.

Le 15ème essai d'allumage sous vide d'un moteur HM7 au banc PF41 était d'une durée nominale de 570 s.

Premier essai de largage de la coiffe en grandeur réelle

La coiffe d'Ariane est conçue pour assurer aux charges utiles une protection contre l'échauffement aérodynamique et les autres effets préjudiciables de l'environnement au cours de la phase ascensionnelle tout en les abritant dans un volume utile d'environ 50 m³. Elle se présente approximativement comme suit: le cône arrière, dont l'interface avec la case d'équipement a un diamètre de 2,6 m, débouche sur une section

After having executed the next separation test, static qualification will finally begin in November of this year, when the second qualification model SM2 will be available.

Should results be as expected, the go-ahead will then be given for manufacture of the first LO1 flight unit.

METEOSAT

Space segment

The main event during the reporting period was the Meteosat-1 Flight-Readiness Review (FRR) in early July, following the Qualification Results Review (QRR) of early June and the completion of all flight-acceptance tests by the end of that month. The FRR Board, under the chairmanship of the Director of Scientific and Meteorological Programmes, declared Meteosat-1 'flight-ready'.

As indicated in the bar chart in Bulletin No. 10, the Meteosat-1 launch date has had to be shifted from 15 September to November 1977 due to the OTS launcher accident in May 1977 and a resulting change in the Delta launch schedule.

At the time of writing (early October) it is not yet known whether the OTS launch failure of 13 September will have an impact on the Meteosat-1 launch date.

Work on Meteosat-2 and its adaptation for launch as principal passenger (on top of the Indian telecommunications satellite APPLE) on the third Ariane test flight (LO3) is progressing according to schedule.

Ground segment
The compatibility tests with the DATTS (Data Acquisition, Telecommand and Tracking Station) have been completed and corrective action on the converters has been taken. After tests in the Odenwald (Germany), the LBT (Land-Based Transponder) has been sent to Kourou for installation and final acceptance tests.

A stabilised DCP (Data-Collection Platform) is now being built for installation on ships for experimental campaigns to be conducted in conjunction with the European meteorological agencies, in 1978.

The SDUS (Secondary Data Users Station) and the PDUS (Primary Data Users Station) have been installed and accepted.

The FRR Board concluded that the ground segment is ready to support the launch phase and the control of the satellite in geosynchronous orbit.

Also, the data-processing system now fulfils all minimum requirements for launch and will progressively provide the services defined, post launch.

Operations
Since the last report, Denmark, France and Italy have signed the Protocol. This means that all participating Member States (except Sweden, which might join later) have signed the Protocol, which has entered into force. The staff build-up is progressing, in line with the November 1977 launch date.

IUE

The current Delta launch schedule now foresees lift-off of IUE on 12 January 1978. The one-month delay is due to the rearrangement of launches needed to accommodate the mishap to the vehicle earmarked to launch OTS.

The full complement of IUE flight cameras and spares have been delivered to NASA by the UK Science Research Council, so that the onus for final preparation of IUE spacecraft and scientific instruments now rests entirely with NASA.

The flight scientific instrument has been subjected to an extensive series of tests in the vacuum optical bench facility at Goddard Space Flight Center (GSFC). The main problem uncovered was a great shortfall in the reflectivity of the short-wavelength spectrograph, which required the dismantling of this instrument. The problem was traced to inadequate coating of one of the mirrors and the instrument was subsequently reassembled. As a result of this problem, integration of the scientific instrument into the spacecraft and the subsequent schedule of joint tests were delayed by about one week. These tests, which included vibration, rapid depressurisation and acoustic tests, were concluded with the successful deployment of the ESA-supplied solar arrays.

In view of the new launch date for IUE, the date for operational readiness of the IUE ground station has been put back to 1 January 1978.

The performance of the contractor responsible for station integration has still not reached the level needed to accomplish the task in time. For this reason, contractor effort has to be increased substantially with the aim of achieving a working station in early October. At this time, the equipment must be accessible by ESOC's Operations Department for pre-launch training and simulation activities. A serious delivery problem associated with the telemetry and data-handling subsystem was resolved by a joint management effort and the essential equipment has recently been installed in the station and successfully tested.

NASA has provided assistance with the erection and integration of the VHF command antenna at Villafranca. This work started at the beginning of July and was completed at the end of August.

Following acceptance of the experiment display system at the end of May, familiarisation with and use of the system is well advanced.

A four-week training course on spacecraft operations held at GSFC in June was attended by the ESA spacecraft operations engineer and three spacecraft controllers. The contractor for the operation and maintenance of the station now has 49 staff in service, and personnel training is proceeding according to plan.

cylindrique de 4 m de hauteur et 3,2 m de diamètre surmontée d'un cône avant qui se termine par une calotte sphérique. Sa hauteur totale est de 8,6 m.

La radiotransparence de la coiffe est obtenue par différents moyens: le cône arrière est fabriqué dans une structure en sandwich fibre de verre – Kevlar; il est possible de ménager des portes d'accès ou fenêtres radiotransparentes dans toutes les parties métalliques, corps cylindrique et cône avant. Les connecteurs standard prévus pour la charge utile sont montés sur un support de longueur variable pour pouvoir être adaptés à une grande variété de dimensions de satellites et d'implantations des connections. Un second dispositif peut être fourni en vue de lancements doubles. Il est possible de doter la coiffe d'une isolation acoustique pour les charges utiles sensibles au bruit du décollage et au bruit aérodynamique.

Le largage de la coiffe s'effectuera entre 110 et 140 km d'altitude, en fonction des impératifs de la charge utile et de la trajectoire suivie. Le mode d'ouverture est parallèle; il fait appel aux principes du système de largage utilisé à nombreuses reprises sur les lanceurs Thor-Delta.

Le mode et l'altitude du largage exigent que les essais au sol soient éffectués dans des conditions simulant le vide. C'est pourquoi la grande Chambre d'Essais dynamiques de l'ESTEC (DTC) a été choisie pour procéder aux essais de largage de la coiffe d'Ariane.

Après une série d'essais menés au niveau des composants et des panneaux afin de développer les systèmes de séparation verticaux et horizontaux, suivie d'une série de trois essais portant sur un cône arrière seul et d'une analyse dynamique approfondie, les activités de développement convergent désormais pour parvenir à la phase des essais de largage en grandeur réelle. Cet essai avait pour objectifs principaux d'étudier le comportement au largage, de valider les procédures d'essai, de rôder un système de mesures d'une grande complexité et de parcourir toutes les étapes d'un processus d'évaluation complète des données.

Le premier essai a eu lieu au DTC de l'ESTEC le 18 juin. La coiffe s'est ouverte de façon normale; tous les systèmes de largage ont fonctionné correctement.

Un certain nombre d'enseignements doivent être tirés de ce premier essai: préparation et exécution ont été considérées comme bonnes; le débattement entre la coiffe et le lanceur s'est révélé meilleur que prévu, mais l'évaluation se poursuit dans le domaine de l'analyse détaillée des déplacements et de la corrélation avec les modèles mathématiques.

La structure ayant été endommagée localement, on procède déjà à certaines modifications pour éviter de nouveaux dommages, touchant en particulier les rivets. La coiffe est déjà en cours de remise en état en vue du deuxième essai qui doit avoir lieu à la fin octobre 1977. Cet essai sera le premier d'une série de deux essais de qualification utilisant le même modèle SM1 de la coiffe.

Après exécution du prochain essai de largage, les essais de qualification statique démarreront en novembre de cette année avec le second modèle de qualification disponible (SM2).

Si les résultats en sont satisfaisants, le feu vert sera donné pour la fabrication du premier modèle de vol, le LO1.

METEOSAT

Secteur spatial

Le principal événement survenu au cours de la période couverte par le présent rapport est l'examen d'aptitude au vol (FRR) de Météosat-1 qui s'est déroulé début juillet, après l'examen des résultats de la qualification (QRR) début juin et l'achèvement de tous les essais de recettes de vol fin juin. La commission responsable du FRR, placée sous la présidence du Directeur des Programmes scientifique et météorologique a déclaré Météosat-1 'apte au vol'.

Comme il a été annoncé dans Bulletin No. 10, la date de lancement de Météosat-1 a du être reportée du 15 septembre à novembre 1977 du fait de l'accident subi en mai par le lanceur d'OTS et du changement qui en est résulté dans le calendrier des lancements Delta.

Pour le moment (début octobre), on ne sait par encore si l'échee du lancement d'OTS le 13 septembre affectera la date de lancement de Météosat-1.

Les travaux relatifs à Météosat-2 et à son adaptation comme passager principal à bord du vol LO3 d'Ariane (il sera placé au-dessus du satellite indien de télécommunications APPLE) se déroulent conformément au calendrier.

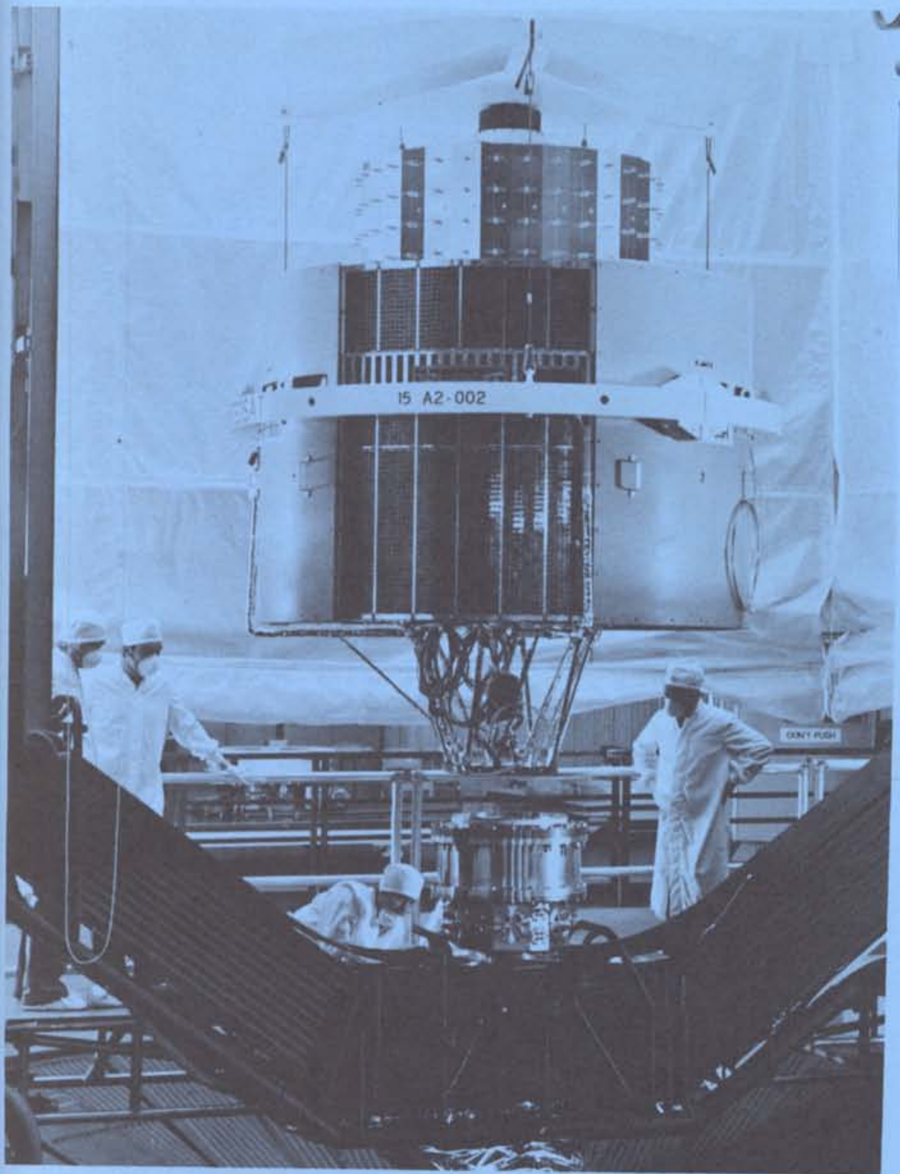
Secteur terrien

Les essais de compatibilité avec la DATTS (station d'acquisition des données, de télécommande et de poursuite) sont terminés et des mesures ont été prises pour remédier au problème des convertisseurs. Après essais dans l'Odenwald, le transpondeur terrestre (LBT) a été envoyé à Kourou pour y être installé et subir les essais de recette définitive.

Une plate-forme de collecte de données (DCP) stabilisée est en cours de construction; elle doit être installée à bord de navires pour des campagnes expérimentales auxquelles participeront des organismes météorologiques européens, en 1978.

La recette de la SDUS (station secondaire d'utilisation des données) et la PDUS (station primaire d'utilisation des données) ont été installées et recettées.

D'après la commission FRR, le secteur terrien est prêt à assurer le soutien de la phase de lancement et le contrôle du satellite sur l'orbite géosynchrone. De même, le système de traitement de données répond d'ores et déjà à tous les impératifs minimaux de lancement et fourniront progressivement, après le lancement, les services définis.



Preparation of Meteosat flight model for solar simulation tests.

Préparation du modèle de vol Météosat aux essais de simulation solaire.

The availability of the microwave communications link permitted a series of voice and data-line tests between the station and NASA/GSFC. These were completed satisfactorily.

The station access road was opened at the beginning of August and the final layer of asphalt was laid in October, giving a substantial improvement in access to the station.

ISEE

ISEE-B spacecraft and payload
Testing of the ISEE-B spacecraft and its experiment payload was completed and they were transported to Eastern Test Range (ETR), Cape Canaveral, for preparation for launch. During the last months they underwent vibration, acoustic and thermal-vacuum environmental testing, as well as electromagnetic, DC magnetic and other electrical tests to ensure that the stringent requirements of the experimenters had been met. The entire test programme was completed approximately 10 days ahead of schedule in early August.

The spacecraft Flight-Readiness Review was held on 10-11 August at ESTEC, with a Review Board composed of senior ESA and NASA executives. Gratifyingly, the Board found the spacecraft and its payload to be in a very satisfactory condition and gave permission for it to proceed to ETR for launch. A remarkably low total of three recommendations were made, two directed to NASA and one to ESOC; all concerned the launcher and in-orbit operations, and not the spacecraft itself.

ISEE-A
Work on ISEE-A also continued on schedule and it was shipped to ETR on 10 September, following a Flight-Readiness Review at Goddard Space Flight Center.

Launch preparations
Initial difficulties in arranging a charter flight at this very busy time of the year were eventually overcome and the spacecraft and its attendant ground equipment were transported by Lufthansa 747 jet on 28 August. There were also some accommodation problems due to the delayed launch of OTS after the Delta 3914 mishap on the launch pad. With considerable co-operation from other teams, these were resolved and the team was able to make the final checkouts prior to mating ISEE-B to ISEE-A and assembling the combination on the launch vehicle.

Prior to shipping the spacecraft from Europe, all documentation needed for launch preparations was completed and approved, and a complete practice countdown, using the integration model spacecraft, was carried out.

Opérations

Depuis le dernier rapport, le Danemark, la France et l'Italie ont signé le Protocole Météosat. Ainsi tous les Etats membres participant au programme (à l'exception de la Suède qui pourrait y adhérer ultérieurement) ont signé le Protocole qui est donc entré maintenant en vigueur. La constitution des effectifs progresse dans l'optique d'un lancement en novembre 1977.

IUE

Le lancement d'IUE est maintenant prévu pour le 12 janvier 1978. Ce retard d'un mois est dû au remaniement du calendrier des lancements Delta auquel il a fallu procéder à la suite de l'incident survenu sur le lanceur qui était réservé à OTS.

Le Conseil de la Recherche scientifique (SRC) du Royaume-Uni a livré à la NASA la totalité des tubes-images aux normes de vol et des pièces de rechange destinés à IUE. C'est donc désormais la NASA qui a l'entière responsabilité de la préparation finale du véhicule spatial et de ses instruments scientifiques.

L'instrumentation scientifique de vol a été soumise à une série d'épreuves poussées au banc d'essais optiques sous vide du Goddard Space Flight Center. Le principal problème qui se soit posé au cours de ces épreuves a été l'importante baisse de réflectance du spectrographe à ondes courtes, qui a nécessité le démontage de cet instrument. On a pu en attribuer la cause à l'absence d'un revêtement adéquat sur l'un des miroirs et l'instrument a été réassemblé mais ce problème a eu pour conséquence de retarder d'une semaine environ l'integration de l'instrumentation scientifique dans le véhicule spatial et la réalisation des essais combinés ultérieurs. Ces essais, qui comprennent les vibrations, la dépressurisation rapide et les essais acoustiques, ont été menés à bien et se sont terminés avec le déploiement satisfaisant du réseau solaire fourni par l'ESA.

Etant donné la nouvelle date fixée pour le lancement du satellite, la date à laquelle la station sol IUE doit être prête à fonctionner a été reportée au 1er janvier 1978.

Le contractant responsable de l'intégration de la station n'a pas encore atteint le niveau d'efficacité voulu pour s'acquitter de son travail dans les délais requis. Il doit donc encore faire un sérieux effort pour que la station soit en état de marche début octobre, car à cette époque l'équipement devra être accessible au Département 'Opérations' de l'ESOC pour les activités de simulation et les exercices d'entraînement avant le lancement. Un grave problème de livraison, concernant le sous-système de télémesure et de traitement des données, a pu être résolu grâce aux efforts conjugués des responsables, et les équipements essentiels viennent d'être installés dans la station et ont été testés avec succès.

Commencées début juillet, les opérations d'installation et d'intégration, avec l'aide de la NASA, de l'antenne de télécommande VHF à Villafranca se sont terminées fin août.

Après la recette du système de visualisation pour les expériences, qui a eu lieu fin mai, le programme de familiarisation des intéressés avec l'utilisation du système a commencé et est déjà bien avancé.

L'ingénieur responsable des opérations du véhicule spatial et trois contrôleurs 'véhicule spatial' de l'Agence ont suivi un stage de formation d'une durée de 4 semaines au GSFC en juin. Le contractant chargé de l'exploitation et de la maintenance de la station a maintenant affecté 49 personnes à ces tâches; leur programme de formation se déroule comme prévu.

La disponibilité de la liaison hyperfréquences a permis de réaliser une série d'essais de communications téléphoniques et de transmission de données entre la station et le GSFC de la NASA, qui ont donné toute satisfaction.

La route d'accès à la station a été ouverte début août, et la dernière couche d'asphalte a été appliquée en octobre, permettant ainsi une amélioration appréciable de l'accès a la station.

ISEE

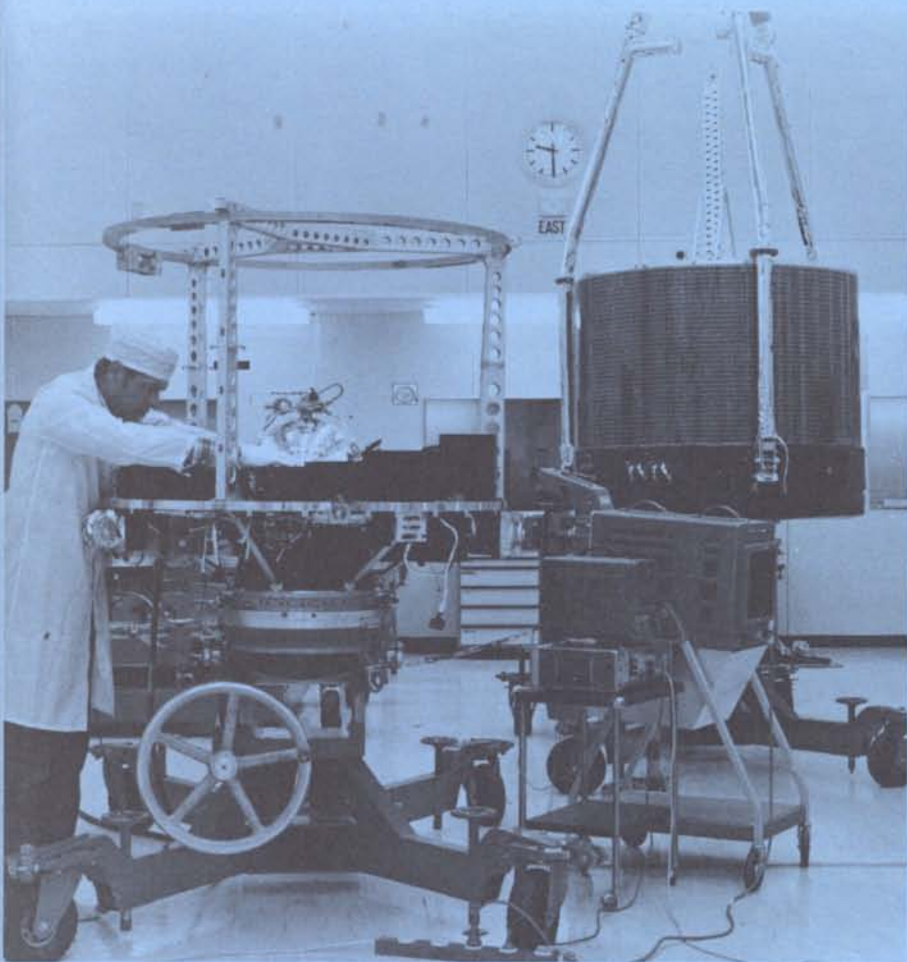
Véhicule spatial ISEE-B et sa charge utile

Ayant satisfait à tous leurs essais, le véhicule spatial ISEE-B et sa charge utile expérimentale ont été transportés à l'Eastern Test Rangé (ETR), à Cape Canaveral, pour la préparation en vue du lancement. Ces derniers mois, le satellite a été soumis aux divers essais: vibrations, acoustiques et environnement sous vide thermique, électromagnétiques, magnétiques CC et autres essais électriques destinés à fournir l'assurance que les impératifs rigoureux formulés par les expérimentateurs ont été respectés. L'ensemble du programme d'essais s'est achevé fin août, avec une dizaine de jours d'avance sur le calendrier.

Une commission composée de responsables au plus haut niveau de l'ESA et de la NASA a procédé à l'examen d'aptitude au vol du satellite les 10 et 11 août à l'ESTEC. On a noté avec satisfaction que cette commission a jugé que le véhicule spatial et sa charge utile étaient en excellente condition et a donné le feu vert pour leur transfert à l'ETR en vue du lancement. Elle a formulé trois recommandations au total – ce qui est exceptionnellement peu – deux à l'adresse de la NASA et une à l'intention de l'ESOC, portant toutes trois sur le lanceur et les opérations en orbite mais non sur le satellite lui-même.

ISEE-A

Les travaux se sont poursuivis sur le véhicule spatial ISEE-A conformément au calendrier; il a été expédié à l'ETR le 10 septembre après un examen d'aptitude au vol au GSFC.



ISEE-B flight model in clean room at ESTEC.

Modèle de vol d'ISEE-B dans la chambre propre de l'ESTEC.

In-orbit operations
Preparations for in-orbit operation are well advanced and all the ESA-produced software and the vast majority of that produced by NASA is now ready. The Spacecraft Operating Procedures (SCOP), which is the key document for in-orbit operations, has been prepared and approved.

During the period of final testing, a training programme for the NASA operators who will control the spacecraft in orbit was carried out. No difficulties were encountered and 'operator status' is considered satisfactory.

Conclusion
The ESA Project Manager would like to thank the experimenters, the Prime Contractor (DSF) and the subcontractors, the NASA ISEE-A team and colleagues in ESTEC and ESOC for the extremely close relationship that has existed throughout the life of the project. In 1973 the launch date was provisionally set as 15 October 1977 and the achievement of readiness for launch by this date was only made possible by the enthusiastic collaboration of all concerned.
(See 'In Brief', page 68, for further information).

EXOSAT

Satellite
The nominal or baseline concept of the satellite design as well as related operational aspects, for both ground and orbit, have been further studied and specified. Following completion of the Subsystem Concept Review in May, major efforts were devoted to the definition and specification of satellite configuration, functions and performance to facilitate proper conduct of the Test Concept Review in July. Incomplete definition of concepts for cleanliness, alignment and payload integration/testing, and of attitude measurement and control subsystems in particular, detected in the course of the reviews, has since been improved.

Allocation of work within the industrial team, although still under discussion for some items, has been consolidated to a great extent, improving the return coefficient for a number of countries, including Italy, Sweden and Switzerland.

In parallel with Phase-B studies, the Ariane Adaptation Study was completed in June. Based on the results of this study, a recommendation to launch Exosat on Ariane (with a Delta 3914 as back-up) was submitted for approval of the Agency's Science Programme Committee (SPC) and Council in June/July. The SPC, by a simple majority, favoured the change of launcher and consequently the change in satellite concept, subject to the fulfilment of certain conditions concerning sharing of the additional costs. The implementation of the new concept, called Variant, was then approved by Council and the contractor MBB accordingly instructed to redirect work where necessary.

The need to repeat some of the design work already carried out in Phase B required an extension of the Project Definition Phase and a consequent shift of Phase C/D, leading to a new target launch date of February 1981.

Payload
With a view to enhancing the scientific mission, and conscious of developments in X-ray astronomy, the six experiment groups and the Observation Programme Panel,

Préparation au lancement
L'organisation d'un transport par charter à cette époque de fort trafic de l'année a causé un certain nombre de difficultés qui ont finalement été résolues et le satellite a été transporté avec l'équipement au sol associé le 28 août à bord d'un jet 747 de la Lufthansa. Quelques problèmes d'installation matérielle se sont également posés en raison du retard du lancement de l'OTS après l'accroc survenu au lanceur Delta 3914 sur l'aire de lancement. Ces problèmes ont eux aussi été résolus grâce à la très active coopération d'autres équipes at l'equipe responsable, a effectué les vérifications finales avant de procéder au couplage d'ISEE-B et d'ISEE-A et à l'assemblage du tout sur le lanceur.

Toute la documentation nécessaire à la préparation au lancement a été établie et approuvée avant que le satellite ne quitte l'Europe et un compte à rebours complet a été effectué aux fins d'entraînement avec le modèle d'intégration du satellite.

Opérations en orbite
Les préparations en vue des opérations orbitales sont bien avancées: le logiciel ESA est prêt dans sa totalité, celui de la NASA dans une très forte proportion. Le document clé pour les opérations en orbite, les 'Procédures d'exploitation des véhicules spatiaux (SCOP)', est déjà établi et approuvé.

Pendant que se déroulaient les derniers essais, un programme de formation a été organisé pour les opérateurs de la NASA qui seront chargés de contrôler le véhicule spatial en orbite. Il n'a donné lieu à aucun problème et l'état de préparation des opérateurs est jugé satisfaisant.

Conclusion
Le Chef ESA du projet tient à remercier les responsables des expériences, le contractant principal (DSF) et ses sous-traitants, l'équipe ISEE-A de la NASA ainsi que ses collègues de l'ESTEC et de l'ESOC pour les relations extrêmement étroites qu'ils ont entretenues avec lui pendant tout le déroulement du projet. En 1973 la date de lancement était provisoirement fixée au 15 octobre 1977 et si l'on était prêt au lancement pour cette date, ce n'est que grâce à l'enthousiasme de tous ceux qui ont collaboré à ce projet.
(Voir 'En bref', page 68 pour plus de détail).

EXOSAT

Satellite
La conception nominale – ou conception de référence – du satellite ainsi que les questions opérationnelles s'y rapportant, tant au sol qu'en orbite, ont été étudiées et spécifiées de façon plus précise. Après achèvement de l'examen de la conception au niveau sous-système qui a eu lieu au mois de mai, l'accent a été mis principalement sur la définition et la spécification de la configuration, des fonctions et des performances du satellite afin de pouvoir mener à bien l'examen de conception des essais au mois de juillet. Il a été depuis lors remédié aux insuffisances de définition des conceptions en matière de propreté électromagnétique, d'alignement, d'intégration et d'essai de la charge utile, ainsi que des mesures d'attitude et en particulier des sous-systèmes de contrôle, insuffisances qui étaient apparues au cours des examens de conception.

La répartition des travaux au sein de l'équipe industrielle, quoique toujours à l'étude pour certains éléments, a été arrêtée dans une large mesure; le pourcentage de retour de certains pays, notamment l'Italie, la Suède et la Suisse, s'en est trouvé amélioré.

Parallèlement aux études de Phase B, l'étude d'adaptation à Ariane s'est achevée en juin. C'est sur la base de ses résultats qu'une recommandation tendant à lancer Exosat au moyen d'Ariane (avec un Delta 3914 comme renfort) a été soumise à l'approbation du SPC et du Conseil en juin/juillet. Le SPC s'est prononcé à la majorité simple en faveur du changement de lanceur et par conséquent de la modification de la conception du satellite, sous réserve que certaines conditions ayant trait au partage des coûts additionnels soient remplies. La mise en oeuvre du nouveau concept, appelé Variante, a été ensuite approuvée par le Conseil; le maître d'oeuvre, MBB, a reçu instruction de réorienter les travaux autant que de besoin.

La nécessité de refaire certains travaux de définition déjà exécutés au cours de la Phase B a entraîné une prolongation de la phase de définition du projet et, en conséquence, un retard de la Phase C/D menant à une nouvelle date objectif de lancement, fixée à février 1981.

Charge utile
Soucieux d'améliorer le niveau de la mission scientifique et conscients des développements apparus dans l'astronomie des rayons-X, les six Groupes Expériences et le Groupe Programme d'observation, représentant ensemble la communauté des utilisateurs d'Exosat, ont recommandé que soient apportées les modifications suivantes aux éléments de la charge utile de référence:

(a) remplacer le concentrateur de rayons par un système de prise d'images de rayons-X afin d'améliorer les performances du bloc faible énergie;
(b) inclure un compteur à scintillateur gazeux (GSC) améliorer les performances du bloc moyenne énergie en donnant des possibilités de spectroscopie.

Le SPC a formellement entériné fin mai cette modification de la charge utile en fondant sa décision sur une recommandation ferme du SAC et de l'AWG.

Le remplacement du concentrateur de rayons par un deuxième miroir Wolter I et l'inclusion d'un GSC sont réalisables sous l'angle de la place disponible, des interfaces et de l'intégration. Le maître d'oeuvre du satellite a donc fait intervenir les nouveaux éléments de la charge utile dans son travail de définition, et pourvu que l'on s'en tienne strictement aux contraintes conceptuelles actuelles du satellite, aucune difficulté ultérieure n'est à prévoir.

together representing the Exosat User Community, recommended a change in baseline payload complement as follows:

(a) the light bucket to be replaced by an X-ray imaging system to enhance low-energy performance
(b) a Gas Scintillator Counter (GSC) to be included to enhance the medium-energy performance in providing for spectroscopy.

The SPC, at the end of May, formally endorsed this change, basing its decision on a firm recommendation by the SAC and AWG.

The replacement of the light bucket by a second Wolter I mirror and the inclusion of a GSC are feasible from the accommodation, interface and integration viewpoints. The satellite contractor has incorporated the new payload complement into the design work and provided current satellite design constraints are strictly adhered to, no further difficulties are foreseen.

The additional Wolter I mirror is identical to that already included and its development will be the responsibility of the existing 'Low-Energy Collaboration'. A call for proposal for the GSC has been issued and the proposals evaluated. An SPC decision taken in September now allows development of this unit to be speeded up, a matter of urgency in view of the advanced status of the satellite programme.

Development of the remainder of the Exosat payload is proceeding satisfactorily in the main.

The 'scientific model' phase is drawing to a close, with valuable results being gained from the building and testing of the X-ray mirrors, channel-multiplier array, position-sensitive proportional counters, and the transmission grating of the low-energy experiment. The long-awaited long-beam X-ray testing of the low-energy telescope will take place in Denver in September/October. Significant difficulties have been experienced with the long-term sealing of the scientific model's medium-energy detectors.

Results from the scientific-model programme have been fed, as and when available, into the development programme for the satellite units, which is proceeding through the definition and detailed design phase, at the four selected contractors, although the contract for the medium-energy detectors has not yet been signed.

Perhaps the most significant or potential areas of difficulty faced at this moment are the adaptation to the new launcher environment, and with this the modification of the focal-plane instrumentation/spacecraft interface to Variant requirements and the incorporation of additional anticoincidence provisions in the medium-energy detectors.

ESOC activities

Definition of the operations-support programme has continued, resulting in refinements to work package and resource specification.

The use of the ground stations at Weilheim (presently used for Helios) and Michelstadt (presently used for Geos) is being studied as an alternative to Villafranca. A study report detailing the technical and financial consequences,due in October, will serve as a basis for decision making.

SPACE TELESCOPE

ESA's participation in the NASA Space Telescope Programme was approved on two conditions:

(1) satisfactory conclusion of negotiations with NASA on a Memorandum of Understanding for the programme and
(2) approval of the overall NASA ST project by the US Congress.

During the reporting period, both of these conditions have been satisfied.

The joint NASA/ESA ST Project Plan was initialled by the ESA and NASA project managers.

The contractors for the major space telescope elements, the optical telescope assembly and the support-systems module, have been selected by NASA. Following this selection, detailed negotiations on the interfaces between the ESA-supplied hardware and the ST have been initiated.

Proposals from European industry for the ST solar array and the photon detector assembly have been received and evaluated. Recommendations for contract award will be presented to the Industrial Policy Committee in September, and the start of Phase-B for these two contracts is scheduled for early October.

The tender documentation for the camera-module contract has been completed and was issued by the end of April. Proposals are due on 26 September. The start of Phase-B for this contract is scheduled for early January 1978.

SPACE SLED

Tenders for the Space Sled Programme have been evaluated and clarified, culminating in a decision by the Industrial Policy Committee (IPC) to select ERNO as Contractor for the Phase B and C/D Development Programme.

A parallel activity, prior to the IPC decision, was to define external interfaces with Spacelab and the experiment package for the concepts proposed by two potential Space Sled contractors. The resource and interface requirements were reviewed with SPICE at the Sled Requirements Review on 25/26 August and these were updated in September.

The programme was formally initiated on 26 September. The first part of Phase B, the Design Evaluation Phase, has a planned duration of approximately 3.5 months during which all necessary trade-off and interface definition activities will be performed to establish subsystem design concepts.

A delay in the First Spacelab Mission, until December 1980, has been announced due to a delay in launching the tracking and data-relay satellites. These satellites will now be placed in orbit using the Shuttle.

Le miroir Wolter I supplémentaire étant identique à celui qui figure déjà dans la charge utile sera développé sous la responsabilité de la 'Collaboration faible énergie', tandis qu'un appel de propositions était lancé pour le scintillateur à gaz et que les propositions étaient évaluées dans l'intervalle. On attend du SPC qu'il prenne une décision en septembre afin d'accélérer le développement de cet élément, eu égard à l'état d'avancement du programme de satellite.

Le développement des autres éléments de la charge utile Exosat se poursuit, dans l'ensemble, de façon satisfaisante.

La phase du 'modèle scientifique' tire à sa fin; des résultats intéressants ont été acquis avec la fabrication et l'essai des miroirs à rayons-X, du détecteur à galette de micro-canaux et des compteurs proportionnels à détection de position, ainsi qu'avec les réseaux en transmission de l'expérience faible énergie. L'essai à long faisceau de rayons-X du télescope faible énergie, qui était attendu depuis longtemps, aura lieu à Denver en septembre/octobre. Des difficultés notables ont été rencontrées avec l'étanchéité sur une longue période des détecteurs moyenne énergie du modèle scientifique.

Au fur et à mesure qu'ils étaient disponibles, les résultats du programme du modèle scientifique ont été insérés dans le programme de développement des éléments du satellite dont la Phase de définition et de conception détaillées se déroule actuellement chez les quatre contractants retenus, bien que le contrat des détecteurs moyenne énergie ne soit pas encore signé.

Les secteurs où les difficultés les plus grandes sont ou risquent d'être rencontrées à l'heure actuelle sont sans doute l'adaptation à l'environnement du nouveau lanceur et, corollairement, l'adaptation de l'interface instrumentation au plan focal/véhicule spatial aux impératifs de la version Variante, ainsi que l'incorporation de dispositifs anticoïncidence supplémentaires dans les détecteurs moyenne énergie.

Activités de l'ESOC

La définition du programme de soutien des opérations s'est poursuivie et a permis d'affiner les spécifications des lots de travaux et des ressources.

On procède à l'étude de l'utilisation des stations sol de Weilheim (actuellement consacré à Hélios) et de Michelstadt (utilisée à présent par Geos) en tant que solution de rechange à la station de Villafranca. Un rapport d'études, indiquant en détail les conséquences techniques et financières, attendu en octobre, devra servir de base pour une prise de décision à cet égard.

TELESCOPE SPATIAL

La participation de l'ESA au Programme de télescope spatial de la NASA a été approuvée sous deux conditions:

(1) que les négociations avec la NASA sur un Mémorandum d'accord pour le projet soient menées à bon terme et

(2) que le Congrès américain approuve le Projet de la NASA.

Ces deux conditions ont depuis lors été remplies.

Les Chefs de projet de l'ESA et de la NASA ont apposé leur visa sur le plan du projet NASA/ESA de réalisation du télescope spatial.

La NASA a procédé à la sélection des contractants qui seront chargés des principaux éléments du télescope spatial: le télescope optique et le module des systèmes de soutien. A la suite de cette sélection, des négociations poussées sur les interfaces entre les matériels fournis par l'ESA et le télescope spatial ont été engagées.

Des propositions pour le réseau solaire et le détecteur de photons du télescope spatial ont été reçues de l'industrie européenne et soumises à évaluation. Le Comité de Politique industrielle présentera en septembre ses recommandations pour la passation des contrats, la mise en route de la Phase B pour les deux contrats étant prévue pour début octobre.

La documentation d'appel d'offres pour le contrat portant sur la chambre optique a été publiée fin avril. Les propositions sont attendues pour le 26 septembre. Le démarrage de la Phase B de ce dernier contrat est prévu pour début janvier 1978.

TRAINEAU SPATIAL

Après que les offres reçues pour le Programme du Traîneau spatial aient été évaluées et clarifiées, le Comité de la Politique industrielle (ICP) a décidé de choisir ERNO comme contractant pour les phases B et C/D du programme de développement.

Avant cette décision, et parallèlement aux autres activités, avaient été définies les interfaces du traîneau avec le Spacelab d'une part et le bloc expérimental d'autre part pour les concepts proposés par les deux contractants potentiels du Traîneau spatial. Les besoins en ressources et les impératifs d'interface ont été revus avec le SPICE lors de l'examen des impératifs du programme les 25 et 26 août et actualisés en septembre.

Le programme a été officiellement mis en route le 26 septembre. La première partie de la phase B, ou phase d'évaluation de la conception, qui doit en principe durer quelque 3 mois et demi, couvrira toutes les activités relatives aux arbitrages et à la définition des interfaces nécessaires pour établir les concepts des sous-systèmes.

Il a été annoncé que la première mission Spacelab serait reportée à décembre 1980 en raison d'un retard intervenu dans le lancement des satellites américains de poursuite et de relais de données qui doivent maintenant être placés sur orbite à l'aide de la Navette.

Meteosat Launch Operations

R. Balvay, Meteosat Integration, Test and Launch Manager, Meteorological Programmes Department, ESA

Meteosat was designed from the outset to be launched by a Delta 2914 vehicle into a geosynchronous transfer orbit from Eastern Test Range (ETR), Florida. The launch operations conducted at the Range included final preparation of both the launcher (assembly, test and fuelling) and the satellite (inspection, test and fuelling), assembly of the satellite on top of the launch vehicle, countdown and lift-off.

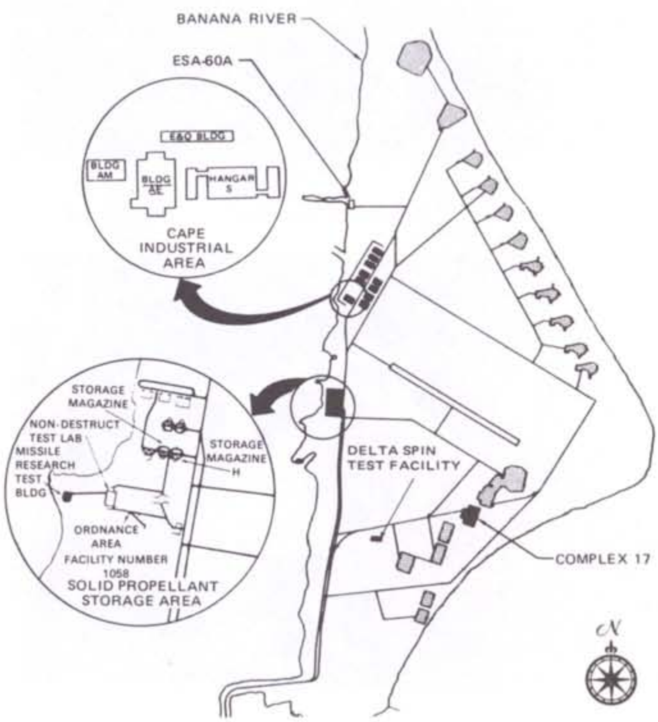


Figure 1 – Layout of the launch site at Eastern Test Range.

The Meteosat Flight-Readiness Review took place at ESA's Meteorological Programmes Office (MPO) in Toulouse from 27 June to 7 July, at which time the Review Board authorised launch, as then scheduled, on 3 November 1977. The launch-vehicle preshipment review had already been conducted by NASA at McDonnell-Douglas, the Thor-Delta Prime Contractor, some months before on 13 April.

All the necessary documentation for the launch campaign had already been prepared prior to the Flight-Readiness Review, including:

- the Launch Operations Manual covering
  - the plan of operation, with task descriptions and durations
  - the roles of the personnel
  - the inventory of equipment to be transported from Europe
  - the equipment, facilities and services required from the Range
- the procedures to be used
- the specification of the support asked from NASA.

THE LAUNCH CAMPAIGN

The sequence of operations followed in preparing Meteosat for launch can be divided into three main parts (ground locations shown in Fig. 1):

- the satellite itself was inspected and tested in a hangar (AE) in the Cape Industrial Area. At the same time, the Apogee Boost Motor (ABM) delivered directly from the supplier, Aerojet, was inspected, X-rayed in the Missile Research Test Building, and integrated with its adaptor.
- The satellite and ABM were then transported to the Delta Spin Test Facility (DSTF), where the satellite's tanks were filled with hydrazine, the satellite and ABM were integrated, and the composite weighed and mated with the third stage of the Thor-Delta vehicle.
- This assembled unit of third stage, satellite and ABM was then transported to the launch pad (17A) to be erected on top of the vehicle and mated to the second stage.

The launch campaign was originally scheduled to begin on 19 September and although this date was reviewed in the light of the OTS launcher failure, it was decided to go ahead as planned. Thus on 19 September, the campaign started, with:

- unloading of the first cargo aircraft carrying Meteosat from Europe

Figure 2 – Satellite container being unloaded from the aircraft.

Figure 3 – Check-out station in hangar.

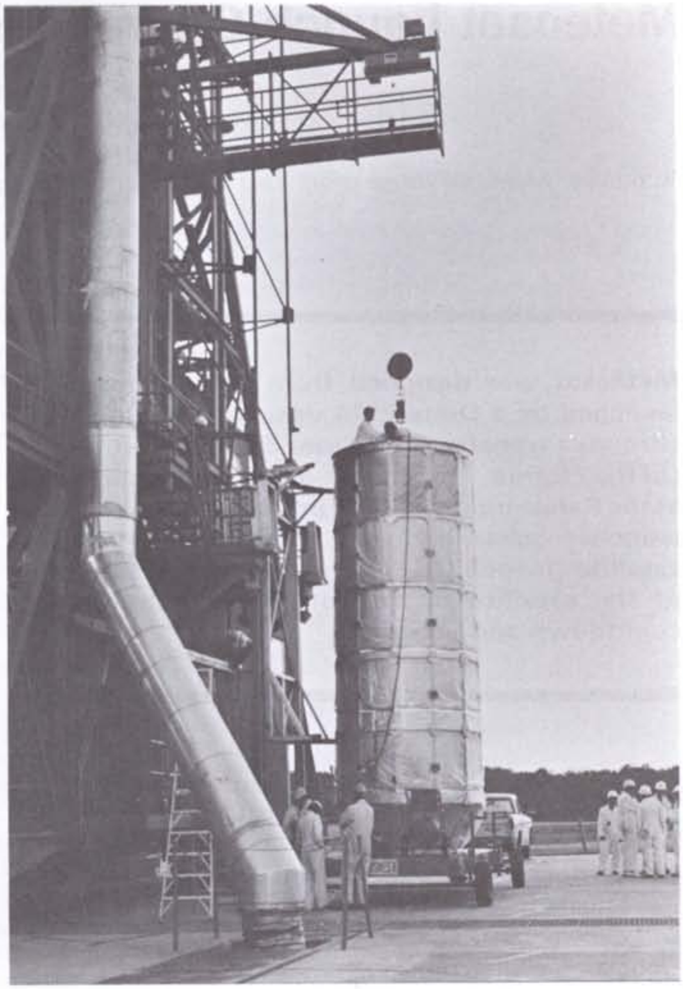


Figure 4 – Hoisting the 'yellow can' – containing the satellite, ABM and third stage – up the side of the gantry.

- ground-support equipment unpacking, inspection and validation
- satellite unpacking, inspection and test preparations
- flight battery conditioning
- ABM inspection, X-ray and leak checking.

Meanwhile, NASA had been continuing its failure investigation of the OTS launcher and on 22 September a postponement of the Meteosat launch date until 15 November was announced.

In view of the consequent uncertainty of the situation, departure of the second cargo plane from Europe was delayed and the overall launch planning reviewed. The diary of the launch campaign that finally ensued reads as follows:

22-27 September:
Visual inspection of the satellite showed that no damage had occurred in transport from SNIAS, Cannes, to ETR.

26 September:
Baseline testing was started, including:
- verification of the performances of the different subsystems. A command decoder was found to be faulty and was replaced by the spare
- leak checking of the hydrazine subsystem and measurement of thruster flow rates
- testing of radiometer performance parameters with optical stimulation
- inspection and performance testing of the solar array
- alignment checking of the spacecraft structure, the attitude-measurement sensors and the radiometer
- system testing of mission performance.

26 October:
The Test Review Board, after evaluating all test results, declared the satellite ready for launch.

27 October:
NASA rescheduled launch for 17 November 1977.

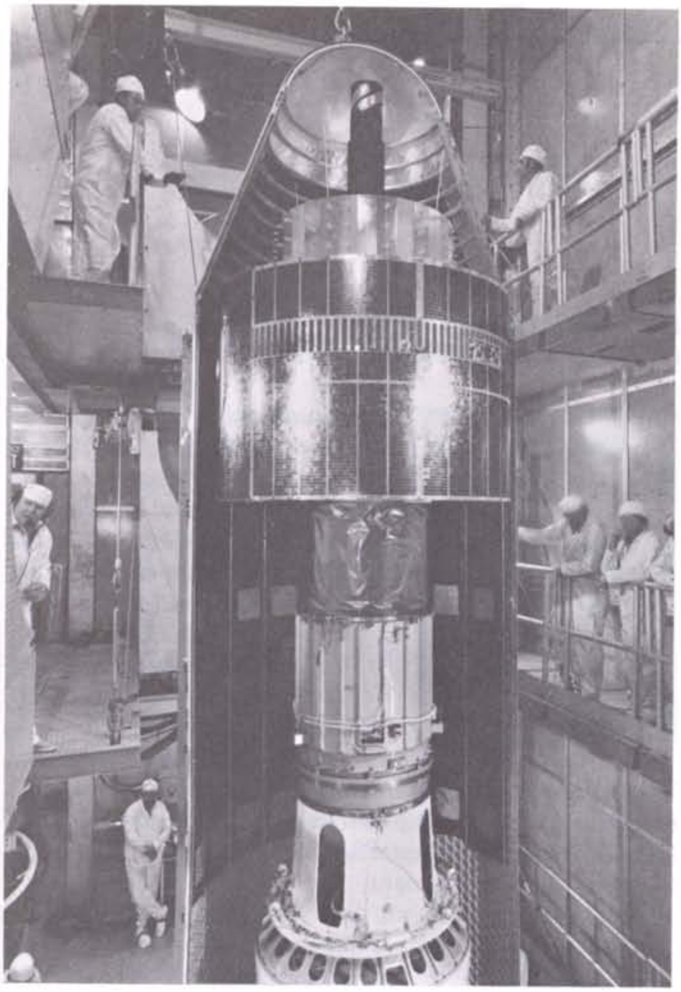


Figure 5 – Fairing installation.

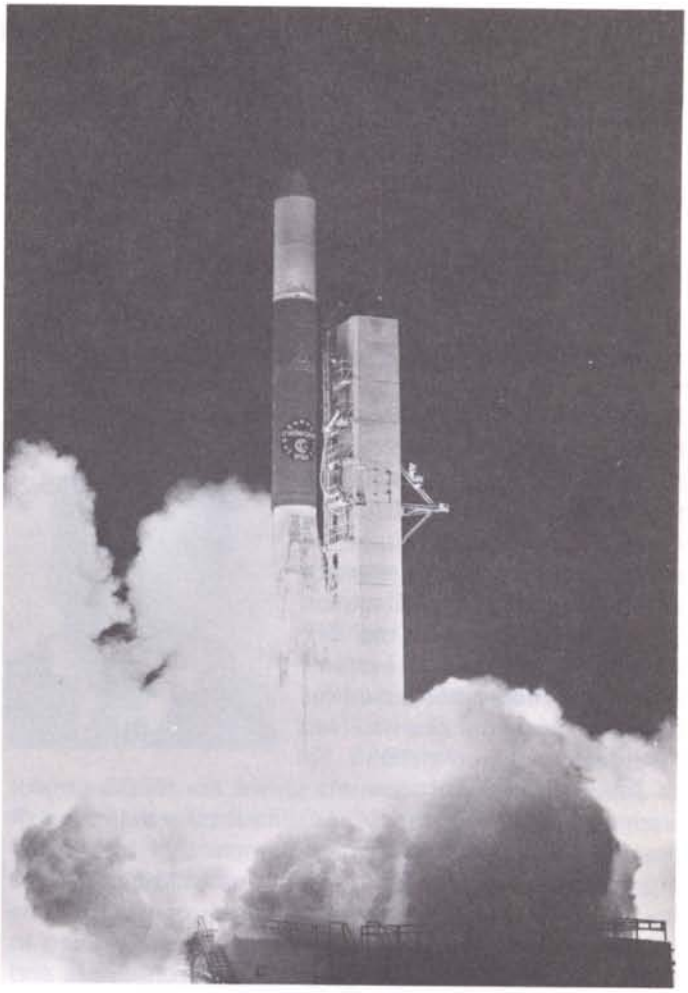


Figure 6 – Lift-off.

31 October:
After final inspection, the satellite and ABM were transported to the DSTF for final preparations before delivery to NASA for mating with the Thor-Delta third stage.

8 November:
The satellite, ABM and third stage were transported to the launch pad and the composite erected on top of the second stage. The satellite was switched on in launch configuration (VHF only) and final checks made prior to fairing installation. A second-stage valve was found to be leaking and launch was postponed until 20 November.

18 November:
The fairing was installed and the pyrotechnic circuitry set in flight configuration.

20 November:
Final countdown was started, but was cancelled two hours before lift-off by NASA. A stray launcher-destruct command had been received some days before and the source had not yet been identified.

22 November:
It was finally proved that the destruct command had been generated by a US Navy ship used as a tracking station by NASA. The final countdown was resumed on Tuesday 22 November, leading to lift-off at 20.35 hrs Eastern Standard Time.

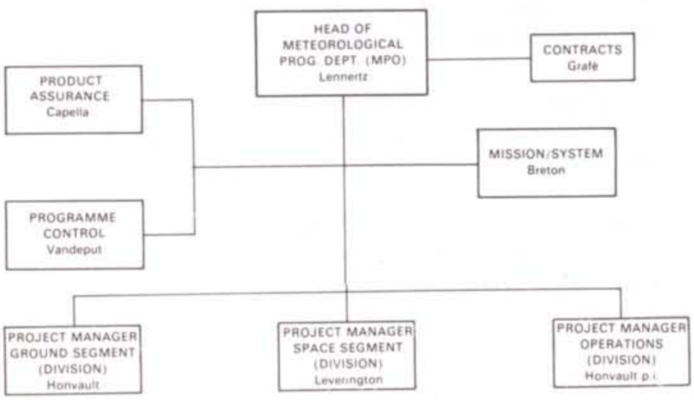
Transfer orbit was nominal and injection into near-synchronous orbit (ABM firing) took place on 23 November at 13 h 19 m 05 s EST on second apogee.

The assessment of early flight data showed correct operation of the satellite, the Active Nutation Damping system was operating satisfactorily and attitude was nominal. □

Meteosat Programme Management Team

D. Lennertz
Head of Meteorological Programmes Department

Dr. D. Lennertz (41) is German. He obtained the Dipl. Ing. degree in Electrical Engineering from the Technische Hochschule, Aachen in 1962. As a scientific assistant, he carried out research at the Institute for Electrical Telecommunication at the TH, Aachen, in the field of systems and signal theory. He based his thesis on this work and received his doctor's degree in 1965.
In January 1966, Dr. Lennertz joined the HEOS project team at ESTEC. He was responsible for the definition of the electrical ground-support equipment, then for satellite integration, tests and launch operations. In March 1969, a few months after the successful launch of HEOS-1, he joined the Directorate of Programmes and Planning at ESRO Head Office as Manager for Aeronautical and Maritime Missions. In January 1973, Dr. Lennertz was appointed Head of the Meteosat team in Toulouse, and in 1975 Head of Meteorological Programmes Department, ESA, Toulouse.



D. Leverington
Project Manager Meteosat Space Segment

Mr. Leverington (35) is British. He studied physics at Oxford University and after graduation in 1963 joined Imperial Chemical Industries. He then spent four years specialising in colour perception in human beings.
In 1967 he joined British Aircraft Corporation to perform research in coherent optics and in 1969 joined BAC's space department. The following year he was appointed Geos design manager and held that position until just before the Geos launch, when he joined ESA MPO as Project Manager, Meteosat Space Segment.

C. Honvault
Project Manager Meteosat Ground Segment and Operations (p.i.)

M. C. Honvault (39) est français. Il a obtenu son diplôme d'Ingénieur de l'Institut Supérieur d'Electronique du Nord (ISEN), ainsi qu'une licence de Sciences Physiques à l'Université de Lille en 1961.
Il a travaillé un an à la SNIAS (Cannes) dans le domaine des antennes de bord, avant de rejoindre le Centre National d'Etudes Spatiales (CNES) en 1964, pour s'occuper dès 1965 du développement d'équipements pour le Centre Spatial Guyanais, qu'il a rejoint en 1968; il y a assuré les fonctions de chef d'un département opérationnel jusqu'en 1971.
Après un an passé au Centre Spatial de Toulouse (CST) au sein de la Division Satellites, il est, depuis 1972, responsable au sein du Bureau des Programmes Météorologiques de l'ESA, du développement du Segment Sol du Programme Météosat, et de la préparation des opérations.

D. Breton
Mission/System Manager

M. D. Breton (43) est français. Il a obtenu le diplôme d'Ingénieur de l'Ecole Supérieure d'Electricité, section Radioélectricité en 1958. Après son service militaire, il a travaillé à la CFTH dans le domaine des antennes et circuits hyperfréquences pour émetteurs de télévision.
Il est entré au CNES en 1964 où il a participé au développement du réseau de stations au sol du CNES et à diverses études de systèmes et de propagation. Il a participé aux études de définition du système Météosat (Phase A) comme responsable des équipements au sol.
En 1972, il a rejoint le MPO. D'abord chargé des aspects télécommunications au niveau système, il occupe depuis 1975 la fonction de Mission/System Manager.

L. Vandeput
Programme Control Manager

Mr. Vandeput (38) is Belgian. He graduated as a Dipl. Industrial Engineer from Louvain University (Belgium) in 1962. Subsequently, he did post-graduate work at Strasbourg University (France) at the 'Centre Universitaire des Hautes Etudes Européennes', and at the 'Institut d'Economie Appliquée aux Affaires', where he obtained his degree in Business Administration in 1964. He joined ESTEC in 1969 as Project Controller for ESRO-IV. In 1972, he was appointed MPO Programme Control Manager, in charge of financial and planning control for the programme.

A. Capella
Product Assurance Manager

Arthur Capella was educated at the College of Aeronautical Engineering and, in part, at the University of London. In over twenty years in the British aerospace industry, his technical activities have ranged from war-time gas-turbine development through aircraft structural analysis, supersonic studies and ram-air turbine development to reliability engineering promotion and co-ordination for the Hawker Siddeley group of companies in the mid- sixties.
He was involved with Blue Streak and ESRO II whilst with HSD, joining ESTEC in October 1966, where he was to become Deputy Head of the Reliability and Quality Division, now the Product Assurance Division, in 1967. In October 1972 he left ESTEC for Toulouse to set up and lead MPO's Product Assurance Section.

C. Grafé
Programme Contracts Officer

Mr. C. Grafé (35) is Belgian. Having graduated in law (doctor, University of Louvain, plus postgraduate specialisation in international affairs, University of Brussels), he worked as legal adviser to the trade unions before joining the Belgian Ministry of Employment and Labour where he was responsible for international affairs (1967–1970). During this period he also participated in the setting-up of interministerial seminars for further training of senior civil servants.
He was recruited by ESTEC Contracts Division in 1970 and was responsible for Aerosat Project preparation until the approval of the Meteosat Programme. In June 1972, he became Contracts Officer for the Meteorological Programme in Toulouse and, with the technical team, was responsible for negotiation and administration of the contracts placed with Industry.

Council of Europe Resolution on the European Space Agency

– Text adopted by the Parliamentary Assembly at its Ninth Sitting (October 1977)

Close relations have existed for many years between the Council of Europe and the Agency. ESA regularly transmits its Annual Report to the Council of Europe and participates actively in some of the latter's activities which have a direct link with the Agency's own work, in particular those of the Technology Commission of the Parliamentary Assembly.

During its last Plenary Session, the Parliamentary Assembly of the Council of Europe unanimously approved a Resolution on ESA, the text of which is as follows:

The Assembly,

Thanking the Council of the European Space Agency (ESA) for the transmission, in accordance with Resolution No. 10 of the Ministerial Space Conference of Plenipotentiaries of 30 May 1975, of the Agency's Annual Report for 1976, thereby, as stated in Recommendation 251 (1960), ensuring 'the parliamentary influence of this Assembly'.

Welcoming the progress made in 1976, which was the first full year of activity of the Agency and a year of consolidation, during which no launchings were made while preparations were being made for the five scheduled for 1977;

Noting with satisfaction the holding of the first ESA Council at ministerial level of 14 and 15 February 1977, where decisions of principle were taken in favour of an Overall Communications Satellite Programme consisting of four elements, namely the Marots maritime communications satellite, a European regional communications satellite system, a heavy satellite of some 900 kg devoted to direct television broadcasts, and an advanced research and development programme;

Appreciating the progress made in the development phase of the Ariane launcher;

Noting with satisfaction that the construction of Spacelab is making satisfactory progress, and that its finance has been assured both until completion of construction and for the first flight in 1980 as well as for its experiments;

Noting with satisfaction that, of a total of 79 scientific and technological experiments to be carried out in Spacelab 1, as many as 62 will be European, of which 37 are in the field of material science;

Believing that Spacelab will probably play an equally important role in future communication, television, navigation and meteorological programmes;

Welcoming the fruitful working relations between the Agency and the Council of Europe, including the existence of common projects in the field of geodynamics, remote sensing and life science research;

Recalling the fruitful co-operation established in space research both between certain European countries and the USSR and between the United States and the USSR, symbolised by the rendezvous in space in 1975;

Noting that, in addition to its ten original signatories (Belgium, Denmark, France, Federal Republic of Germany, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom) Ireland has also signed the ESA Convention, hopes that further Western European states will become members of or associated with ESA;

Determined to take steps in national parliaments to accelerate the ratification procedures of the ESA Convention;

Welcoming the decisions of the Ministerial Council on the role of Europe in the field of remote sensing from satellites, and the setting-up of the Earthnet programme aiming at monitoring on a worldwide co-operative basis earth resources and environment from space;

Recalling its opinion that the development and management of European operational systems is of paramount importance for Europe's future role in space, welcomes the view of the Ministerial Council that operational activities will enable the Agency to exploit its capabilities and capital investments to the full for the benefit of European users of space applications;

(cont. page 66)

Résolution du Conseil de l'Europe relative à l'Agence

– Adoptée par l'Assemblée parlementaire lors de sa neuvième session (octobre 1977)

Des relations étroites existent depuis des années entre le Conseil de l'Europe et l'Agence. L'ESA communique son rapport annuel au Conseil de l'Europe et participe activement à certains travaux de ce dernier qui touchent directement aux activités de l'Agence, en particulier ceux de la Commission de la Technologie de l'Assemblée Parlementaire.

Lors de sa dernière session plénière, l'Assemblée Parliamentaire du Conseil de l'Europe a approuvé à l'unanimité une Résolution sur l'ESA dont le texte est le suivant:

L'Assemblée,

Remerciant le Conseil de l'Agence spatiale européenne (ESA) d'avoir transmis, conformément à la Résolution no. 10 de la Conférence ministérielle des plénipotentiaires de l'Espace du 30 mai 1975, le Rapport annuel de l'Agence pour 1976, assurant ainsi, comme le demande la Recommandation 251 (1960), 'l'influence parlementaire de l'Assemblée';

Saluant les progrès réalisés en 1976, première année de pleine activité de l'Agence et année de consolidation, pendant laquelle, si aucun satellite n'a été lancé, les cinq lancements prévus pour 1977 ont été dûment préparés;

Se félicitant de la tenue, les 14 et 15 février 1977, du premier Conseil à l'échelon ministériel de l'ESA, au cours duquel des décisions de principe ont été prises en vue d'un programme d'ensemble des satellites de télécommunications comportant quatre éléments, à savoir le satellite Marots de communications maritimes, un système régional européen de satellites de communications, un satellite de quelque 900 kg destiné à la diffusion directe des émissions de télévision, et un programme avancé de recherche et de développement;

Saluant les progrès enregistrés dans la mise au point du lanceur Ariane;

Heureuse de constater que la construction de 'Spacelab' progresse de façon satisfaisante, et que le financement en est assuré à la fois jusqu'à son achèvement, pour le premier vol prévu en 1980 et pour les expériences;

Notant avec satisfaction que, sur 79 expériences scientifiques et technologiques à réaliser à bord de Spacelab 1, 62 seront européennes, dont 37 dans le domaine des sciences matérielles;

Estimant que 'Spacelab' est appelé à jouer un rôle également important dans les futurs programmes de communications, de télévision, de navigation et de météorologie;

Saluant les fructueuses relations de travail nouées entre l'Agence et le Conseil de l'Europe, et notamment l'existence de projets communs en matière de géodynamique, de télédétection et de recherche sur les sciences de la vie;

Rappelant la coopération fructueuse instaurée en matière de recherche aérospatiale tant entre certains pays européens et l'URSS qu'entre les Etats-Unis et l'URSS, symbolisée par le rendez-vous spatial de 1975;

Notant que l'Irlande vient de rejoindre les dix premiers signataires de la Convention de l'ESA (Belgique, Danemark, France, République Fédérale d'Allemagne, Italie, Pays-Bas, Espagne, Suède, Suisse et Royaume-Uni), exprime l'espoir que d'autres Etats d'Europe occidentale adhèreront ou s'associeront à l'ESA;

Résolue à susciter des interventions dans les parlements nationaux en vue d'accélérer les procédures de ratification de la Convention de l'ESA;

Saluant les décisions du Conseil ministériel sur le rôle de l'Europe dans le domaine de la télédétection par satellites, et l'élaboration d'un programme Earthnet fondé sur la coopération internationale et visant à répertorier les ressources terrestres et à observer l'environnement à partir de l'espace;

Réaffirmant que la mise au point et la gestion de systèmes opérationnels européens détermineront de façon décisive le rôle futur de l'Europe en matière spatiale, approuve le Conseil ministériel lorsqu'il déclare que les activités

(suite page 67)

Noting that the Ministerial Council stipulated that the Agency should limit its operational activities to the launching, placing in orbit and orbital control of satellites and space transport systems, welcomes the power entrusted to the Agency Executive to recommend to member states measures for the harmonisation of the policies of user administrations and entities with the Agency's policy;

Recalling that past European space failures stemmed from the unco-ordinated activities of separate space organisations;

Recalling its view that any durable European space project depends in no little measure on finding external markets for Europe's space products, welcomes the ministerial resolution affirming its will to establish Europe in the space applications market;

Noting that one substantial limitation has been put on the competency of the Agency to the effect that it will not itself enter into contracts for the development or provision of space systems for external markets, except in the case of launch services, expresses its satisfaction with the authority invested in the Agency Executive to set up and maintain contacts with the potential users of space systems in non-member states and in international organisations, with a view to making the Agency's scientific and technological management capabilities better known;

Recalling that the difficulties of the European Communities JET project were due *inter alia* to the unanimity rule;

Invites the Council of the European Space Agency:

i. to use the unanimity rule with moderation, in order that it does not serve as a frequent brake on the Agency's internal and external activities;

ii. to launch a dynamic marketing policy;

iii. to let the Agency's Executive exercise its powers in such a way as to enable the Agency to play the required co-ordinating role in relation to existing and potential users, as well as to assure a co-ordinated European space policy in regard to Unesco, the UN, Intelsat, the World Meteorological Organisation and the International Telecommunications Union;

iv. to favour a close co-ordination between the European Space Agency and the Communities for the elaboration of a general European scientific and technological policy, in which the space programmes could play an important role;

v. to transform in due course the Earthnet programme into a mandatory one whereby all member states participate according to their GNP;

vi. to integrate fully the knowhow and experience of member states in the space field, and in particular telecommunications, into the Agency programmes;

vii. to take a final decision in favour of starting the production of the Ariane launcher before the end of 1977;

viii. to explore, while respecting the major options taken at European level, the lines of mutually advantageous co-operation with the USSR and with other countries possessing space research potential, in accordance with the mutual commitments undertaken at the time of the signature of the Act of Helsinki. □

opérationnelles permettront à l'Agence de tirer pleinement parti de ses capacités et de ses investissements dans l'intérêt des utilisateurs européens des applications spatiales;

Notant que le Conseil ministériel a stipulé que l'Agence limiterait ses activités opérationnelles au lancement, à la mise en orbite et au contrôle orbital des satellites et des systèmes de transports spatiaux, se félicite que l'exécutif de l'Agence ait été autorisé à recommander aux Etats membres des mesures visant à harmoniser la politique des administrations et organismes utilisateurs avec celle de l'Agence;

Rappelant que les récents échecs spatiaux européens sont dus à un manque de coordination des activités de plusieurs organisations spatiales distinctes;

Réaffirmant que tout projet spatial européen qui se veut durable dépend pour beaucoup de la découverte de marchés extérieurs pour les produits spatiaux européens, salue la résolution ministérielle où s'exprime la volonté de voir l'Europe prendre sa place sur le marché des applications spatiales;

Constatant que la compétence de l'Agence a fait l'objet d'une limitation substantielle en ce sens qu'elle ne conclura pas elle-même de contrats de développement ou de fourniture de systèmes spatiaux pour les marchés extérieurs, à l'exception des services de lancement, se félicite que l'exécutif de l'Agence soit habilité à nouer et à maintenir des contacts avec les utilisateurs potentiels de systèmes spatiaux des Etats non membres et des organisations internationales, afin de faire mieux connaître les capacités scientifiques, technologiques et de gestion de l'Agence;

Rappelant que les difficultés du projet JET des Communautés européennes sont dues en particulier à la règle de l'unanimité,

Invite le Conseil de l'Agence spatiale européenne:

i. à user avec modération de la règle de l'unanimité, de façon qu'elle ne vienne pas à tout moment contrarier les activités intérieures et extérieures de l'Agence;

ii. à inaugurer une politique dynamique de commercialisation;

iii. à laisser l'exécutif exercer ses pouvoirs de façon que l'Agence puisse jouer le rôle coordinateur qui lui est dévolu auprès des utilisateurs effectifs ou en puissance, ainsi que pour harmoniser la politique spatiale européenne en ce qui concerne l'Unesco, les Nations Unies, Intelstat, l'Organisation météorologique mondiale et l'Union internationale des télécommunications;

iv. à favoriser une coordination étroite entre l'Agence spatiale européenne et les Communautés pour l'élaboration d'une politique générale européenne dans les domaines scientifiques et technologiques, dans laquelle les programmes spatiaux pourraient jouer un rôle important;

v. à transformer, le moment venu, le programme Earthnet en un programme obligatoire auquel tous les Etats membres participeraient au prorata de leur PNB;

vi. à intégrer pleinement dans les programmes de l'Agence le savoir-faire et l'expérience des Etats membres dans le domaine spatial, et notamment en matière de télécommunications;

vii. à se prononcer définitivement pour le démarrage de la fabrication du lanceur Ariane avant la fin de 1977;

viii. à explorer, en respectant les grandes options prises au niveau européen, les voies d'une coopération mutuellement avantageuse avec l'URSS et avec les autres pays disposant d'un potentiel de recherche en matière aérospatiale, conformément aux engagements réciproques pris lors de la signature de l'Acte d'Helsinki. □

In Brief

Launch of ISEE/A-B

The first two of the three International Sun-Earth Explorer satellites, ESA's ISEE-B and NASA's ISEE-A spacecraft, were launched successfully in tandem into a highly elliptical orbit by the same Thor-Delta 2914 vehicle from Cape Canaveral on 22 October at 14.53 GMT. Both satellites are functioning perfectly and the mission is expected to make an important contribution to the International Magnetospheric Study (1976–1979), the aim of which is a fuller understanding of the near-earth environment and solar-terrestrial phenomena.

ISEE-B, built for ESA by industry in ten European countries (Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Sweden, Switzerland and the United Kingdom) with Dornier System as Prime Contractor, is the tenth scientific satellite to be launched by ESRO/ESA. The satellite and its mission will be featured in the next issue of the Bulletin.

ESA-NASA Co-operation in the Space Telescope Programme

During a working meeting on 7 October at ESA Head Office in the course of the ESA/NASA Annual Spacelab Programme Review, Dr. Robert A. Frosch, Administrator of NASA, and Mr. Roy Gibson, Director General of ESA, signed the Memorandum of Understanding laying down the terms for co-operation between the two Agencies in the NASA Space Telescope Programme.

Designed for an operational lifetime of fifteen years, the Telescope will allow the international astronomical community to make observations of unprecedented sophistication. In particular, it will be possible to separate objects less than a tenth of a second of arc apart and to observe remote celestial objects nearly 100 times fainter than those observable from the ground.

In return for its participation, ESA has been allocated 15% of the observing time throughout the duration of the programme. The data are to be made available to astronomers in the Member States and then archived for use by the international scientific community.

Signature at ESA Head Office of the Space Telescope Memorandum of Understanding. Seated, from left to right, are: Dr. H. Kaltenecker (ESA), Dr. R.A. Frosch (NASA), Mr. R. Gibson (ESA) & Dr. E. Trendelenburg (ESA).

State Visitors at ESTEC

In the course of an official visit to the Netherlands, the President of Surinam Mr. J.H.E. Ferrier, and Mrs. E. Ferrier-Vas, visited ESTEC on 16 September in the company of Their Royal Highnesses Princess Beatrix and Prince Claus of the Netherlands.

The accompanying photograph shows the Princess (left) and President and Mrs. Ferrier, with Prince Claus (right) and Mr. G. van Reeth (Director of Administration, ESA) in the background, being welcomed by Dr. Berghuis, Director of ESTEC.

Japanese Visitors at ESTEC

The accompanying photograph shows members of a study team from the Japanese Vacuum Industry, on ESTEC's Test Floor during the course of a visit to the establishment on 23 September. The group was led by Mr. Lichiro Kasaoka, President of Osaka Vacuum Ltd.

Visit by Chinese Delegation

A delegation of nine telecommunications experts from the Chinese Electronics Society visited Europe from 12 September to 20 October to study European space technology and space programmes. The Agency organised visits to the principal national space facilities and industrial firms of its Member States for the delegation, led by Mr. Lei Hung, and the topics discussed included the many facets of communications satellite programmes.

This visit provided ESA and many European industrialists with their first opportunity to meet and establish contact with space experts from the Chinese People's Republic.

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Starting with the next issue, a limited number of pages in the Bulletin will be available for the advertisement of *space-related products and services*.

As the European Space Agency's quarterly magazine carrying information on the Agency, its activities and its programmes – on-going and future – the Bulletin is read not only by professional engineers and scientists, but also by national delegations to ESA's governing bodies and by administrators of political and government institutions concerned with the exploration or exploitation of space.

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ESA Journal

The following papers were published in Vol. 1, Nos. 2 and 3.

VOL. 1, NO. 2.

A Methodology Applicable to the Identification and Quantification of the Benefits of a European Remote-Sensing Satellite Programme, *by P. Brunt, L.P. White & L.W. Steines*

A methodology is developed for the identification and quantification of benefits from a European Remote-Sensing Satellite Programme. The methodology also covers the definition of programme objectives, the selection of geographical areas of application, the assessment and choice of 'ideal' sensor packages and spacecraft configuration, and the identification of sensing programmes. A brief example of the methodology applied to the problem of desert locust control is presented.

On expose ici une méthodologie permettant de déterminer et de chiffrer les profits à attendre d'un programme européen de télédétection par satellite. Cette méthodologie porte également sur la définition des objectifs du programme, sur la sélection des zones géographiques à couvrir, sur le choix d'instruments de détection et de modèles de satellite les mieux adaptés, et enfin sur la mise au point du programme d'observation. On donne un exemple d'application de cette méthodologie au problème de la surveillance des migrations d'acridiens dans les zones désertiques.

A Spacelab Facility for Spectroscopy and Polarimetry of X-Ray Sources (EXSPOS), *by V. Manno*

High-resolution spectroscopic and polarimetric studies of X-ray sources are required to provide us with a basic understanding of the nature of these sources. Preliminary results obtained with proportional counters on the OSO-8 and Ariel V satellites are indicative of the existence of line emissions from such X-ray emitters as clusters of galaxies, supernova remnants and X-ray binary systems. The measured fluxes are well below the sensitivity limit of the Bragg crystal spectrometers also on board; it is therefore necessary that large areas and exposures be achieved to obtain detailed measurements of emission and absorption lines. A payload achieving high sensitivity and flexibility in its configuration has been studied by ESA for a series of flights on Spacelab.

L'étude spectroscopique et polarimétrique à haute résolution des sources de rayonnement X est fondamentale pour la compréhension du mécanisme de ces sources. Les premiers résultats obtenus à l'aide de compteurs proportionnels embarqués sur les satellites OSO-8 et Ariel-V révèlent la présence de raies d'émission en provenance de diverses sources de rayonnement X telles que les amas de galaxies, les restes de supernova et certains systèmes binaires. Les flux mesurés se situant bien en dessous de la limite de sensibilité des spectromètres à cristal de Bragg qui se trouvent également à bord, il faudra par conséquent prévoir de vastes surfaces de détection et de longues durées d'exposition pour arriver à une mesure fine des raies d'émission et d'absorption. Une charge utile caractérisée à la fois par une haute sensibilité et une grande souplesse d'utilisation fait actuellement l'objet d'étude à l'Agence en vue d'une série de vols à bord du Spacelab.

Analyse de fonctionnement et de dégradation à long terme des performances d'un oscillateur haute fréquence à transistor, *par M. Pollacsek & J.G. Ferrante*

L'analyse de fonctionnement d'un circuit électronique est une phase préalable essentielle à l'évaluation de la dégradation de ses performances dans le temps (vieillissement des composants, variation des caractéristiques, etc.). On analyse le fonctionnement d'un oscillateur haute fréquence à transistor à l'aide du logiciel de conception aidée par ordinateur (CAO) 'ESAMEC', en mettant l'accent sur sa modélisation, la recherche du point de fonctionnement nominal et la nécessité d'obtenir des *données sur l'évolution des paramètres critiques. Ce dernier point est essentiel pour prédire d'une façon réaliste la dégradation à long terme du circuit analysé, surtout lorsqu'il est destiné à être embarqué sur un satellite d'application dont la durée de vie prévue est de l'ordre de 5 à 7 ans.*

Analysis of the functioning of an electronic circuit is an essential step prior to evaluation of degradation of performance with time (ageing of components, variation in the characteristics, etc.). The functioning of a high-frequency transistor oscillator is being analysed using the computer-aided-design (CAD) program 'ESAMEC', with emphasis on its modelling, research on the nominal operating point, and the need to obtain data on the variation of critical parameters with time. The latter data is essential in order to realistically predict the long-term degradation of the circuit analysed, particularly when it is designed to be flown on board an applications satellite that has a planned lifetime of the order of five to seven years.

The Implications of Using High-Power Travelling-Wave-Tube Amplifiers with Uplink Power Control at OTS-Type Earth Stations, *by R.J. Colby*

This paper presents the preliminary results from a programme of tests designed to assess the problems associated with the use of high-power travelling-wave-tube amplifiers (TWTAs) as the transmitters in earth stations of the type to be used with ESA's Orbital Test Satellite (OTS). The tests were carried out using a realistic hardware simulation of an OTS system and were extended to give a first look at the advantages, if any, of using an uplink power control system to compensate for precipitation-induced fading associated with satellite transmission in the 11 and 14 GHz bands. The results show that under clear-weather conditions the additional distortion contributed by the transmitter TWTA is small, but as the TWTA is driven towards full output power the distortion rises rapidly. When this rise in distortion and the additional degradation in the cross-polar and adjacent channels is assessed, uplink power control does not seem to offer any significant advantage, and may be viewed as an undesirable increase in the complexity of an earth station.

On présente les premiers résultats d'un programme d'essais destiné à évaluer les problèmes de l'utilisation des ATOP (amplificateurs à tube à ondes progressives) de grande puissance dans les émetteurs de stations terriennes de même type que celles qui seront utilisées pour le satellite OTS. Ces essais faisant intervenir une simulation poussée du matériel OTS ont été ensuite élargis pour permettre de se faire une première idée des avantages éventuels d'un système de régulation de puissance sur la liaison montante destiné à compenser l'atténuation due aux précipitations dans les bandes de 11 et 14 GHz. Les résultats montrent que par beau temps la distorsion supplémentaire causée par l'ATOP d'émission est minime, mais que la distorsion totale augmente rapidement lorsqu'on s'approche de la puissance d'émission maximale. Si l'on ajoute par ailleurs la dégradation subie par le signal dans les canaux adjacents à la polarisation croisée, on en vient à la conclusion que la formule envisagée ne semble pas présenter un grand intérêt et ne ferait que compliquer inutilement le fonctionnement de la station.

The Analysis, Synthesis and Multiplexion of Bandpass Dual-Mode Filters, *by R.J. Cameron & M.H. Gibson*

The application of dual-mode bandpass filters to satellite repeaters in single and multiplexed form is outlined. The synthesis and realisation of such filters is facilitated by a suite of computer programs whose derivation, content and use is also summarised.

On décrit l'application de filtres passe-bande à mode double, en configuration simple et multiplexée, à des répéteurs de satellite. La synthèse et la réalisation de tels filtres est rendue aisée par l'emploi d'une suite de programmes d'ordinateur dont l'élaboration, le contenu et l'utilisation son décrits brièvement.

Etat actuel de la recherche sur la dynamique des fluides en rotation – 2ème partie –, *par Y. Ousset*

On présente une revue bibliographique des études qui ont été menées dans le domaine de la dynamique des fluides en rotation, en l'orientant vers l'application particulière aux amortisseurs montés en bout de bras et vers *l'évaluation de la dissipation créée par le mouvement relatif du (ou des) fluide(s) par rapport aux parois du réservoir. Sont successivement abordés: l'étude analytique des équations du problème, les études expérimentales qui ont été menées pour évaluer la dissipation du liquide; la résolution numérique des équations de Navier-Stokes et les applications qui en ont été faites aux fluides en rotation; et enfin les problèmes liés aux tensions superficielles aux interfaces lorsque le fluide est sous faible pesanteur. Une conclusion fait le point de ce que l'on peut attendre des différentes approches possibles du problème.*

A bibliographical review of studies conducted in the field of rotating fluid dynamics is presented, with special emphasis on applications to tip-dampers and on evaluation of the dissipation due to fluid movement against the tank walls. The following topics are covered: an analytical study of the problem equations; experimental studies for evaluating the fluid dissipation; numerical resolution of Navier-Stokes equations and subsequent applications to rotating fluids; and lastly problems related to surface tensions at interfaces when the fluid is under low gravity. The conclusions point out various possible approaches which might be used to tackle the different problems.

Comparaison des mesures thermo-optiques de six laboratoires européens (Essai de normalisation des méthodes et appareillages de mesure), *par F. Levadou*

Il existe de très nombreuses méthodes de mesure des propriétés thermo-optiques des matériaux. Chaque laboratoire, en fonction de ses crédits, de ses besoins et des équipements existants, a développé des appareillages et des méthodes de mesure qui lui sont propres. Sous l'instigation de la Section Matériaux de l'ESTEC et dans le cadre de la coordination des travaux de recherche sur les Matériaux, six laboratoires européens ont entrepris des mesures conjointes des propriétés thermo-optiques des matériaux de contrôle thermique. Le but de cette étude était de déterminer les méthodes de mesure et de calcul des propriétés thermo-optiques, de comparer les résultats ainsi que les erreurs de mesure, et éventuellement, dans un dernier stade, d'unifier, voire de normaliser les méthodes et les appareillages au niveau européen.

There are many methods available for measuring the thermo-optical properties of materials. Each laboratory, given its available resources, needs and facilities, has tended to develop its own equipment and methods in this field. At the instigation of the ESTEC Materials Section and within the framework of a coordinatory effort on materials research, six European laboratories have jointly undertaken measurements of the thermo-optical properties of thermal control materials. The aim of this paper is to evaluate the measurement and calculational methods used, to compare the results obtained and the measurement errors incurred and, possibly, in the long term, to contribute to the unification and even standardisation of the methods and equipment used in European laboratories.

VOL. 1, NO. 3.

Mission Analysis for Terrestrial Satellite and Planetary Orbiters, with Special Emphasis on Highly Eccentric Orbits. 1. The Mathematical Background, *by E.A. Roth*

The aim of this contribution is to outline the various orbital and related problems to be solved during the definition of a new mission satisfying the scientific and technical requirements of a particular satellite project. This first part presents the mathematical background and the particular methods developed during the past decade for responding efficiently to the numerous questions arising during the development phase of a project. A short survey of the various orbit computation methods is included. Emphasis is given to the stroboscopic method for orbit computation, which has been used since 1966 and which can be adapted to many classes of orbit. Finally, a brief account is given of the auxiliary calculations needed, such as determination of eclipse duration and periods, visibility from ground stations, crossings of particular spatial regions of interest, etc. The second part of the article, to be published in a subsequent issue of the Journal, will describe the design philosophy and structure of the flexible and inexpensive system of computer programs which is now operational at ESOC. The strong capabilities of the system were demonstrated during the Geos satellite's rescue operations, when a new orbit had to be defined within two days.

On présente les différents problèmes orbitaux qui se posent au cours de la définition d'une nouvelle mission répondant aux exigences scientifiques et techniques d'un projet de satellite. Dans une première partie, on expose les bases mathématiques et les méthodes particulières développées au cours de la dernière décennie en vue de répondre efficacement aux nombreuses questions surgissant pendant la phase de développement. Les différentes méthodes de calcul d'orbite sont rapidement passées en revue, l'accent étant mis en particulier sur la méthode stroboscopique pour la trajectographie, méthode utilisée depuis 1966 et qui est adaptable à différentes classes d'orbites. Finalement, un bref aperçu des calculs auxiliaires est donné, tels que; détermination de la durée d'une éclipse et des périodes d'éclipses, visibilité depuis les stations sol, traversées de régions spatiales particulières, etc. La deuxième partie de l'article, qui sera publiée dans un prochain numéro du Journal, décrira la conception de base et la structure d'un système de logiciel à la fois économique et souple qui est actuellement en usage à l'ESOC. Ce système a d'ailleurs démontré ses possibilités lors des opérations de sauvetage de Geos, au cours desquelles on a pu définir la nouvelle orbite en moins de deux jours.

Dynamic Analysis of a Nonrigid Spacecraft – An Eigenvalue Approach, *by D.H.L. Poelaert*

A method is presented for the modal analysis of spinning (or nonspinning) flexible bodies which takes maximum advantage of the properties of the distributed co-ordinates when the flexible part can be represented by a continuum. By working in the frequency domain, the dimension of the associated eigenvalue problem is reduced to six, the number of overall degrees of freedom. The elastic modes of the system are then obtained in a single step. The main byproducts of modal analysis are a set of modal frequencies and modal gains that form interesting series whose convergence properties are used as a truncation criterion. This method of solving an eigenvalue problem of reduced dimension also applies when the flexible appendage deformations cannot be represented by distributed co-ordinates and 'assumed functions' are used (e.g. obtained from finite-element analysis of a cantilevered configuration). Dynamic analyses of ESA's Geos satellite and of an early version of the NASA Space Telescope are presented as examples. The method accounts for coupling terms between all six translational and rotational degrees of freedom, and it allows a 'user-defined' accuracy for the solution.

On présente une méthode d'analyse modale de corps flexibles (en rotation ou non) en tirant le meilleur parti des propriétés des systèmes à paramètres répartis, lorsque la représentation des parties flexibles par un continuum s'impose. Par passage au domaine fréquentiel, la dimension du problème aux valeurs propres est réduite à six, nombre des degrés de liberté d'ensemble. Les modes élastiques du système sont ensuite calculés d'emblée. Les principaux sous-produits de l'analyse modale consistent en un ensemble de fréquences modales et de gains modaux qui forment d'intéressantes séries dont les propriétés de convergence sont utilisées comme critère de troncature modale. Cette méthode qui revient à résoudre un problème aux valeurs propres de dimension réduite est également applicable lorsque les déformations des parties flexibles ne peuvent être représentées par des coordonnées réparties et que des 'fonctions admissibles' sont utilisées pour les déformées (par exemple déduites d'une analyse par éléments finis d'une configuration encastrée sur base fixe). L'analyse dynamique du satellite Geos de l'ESA et d'une version provisoire du Télescope spatial de la NASA est traitée en exemple. Il est souligné que la méthode proposée tient compte des éventuels termes de couplage entre les six degrés de liberté dans l'espace (rotations et translations) et qu'elle permet à l'utilisateur d'imposer la précision qu'il désire sur la solution.

Influence de l'effet de stockage sur la modélisation et la dynamique des cellules de puissance, *par A.J. Fossard & M. Clique*

Le modèle développé au CERT pour l'analyse automatique des performances des cellules de puissance est développé ici pour prendre en compte l'effet de stockage des transistors de commutation. Le modèle obtenu, valable pour toutes les cellules (buck, boost, buck-boost), dans les deux modes de conduction (continue et discontinue), et tenant compte des filtres d'entrée et de sortie associés à la cellule, met en évidence l'effet de modulation du rapport cyclique par la tension de sortie à travers le temps de stockage. La très bonne qualité de ce *modèle ayant été vérifiée par tous les essais – sur maquette ou en simulation – réalisés jusqu'à présent, il constitue l'un des outils d'analyse synthétique les plus précieux en usage aujourd'hui.*

The model developed at CERT/Toulouse for the computer analysis of switching DC-DC converters is extended in this paper to account for the storage effect of the switching transistors. The model thus obtained is valid for all types of cells (buck, boost, buck-boost) in both modes of conduction (heavy and light) and includes the influence of input/output filters. The modulation of the duty cycle by the output voltage during the storage time is clearly evidenced. This computer model, the excellent quality of which has been confirmed by all breadboard tests and simulations conducted so far, is one of the most powerful analytical synthetic tools currently available.

Dynamic Analysis of the Battery Discharger for the European Communications Satellite (ECS), *by A. Capel, A. Weinberg & J.G. Ferrante*

A practical dynamic analysis of the European Communications Satellite's eight-module battery discharger, made using the continuous linear model developed by LAAS and CERT, Toulouse, France, is presented. The new aspects of input-filter influence and modularity are highlighted by considering a single module of the Battery Discharge Regulator and the overall modular system separately.

On présente une analyse dynamique assistée par ordinateur (CAD), du déchargeur de batterie à huit modules du satellite européen de communications (ECS), basée sur un modèle linéaire continu mis au point par le LAAS et le CERT, à Toulouse. On met en évidence les nouveaux aspects de l'influence du filtre d'entrée et la modularité du système en étudiant séparément un module isolé du régulateur de décharge de batterie et le système modulaire dans son ensemble.

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