esa bulletin

number 21

february 1980

european space agency

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

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

Director General: Mr R. Gibson.

agence spatiale européenne

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

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

(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 scientifiques, du Directeur des Programmes d'Applications, du Directeur du Programme Spacelab, du Directeur technique 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.

ESRIN, Frascati, Italie.

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

Directeur général: M. R. Gibson.

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ARIANE

après le premier vol d'essai

Rappel
Dès ses débuts, le programme de développement Ariane prévoyait, après une étape de définition et de mise au point par des essais au sol, une phase d'essais en vol de quatre lancements destinés à prouver l'aptitude du lanceur à remplir sa mission et donc à disposer d'une capacité opérationnelle dès la fin de 1980. Le premier essai en vol (L01) était initialement fixé en juillet 1979, le dernier (L04) en octobre 1980.

Après un déroulement quasi nominal des travaux jusqu'en fin 1978, un incident sur le 3ème étage venait perturber le programme. En effet, une explosion sur un banc d'essai cryogénique, due au fonctionnement défectueux d'un système de sécurité, endommageait le seul 3ème étage disponible en ce moment pour les derniers essais de mise au point de l'étage et retardait de ce fait sa qualification. Compte tenu de l'avancement de la qualification des autres étages et systèmes du lanceur (acquise ou en cours d'exécution) et du cycle de fabrication du 3ème étage, deux voies étaient ouvertes:

- soit procéder le plus tôt possible au premier essai en vol après une série d'essais de développement du 3ème étage sans toutefois attendre la qualification de cet étage, ce qui permettait un lancement L01 en fin 1979;
- soit différer l'essai en vol jusqu'à la qualification complète du 3ème étage, ce qui aurait reporté le premier lancement au printemps 1980.

Pour répondre au souci des responsables du programme de procéder au plus tôt à la démonstration en vol d'un maximum de systèmes et fonctions du lanceur, c'est la première voie qui fut choisie, le lancement étant fixé en novembre, puis décembre 1979.

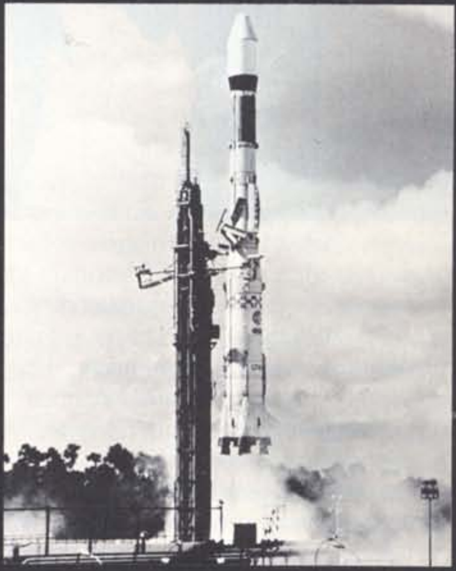
Objectifs
Pour que le lanceur Ariane soit qualifié 'opérationnel', il faut qu'au moins deux des quatre essais en vol soient réussis. Le premier lancement (qui n'emportait pas de satellite, mais une simple 'capsule technologique' injectée en orbite pour effectuer un certain nombre de mesures de trajectoire et d'environnement) gardait donc les caractéristiques d'un essai, à savoir:

- vérifier, dans les conditions réelles du vol, le fonctionnement des organes dont les essais au sol auront été poussés le plus loin possible;
- fournir des informations sur des éléments non simulables au sol;
- vérifier les performances du lanceur et de ses sous-systèmes.

Le passage aux essais en vol comportait donc un risque calculé. Ce risque ne

R. Orye, Ariane Department, ESA, Paris

the first test flight and after



Background
From its inception, the Ariane development programme has provided for a definition and ground-testing phase, to be followed by a test-flight phase. The latter comprises four launches, to prove that the launcher can execute the missions foreseen and hence offer an operational launch capability from late 1980. The first test flight (L01) was originally scheduled for July 1979, and the last (L04) for October 1980.

Work progressed substantially as planned until the end of 1978, when an incident affecting the vehicle's third stage upset the programme. An explosion on a cryogenic test stand, attributable to malfunctioning of a safety system, damaged the only third stage available at the time for final development testing, and accordingly delayed its qualification. In view of progress in the qualification of the other stages and launcher systems (complete or in course of execution) and of the third-stage manufacturing cycle, two courses of action were then open:

- either to carry out the first test flight as soon as possible after a series of development tests of the third stage and without waiting until it was qualified, which would allow the L01 launch to take place in late 1979;
- or to defer the test flight until the third stage could be fully qualified, which would have meant postponing the first launch until Spring 1980.

Since those responsible for the programme were anxious to test as many launcher systems and functions as possible in flight without delay, the first alternative was chosen, and the launch initially scheduled for November, and later December 1979.

Objectives
The conditions for the operational qualification of the Ariane launcher stipulate that at least two of the four test flights must be successful. The first launch, on which no satellite was flown but only a simple 'Technological Capsule' put into orbit to make trajectory and environment measurements, was therefore intended to:

- verify how equipment that had been tested as far as possible on the ground functioned under actual flight conditions;
- provide data on elements not amenable to ground simulation;
- check the performance of the launcher and its subsystems.

The transition to test flights therefore entailed a calculated risk. The latter did not relate to the quality of the hardware, insofar as this could be established by the ground-testing programme, but to the unknowns stemming from the differences between ground and flight operating conditions. For the third stage, the risk, albeit limited, was greater than for the other launcher elements, because the test programme had not been completed.

portait pas sur la qualité des matériels – qui a déjà été établie au cours du programme d'essais au sol – mais provenait en fait des éléments inconnus dus aux différences des conditions de fonctionnement entre le sol et le vol. Pour le 3ème étage, un risque limité mais un peu plus fort que sur les autres éléments du lanceur subsistait, compte tenu de l'état d'avancement de son programme d'essais.

La prise en compte de ces risques fait que, contrairement à un lancement opérationnel, l'obtention de l'orbite prévue n'est pas le seul critère de succès. Certes elle fournirait une présomption de bon fonctionnement des divers systèmes, mais il est tout aussi important de recueillir de ce vol le maximum d'informations sur le fonctionnement du lanceur. C'est pourquoi le lanceur L01, comme les trois autres lanceurs du programme de développement, était doté d'un équipement de mesures extrêmement détaillées permettant d'analyser plus de 1000 points de fonctionnement et s'était vu attribuer des objectifs étroits.

Les résultats de cet essai seront analysés selon des critères très exigeants et devront permettre de vérifier de façon détaillée le fonctionnement de chaque élément.

Déroulement de la campagne

Après intégration du lanceur complet au Site d'Intégration du Lanceur (Les Mureaux, France), le lanceur fut acheminé à Kourou (Guyane française) où il arriva le 27 septembre. La campagne de lancement commençait le 1er octobre; sa durée initialement prévue était de 56 jours ouvrables, ce qui fixait son lancement au 15 décembre. Signalons quelques étapes-clés de cette campagne:

- l'exécution de la chronologie du 3ème étage (y inclus le remplissage de l'étage) effectuée le 21 novembre;
- l'installation de la capsule technologique sur le lanceur le 3 décembre, suivie de celle de la coiffe effectuée le 5 décembre.

Le 14 décembre commençait la chronologie pour un lancement prévu le lendemain à 11 h (heure locale, soit 14 h TU). Après un déroulement sans heurts de la chronologie jusqu'à la mise à feu des moteurs du 1er étage, 2,8 s après cet événement, un des capteurs de pression du système propulsif du 1er étage 'informa' l'ordinateur dirigeant la séquence automatique d'une anomalie de fonctionnement de l'étage, ce qui conduisit à l'arrêt de combustion des moteurs et à l'interruption de la séquence de lancement.

L'évaluation des données de télémesure entreprise immédiatement montrait rapidement que tous les moteurs fonctionnaient nominalement, l'indication erronée d'une anomalie d'un des moteurs étant due à un phénomène de surpression dans une canalisation de mesure.

L'interruption de la séquence de lancement après mise à feu des moteurs conduisait ainsi à un 'tir avorté'; la reprise des opérations posa un certain nombre de problèmes techniques particuliers. Grâce aux mesures prises à l'avance par le CNES et les industriels, des renforts en personnel venus d'Europe permettaient de remettre dans un temps record le lanceur en configuration de lancement et de reprendre la chronologie. Entretemps, des mesures étaient également prises pour éviter une éventuelle répétition du phénomène décrit ci-dessus.

La chronologie reprenait donc le 22 décembre pour un lancement prévu le 23 à 11 h, heure locale. Pendant l'exécution de la séquence automatique à H-55 s, une indication erronée fournie lors du passage de l'alimentation électrique au sol à l'alimentation de bord, suivie de la détection d'une pression insuffisante sur la bouteille hélium du 3ème étage, conduisait au report du tir au lendemain.

C'est finalement le 24 décembre, à 17 h 14 mn 38 s (TU), après une chronologie retardée par quelques incidents relativement mineurs, que le lanceur s'élevait de sa table de lancement pour entamer un vol parfaitement réussi, dont les résultats sont résumés ci-après.

The existence of these risks means that, unlike an operational launch, achievement of the planned orbit was not the sole criterion of success for the first flight. Admittedly, this would warrant a presumption that the various systems functioned correctly, but it was equally important to obtain from this first flight the maximum of information on how the launcher functions. The L01 vehicle, like the other three vehicles in the development programme, was fitted with very detailed instrumentation, enabling more than one thousand parameters to be monitored, and was given very specific objectives.

The information gained from this test is being analysed against very stringent criteria and should enable the operation of each launcher element to be checked in detail.

The campaign

After integration on the Launcher Integration Site at Les Mureaux, France, the complete vehicle was shipped to Kourou, French Guiana, where it arrived on 27 September. The launch campaign started on 1 October. It was initially planned to last 56 working days, which meant a launch on 15 December. The following are some of the key dates in the campaign:

- checking of the third-stage countdown (including stage fill) on 21 November,
- installation of the technological capsule on 3 December, followed by fitting of the fairing on 5 December.

On 14 December, the countdown for a launch scheduled for 15 December at 11.00 local time (14.00 Universal Time) began. Everything went smoothly up to the ignition of the first-stage engines, 2.8 s after which one of the pressure sensors in the first-stage propulsion system flagged the computer commanding the automatic launch sequence of a stage malfunction, and this led to engine cut-off and interruption of the launch sequence.

An immediate evaluation of the telemetry data showed at once that all the engines had functioned nominally, and that the false report of an engine malfunction was due to an overpressure effect in a measurement unit.

The interruption of the launch sequence after engine light-up led to an aborted firing, and a number of technical problems had to be solved before operations could be resumed. Thanks to prior contingency arrangements by CNES (Centre National d'Etudes Spatiales) and the firms concerned, reinforcements from Europe allowed the vehicle to be restored in record time to a configuration in which the chronology of launch events could be resumed. In the meantime, steps had been taken to avoid any recurrence of the pressure-sensor phenomenon.

The countdown was therefore resumed on 22 December for a launch scheduled for 23 December at 11.00 local time. At H-55 s, again during the automatic sequence, a false signal at the instant of switching from ground to on-board electrical power supply, followed by the detection of insufficient pressure in the third-stage helium bottle, led to the launch being postponed once more to the following day.

Résultats
L'orbite atteinte par la charge utile, telle que déterminée par le réseau de stations aval, se situe bien à l'intérieur de la dispersion admise:

orbite	réelle	nominale
périgée	200,8 km	200 km
apogée	36 021 km	35 753 km
inclinaison	17,559°	17,5°

Une première analyse détaillée des paramètres enregistrés durant l'esai en vol L01 a été effectuée par le Centre National d'Etudes Spatiales et les principaux industriels impliqués dans ce programme; cette analyse permet de confirmer le complet succès constaté dès la fin du vol.

Les conditions garanties aux satellites lors des futurs vols opérationnels et qui constituent des critères de qualification du lanceur ont été satisfaites dès ce vol pour ce qui concerne les caractéristiques de l'injection en orbite: position et vitesse du satellite, mise en rotation finale, ambiance acoustique, etc. Seule l'ambiance dynamique excède très légèrement les spécifications durant cinq secondes du vol du 2ème étage (phénomène Pogo). Il convient de noter sur ce point que pour ce premier vol il n'avait pas été jugé indispensable d'activer le dispositif correcteur de ce phénomène pendant le vol du 2ème étage.

Les caractéristiques fonctionnelles des trois étages, de la case à équipement et de la coiffe ont été parfaitement conformes aux prévisions effectuées avant le vol. Les performances de chacun des trois étages propulsifs apparaissent sensiblement supérieures aux valeurs estimées; le gain sera annoncé après l'essai en vol L02.

Commentaires
La première phase de l'évaluation détaillée a donc confirmé que le lancement de L01 a été un succès total. Il est presque inutile d'en dire plus sur le plan strictement technique, si ce n'est de souligner que ce succès s'est produit dès le premier essai en vol.

Quelques considérations d'ordre programmatique méritent d'être mises en avant:

- la décision, prise au début du programme Ariane, de procéder, dès le premier essai en vol, au lancement de la fusée complète et complètement activée, sans passage par des étapes intermédiaires telles que utilisation d'étage provenant d'autres programmes ou lancement de lanceurs partiellement inertes. Le succès de L01 constitue de ce point de vue une 'première';
- la décision de ne pas attendre la qualification complète du 3ème étage pour effectuer le premier essai en vol;
- l'adoption d'une approche technique conservative, qui avait déjà porté ses fruits en matière de performance.

En outre, sur le plan de l'utilisation, ce succès renforcera encore la position compétitive d'Ariane qui, après la décision d'INTELSAT d'utiliser ce lanceur pour son programme Intelsat-V, avait marqué plusieurs points en 1979. On peut sans exagérer dire que le lancement de L01 a été suivi par tout le monde spatial, plus particulièrement par des utilisateurs potentiels tels que l'Indonésie, la Ligue Arabe et plusieurs firmes américaines utilisatrices de satellites de télécommunications domestiques (American Telephone & Telegraph, Western Union) qui sont sur le point de lancer de nouveaux programmes de satellites et pour lesquels le choix des moyens de lancement est imminent.

Et maintenant . . .
La qualité des résultats de l'essai en vol L01 a permis de poursuivre l'intégration du deuxième lanceur sans autre modification qu'une activation ponctuelle du système correcteur Pogo du 2ème étage. Le deuxième exemplaire d'Ariane (L02) est actuellement en intégration au Site d'Intégration du Lanceur aux Mureaux; il quittera l'Europe début mars pour la Guyane. La campagne de lancement commencera à la fin de mars, pour aboutir à un lancement prévu à partir de la deuxième quinzaine de mai. Rappelons que ce lanceur emportera, outre la capsule technologique, deux passagers, Firewheel et Oscar. Firewheel est un satellite scientifique allemand destiné à l'étude de la très haute atmosphère; Oscar est un satellite de télécommunication pour radio-amateurs réalisé en Allemagne pour AMSAT Corporation.

Les deux derniers essais en vol (L03 et L04) restent prévus respectivement pour le mois de septembre et décembre 1980. Outre leur objectif principal, qui est de contribuer à la qualification du lanceur, ils emporteront des charges utiles d'une grande importance pour l'Agence (Météosat-2 et Marecs-A), ainsi qu'un satellite expérimental de télécommunications indien (Apple).

L'expérience qu'apporte L01 démontre que la conception est adéquate et que les procédures de mise en oeuvre du lancement sont bien au point. La prochaine étape verra la qualification du lanceur qui sera en toute probabilité acquise au début de 1981 comme prévu dès le début du programme.

Je saisis cette occasion pour présenter aux équipes du Centre National d'Etudes Spatiales, des industriels européens et de l'Agence qui ont participé à la réalisation du lancement L01 mes plus sincères félicitations.

Finally, on 24 December, at 17 h 14 min 38 s UT, after a countdown interrupted by a number of comparatively minor incidents, the launcher lifted off from its launch table for a totally successful flight, the results of which are summarised below.

Results

The data below show how the actual orbit, as determined by the down-range station network, compared with the nominal orbit:

orbit	actual	nominal
perigee	200.8 km	200 km
apogee	36 021 km	35 753 km
inclination	17.559°	17.5°

The actual orbit lies well within the permissible dispersion.

A preliminary detailed analysis of the parameters recorded during the L01 test flight has been carried out by CNES and the main firms involved in the programme: it has confirmed the total success that was apparent from the completion of the flight.

The conditions guaranteed to satellites on future operational flights, which constitute launcher-qualification criteria, were already met on this first flight in terms of orbit-injection characteristics: satellite position and velocity, final spin-up, acoustic environment, etc. The dynamic environment alone slightly exceeded specification for 5 s during the second-stage flight, when the expected Pogo effect occurred. It was considered unnecessary to activate the device for correcting this effect during this phase of the first flight.

The functional characteristics of the three stages, the equipment bay and the fairing agreed exactly with the pre-flight predictions. The propulsion performances of each of the three stages were shown to be appreciably greater than the pre-flight estimates. The gains will be published after the L02 test flight.

Comment

The first phase of detailed evaluation has confirmed then that the L01 launch was a complete success. From a strictly technical point of view, further comment is almost unnecessary, except perhaps to stress the fact that this success was achieved on the first test flight.

Several programme policy decisions merit mention:

- The decision taken at the start of the programme that, as from the first test flight, the vehicle would be complete and fully activated, without resort to intermediate procedures such as the use of a stage derived from other programmes or the launch of partially inert vehicles. In this respect, the success of L01 is a 'first'.
- The decision not to await complete qualification of the third stage before carrying out the first test flight.
- The adoption of a conservative technological approach, which has already proved its worth where performance is concerned.

Furthermore, from the user angle, this success will enhance Ariane's competitive position, which had already made progress in 1979, following INTELSAT's decision to use this launcher for its Intelsat-V programme. Suffice it to say here that the L01 launch was followed with extreme interest by everyone in the space business, particularly potential users such as Indonesia, the Arab League, and several American firms operating domestic communications satellites (American Telephone & Telegraph, and Western Union), who are about to embark on new satellite programmes and who must shortly choose their launch systems.

Latest situation

The high quality of the results from the L01 test flight has allowed the second vehicle to be integrated without modification, other than the specific activation of the second-stage Pogo-correction system. This second vehicle is currently undergoing integration at Les Mureaux, and it will leave Europe early in March for Guiana, where the campaign will start towards the end of that month with a view to a launch towards the end of May.

It will be recalled that this second vehicle will fly two passengers – Firewheel and Oscar – in addition to the Technological Capsule. Firewheel is a German scientific satellite for the study of the upper atmosphere, while Oscar is a communications satellite for radio-amateurs, built in Germany for AMSAT Corporation.

The last two test flights, L03 and L04, are still scheduled for September and December 1980. In addition to their main objective – to contribute to the qualification of the launcher – they will be used to launch two payloads of great importance to ESA, namely Meteosat-2 and Marecs-A, as well as an Indian experimental communications satellite (Apple).

The experience acquired with L01 has shown that the vehicle's design is sound and that the launch procedures are altogether correct. The next major milestone is the flight qualification of the launcher, which in all probability will be achieved early in 1981, as planned from the outset of the programme.

I should like to take this opportunity to extend my heartiest congratulations to the teams of CNES, the European firms and ESA who contributed to the unquestionable success of the L01 launch

The Solar Satellite Power System as a Future European Energy Source

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The solar Satellite Power System (SPS) is the basis of a proposal to place large solar-energy converters into outer space and to transmit the energy gathered to earth as microwave radiation. Such a system could supply an important part of Europe's electrical energy demand in the next century.

The SPS has a number of potential advantages over terrestrial solar electricity generation, mainly because it can deliver electrical energy almost continuously and is not affected by terrestrial day/night cycles or climatic conditions. The development and demonstration of the SPS concept will require a tremendous extension of technology, particularly in the space segment. This article discusses the potential of the SPS as an energy source for Europe and describes the current status of the overall concept's assessment.

The companion article on page 15 reviews the status of European space technology and its potential application for early exploratory technological experiments and perhaps eventual cooperative development of the SPS in the 1990s.

The European energy situation
Only thirty years ago Europe was almost self-sufficient in the supply of energy. Since then, however, its energy consumption has more than doubled and the additional demand has had to be met by imported energy, mostly in the form of oil and gas. Recent events have demonstrated just how dangerous this import dependence can be for economic and social development, and all European countries have initiated large-scale research and development programmes aimed at reducing dependence on imported energy sources.

A growing public awareness of the limitations and drawbacks of each of the available energy sources has also led to recognition of the fact that no single energy source will be able to meet even a major part of our energy demand in the future. The nonrenewable energy sources, such as oil, gas, coal and uranium, and the renewable or almost inexhaustible sources, such as wind, hydro-power, bio-mass, direct solar energy conversion or nuclear fusion, are all limited in their use by geophysical, environmental, economic or political factors. Europe is in a particularly difficult position. Its primary energy resources, such as oil, gas, wind, wave and geothermal energy are relatively small, coal reserves are difficult to mine, and uranium is scarce.

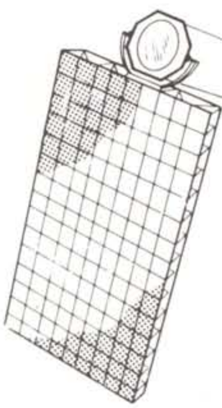
Europe now imports 50 to 60% of its energy needs, and according to most predictions this situation will probably worsen. Terrestrially-converted solar energy, although a renewable energy source, could only meet a few percent of the expected energy demand in the year 2000, due to the high incidence of cloudy days each year in most European countries. Existing projections of European energy supply and demand trends discuss only fast-breeder reactors and thermonuclear fusion as nonfossil energy sources that could reduce Europe's dependence on energy imports on a large scale.

Studies in the USA and, on a much smaller scale, in Europe have now shown that the solar Satellite Power System (SPS) (Fig. 1) might be another energy source, next to nuclear-breeder and nuclear-fission reactors, which could help to make Europe less dependent on energy imports. The potential impact of the SPS on the European electrical energy supply is illustrated in Figures 2 and 3.

Figure 2 shows the growth in demand for electricity in the European Communities over the last ten years, based on OECD data, and a projection of demand until the year 2030. The predictive model assumes that the growth in demand will fall to 3% or even 1% (low case) in 2030, taking into account a lower but still positive economic growth and the increasing effects of energy conservation and technological advancement. Energy conservation will certainly reduce future demand for fossil fuels, but it will only delay their ultimate exhaustion. In addition, certain energy-conserving systems, such as the use of heat pipes in terrestrial solar or geothermal systems, will reduce the direct use of fossil fuels, but will increase electrical consumption.

Figure 1 – Artist's impression of a solar power satellite transmitting energy to European utilities

Figure 2 – Scenario for electricity consumption in the European Communities



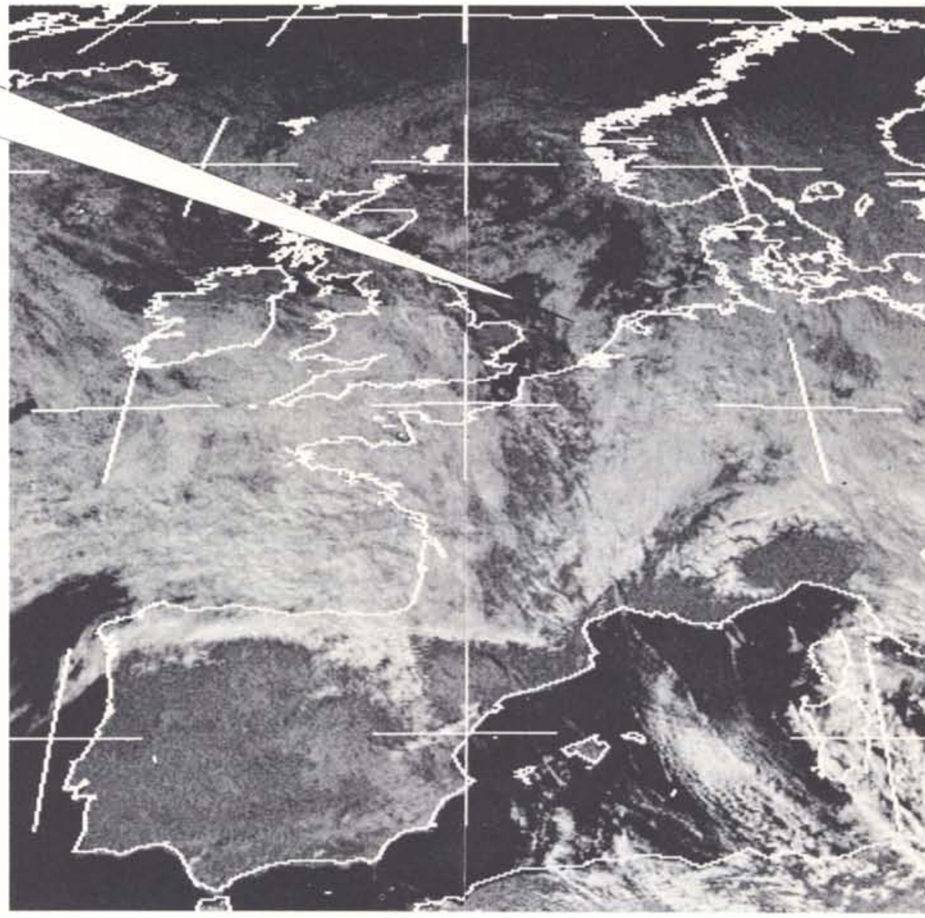
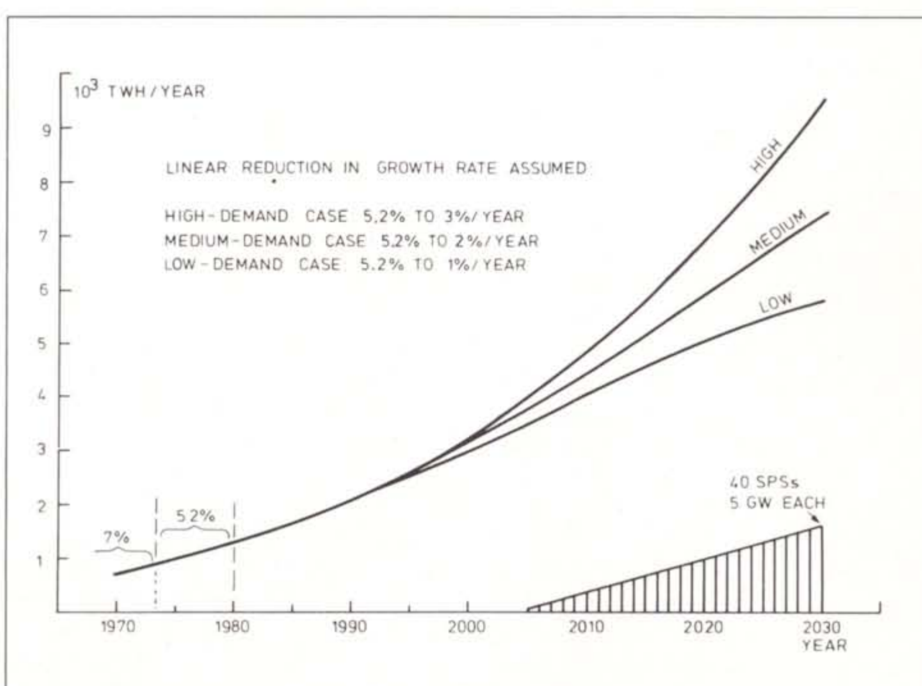


Figure 3 shows a long-term electricity-mix projection for the European Communities adapted from an American projection, assuming similar conditions on both continents in the future. Even with coal and nuclear systems producing four times the energy that they do today, there is a potential increasing shortfall after the year 2000.

The two figures demonstrate that a fleet of 40 solar-power satellites, each with an output of 5 GW, could satisfy today's electricity consumption in all of the member countries of the European Communities. Even in the event of a continuing increase in the demand for electrical power, they could still cover a major part of any shortfall in Europe early in the next century.



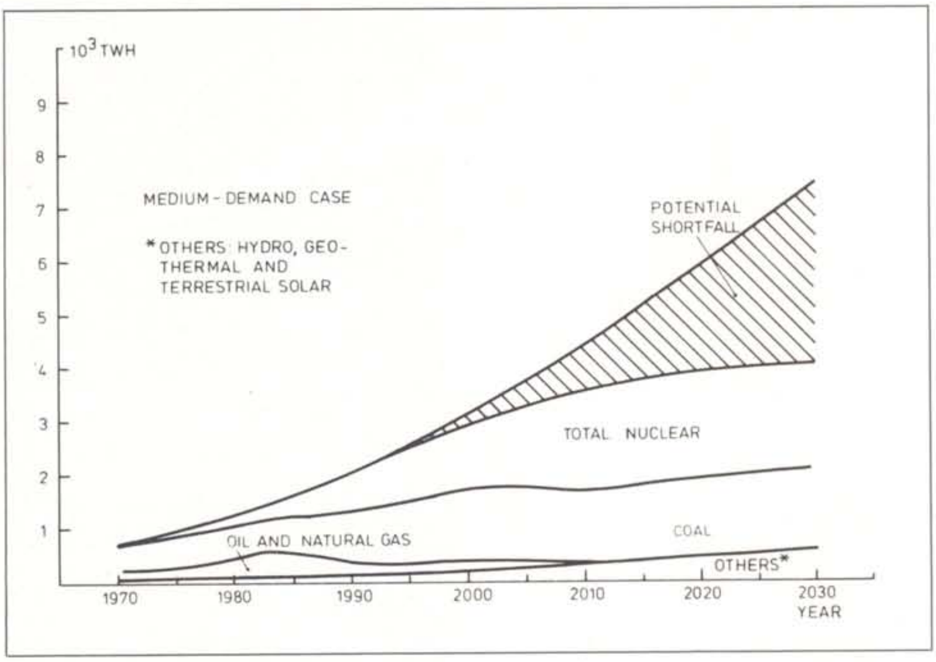
The solar SPS concept

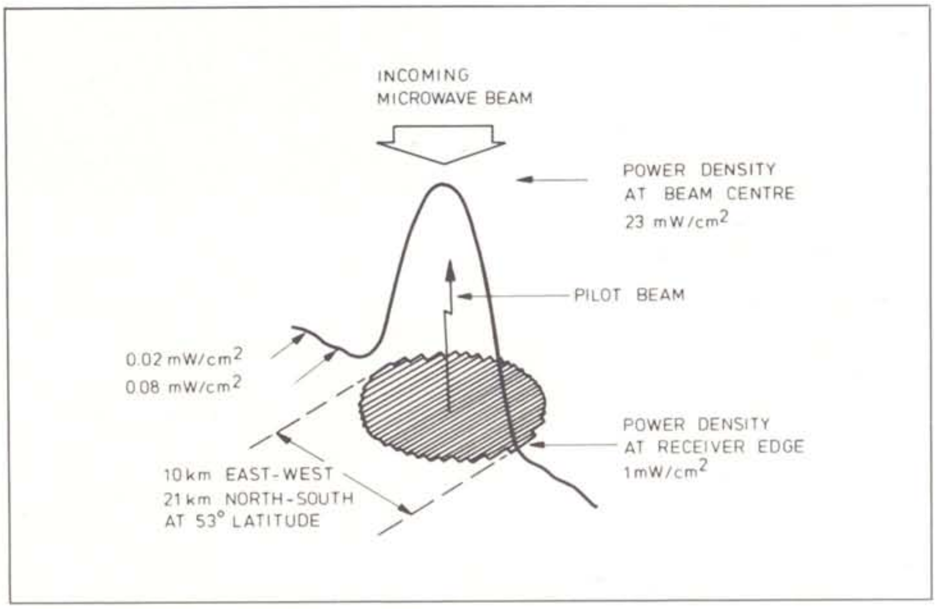
In the solar Satellite Power System concept, the solar energy is collected and converted into electrical energy in space. The electrical energy is transmitted to earth as microwave energy, which is then collected and rectified on the ground.

The major elements of one possible SPS power-plant configuration and their characteristics are shown in Table 1. This particular configuration is presently being used by the US Department of Energy and by NASA to evaluate the SPS concept. A practical power system based on this configuration would consist of a

Figure 3 – Scenario for the potential electricity-generation shortfall in the European Communities, adapted from a projection of electricity-generation mix for the USA (source: EPRI, 1977)

Figure 4 – Characteristics of the SPS microwave beam at the earth's surface





number of individual generator 'plants' in geostationary orbit, each with an associated ground station.

The DOE/NASA SPS 'reference system' contains two alternative photovoltaic energy-conversion systems. One employs silicon solar cells without concentration, and the other uses gallium-arsenide cells with reflectors providing a concentration ratio of 2. The SPS solar converter consists of a lightweight space-assembled structure, with graphite-composite structural elements supporting thin, flexible solar-cell blankets. It is assumed that a conversion efficiency of 15% will be achieved, corresponding to an average output of 200 W/m² solar-cell area. This energy would be available almost continuously since the space power plant would be in the earth's shadow for less than 1% of the time.

A major problem is, of course, to transfer the electrical energy from the satellite to the ground with a high efficiency. The reference system uses a microwave power-transfer subsystem, with direct current-to-microwave frequency power amplifiers feeding a 1 km-diameter phased-array transmitting antenna. This antenna is designed to provide a single coherent beam focussed at the centre of the ground rectifying antenna. Near the earth's surface, about 88% of this power beam's energy is concentrated within a 5 km radius of boresight, and the beam is controlled by a pilot-beam signal emanating from the earth-based receiving station (Fig. 4). If the SPS microwave beam control should fail, the beam would immediately be defocussed and its power level would fall to 0.003 mW/cm², well below the most stringent safety level presently imposed. The microwave power-transmission system is therefore inherently fail-safe. The receiving antenna has an active area of about 75 km², and is comprised of a series of panels mounted perpendicular to the incident beam.

The construction of an SPS will call for a new space transportation system (Fig. 6). Firstly, a large space-freighter with a capacity of about 400 t per flight is needed for transporting building materials and construction equipment to a 500 km parking orbit. Subsequently, a dedicated, electrically-propelled orbital transfer vehicle will be needed to raise these materials to geostationary orbit, 36 000 km above the earth's surface. The number of persons needed in space for the construction process will be a function of the degree of automation employed, but present estimates are in the order of 500. Use of an advanced Shuttle-type, chemically-propelled launcher is foreseen for the transportation of personnel and high-priority equipment.

Table 1 – Characteristics of the current 'reference system' (US DOE/NASA, 1978)

SPS generation capability (utility interface)	5 million kW	
Overall dimensions (km)	5.3 × 10.4	
Power conversion – photovoltaic	Silicon	GaAlAs (with concentration)
Satellite mass (kg)	51×10^6	34×10^6
Structure material	Graphite composite	
Construction location	Geostationary earth orbit (GEO)	
Transportation:		
– Earth-to-low earth orbit (LEO)		
Cargo	Vertical take-off, winged two-stage	
Payload	424 000 kg	
Personnel	Modified Shuttle	
Capacity	75 passengers	
– LEO-to-GEO		
Cargo	Dedicated elect. orbit transfer vehicle	
Personnel	Two-stage LOX/LH_2	
Capacity	75 passengers	
Microwave power transmission:		
– Antenna diameter (km)	1	
– DC-RF converter	Klystron	
– Frequency (GHz)	2.45	
– Rectenna dimensions (km)	10 × 13	
– Rectenna power density (mW/cm²): centre	23	
edge	1	

The US DOE/NASA SPS 'reference system' contains only technology that appears to be feasible today and is extrapolated from existing technologies. The SPS system would therefore fit into a relatively low-risk mission scenario in which a first power unit could be operating in space shortly after the year 2000. The reference concept is only a design against which cost, environmental and social considerations, and technical alternatives can be evaluated. It is not intended as a baseline for a prototype SPS. On the contrary, the results of a future technology-advancement programme and further system design studies are expected to result in a final configuration quite different from the present reference system.

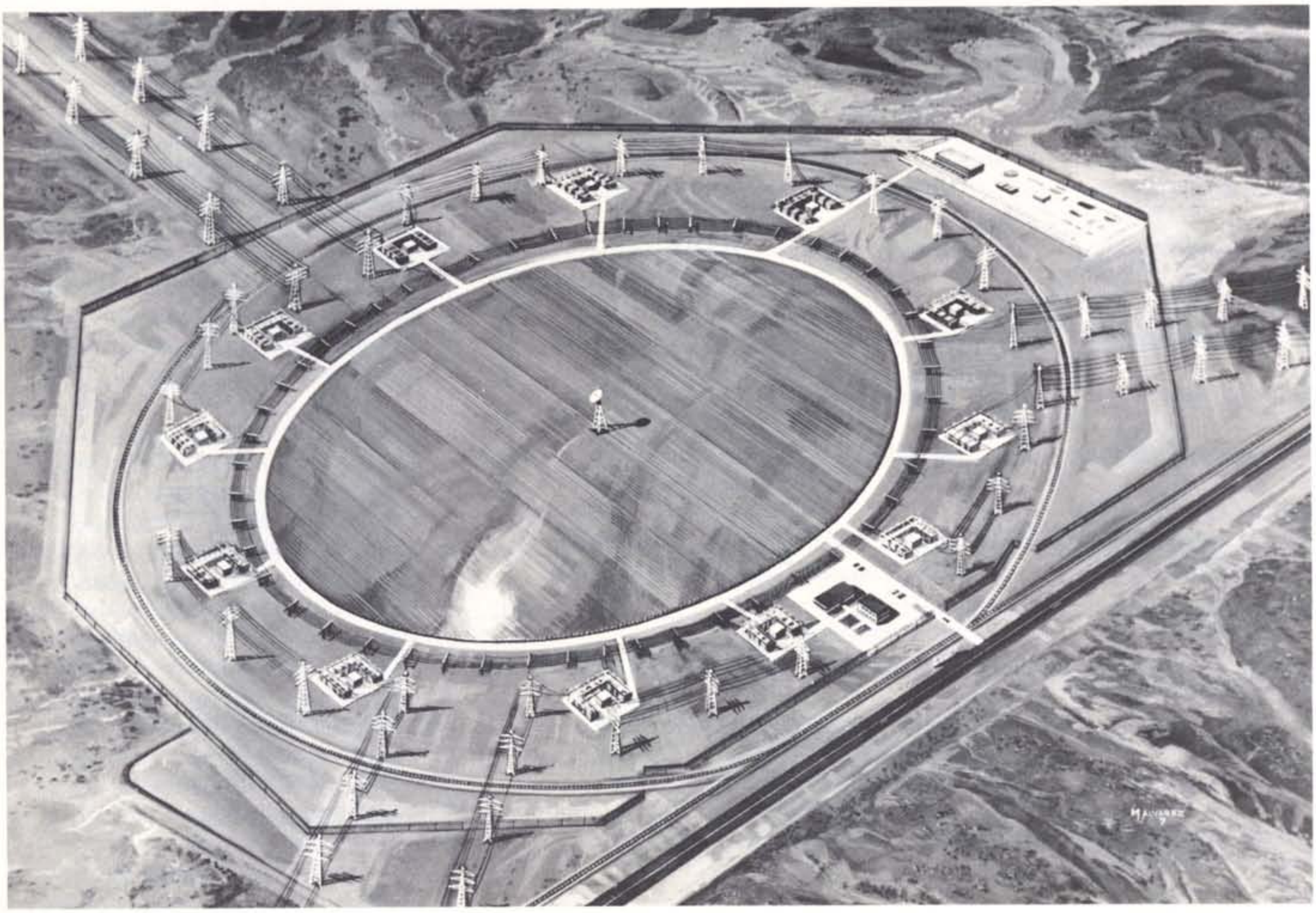
Why solar-energy conversion in space?
There is a general, worldwide consensus that use of solar energy has to be developed on a large scale in order to reduce the present dependence on nonrenewable energy sources like oil, gas, and eventually also coal. Unfortunately, one cannot just employ the solar energy available at the earth's surface because even at the best locations sunlight is not available during the night, and in many areas, particularly in Europe, a large part of the sun's energy is absorbed in the atmosphere and never reaches the ground. Figure 7 demonstrates why the average energy density of the available sunlight in central Europe is less than 10% of the radiated solar energy.

An additional problem with the use of terrestrial solar energy in Europe stems from the wide and unpredictable variations in available energy due to the unstable weather conditions and the seasonal mismatch between energy demand and supply. In the absence of efficient and low-cost energy storage systems, it is therefore unlikely that Europe can cover any significant part of its energy demand – more than a few percent – with terrestrial solar-energy conversion systems sited within its geographical boundaries.

The solar SPS, in contrast, is almost constantly illuminated throughout the year and the microwave beam transferring the energy to the ground is virtually unaffected by atmospheric conditions. Bearing in mind the loss in the microwave transmission system, which is estimated to be less than 40%, each square metre of solar cells in an SPS will deliver approximately five times more energy to the electricity user than would a terrestrial photovoltaic power plant.

The utility of the SPS energy will be very high because it represents a 'base load' power source which is continuously available. The system could therefore be capable of supplying a significant part of Europe's future electrical energy needs and lessen our dependence on imported energy, be it fossil fuels, uranium for nuclear reactors or solar-based energy from sunnier parts of the world.

Figure 5 – Artist's concept for an SPS earth station



The SPS concept could offer Europe a means of tapping the sun's energy on a large scale, but it should not be forgotten that its technical feasibility and economic viability in relation to other potential renewable energy sources have still to be demonstrated. It is also difficult to judge public reaction to a proposal to develop and install a complex orbital space power system that will have a considerable global impact, technically as well as politically.

Status of the SPS concept evaluations
So far Europe has not shown a strong interest in evaluating the SPS as a potential energy source. Following a number of feasibility studies in the early seventies, the US Department of Energy and NASA are now jointly undertaking an SPS assessment and evaluation. This $22 million effort was started in 1977 and will be completed in mid-1980, with a recommendation as to whether or not the studies should be continued and possibly expanded into an experimental phase. The organisation and the main elements of the evaluation are shown in Figure 8.

The present US effort is comprised of an assessment of the technical feasibility of SPS, an investigation of its impact on the environment and on health, an analysis of the societal, legal and political issues, and a comparative assessment of the direct and indirect costs of electrical energy from an SPS in relation to alternative systems that may exist in the USA around the year 2000. The preliminary results of these studies have already been published. So far, no 'show stopper' has been identified, but it is also clear that most of the environmental, economic and societal issues associated with SPS development and operation cannot yet be predicted with reasonable confidence. In Europe, both the Western European Union and the Council of Europe have recommended study of the SPS, but current European activities are a very small fraction of the American effort; the British Government and, to a lesser extent ESA, are presently studying the SPS and its potential for Europe.

In view of the relatively large programme in the United States it can be asked whether it is in fact necessary to study the SPS in parallel in Europe. There are at least two reasons for an independent

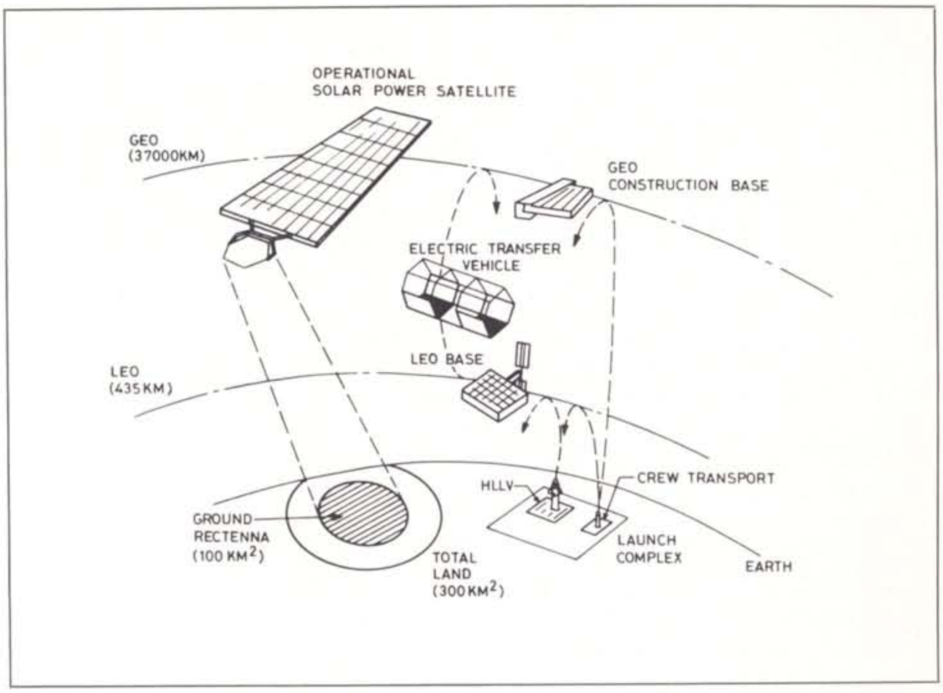
Figure 6 – Constructional elements fundamental to the realisation of an SPS

Figure 7 – Sources of solar-radiation loss between geostationary earth orbit and earth

European assessment. Firstly, the European geographical, environmental and societal conditions are sufficiently different to imply that many of the conclusions reached in the American studies are probably not valid here. Secondly, even if Europe decides eventually not to participate in any future development by the USA, it is extremely important that the European countries nevertheless achieve a full understanding of the SPS if only because of its potential worldwide technical, environmental, economic and political impacts.

European issues
Two fundamental issues should be addressed in any early investigation: firstly, is there any insurmountable problem that would prohibit SPS utilisation in Europe? Secondly, what must be done in the near future to safeguard European interests in case SPS implementation should prove desirable?

Examples of the particular questions to be studied are:
- whether the cost per kilowatt-hour of electrical energy on the ground will be in such a range as to be generally competitive with other advanced energy sources;
- whether suitable sites for SPS receiving antennas on land or offshore are available in Europe;
- whether power transmission from space will be highly reliable in operation, totally 'fail safe' in the event of any technical malfunction, and harmless in the baseline operational mode;
- whether the side lobes, noise and scattering of the microwave beam can be reduced well below European tolerance standards;
- whether the European power grid would be able to maintain stable operation if an SPS shut down unexpectedly;
- whether the space-transportation system required for an SPS can be operated safely and economically, and be compatible with



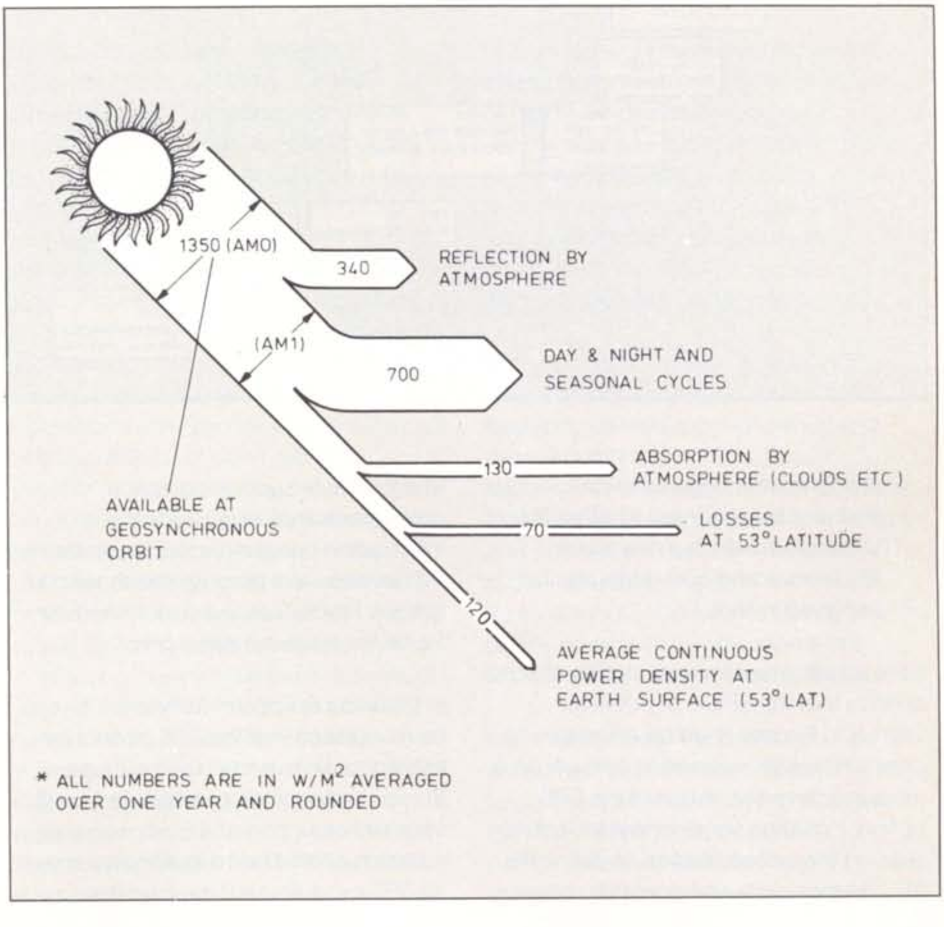
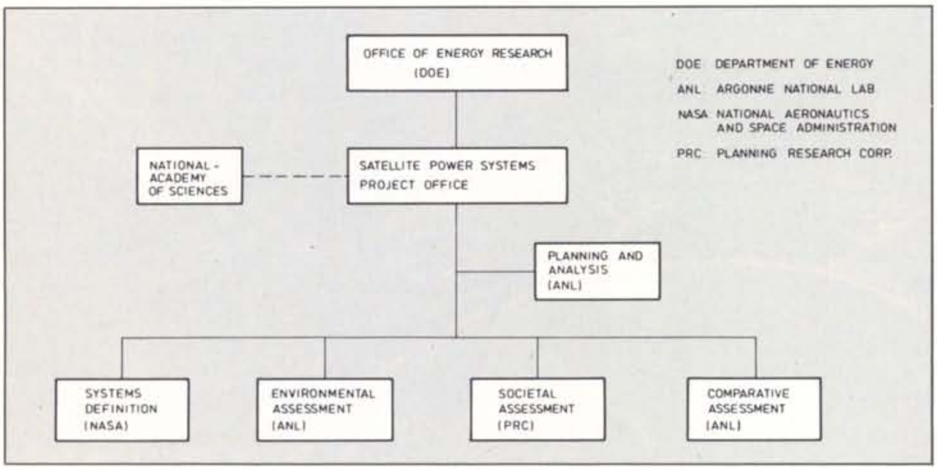
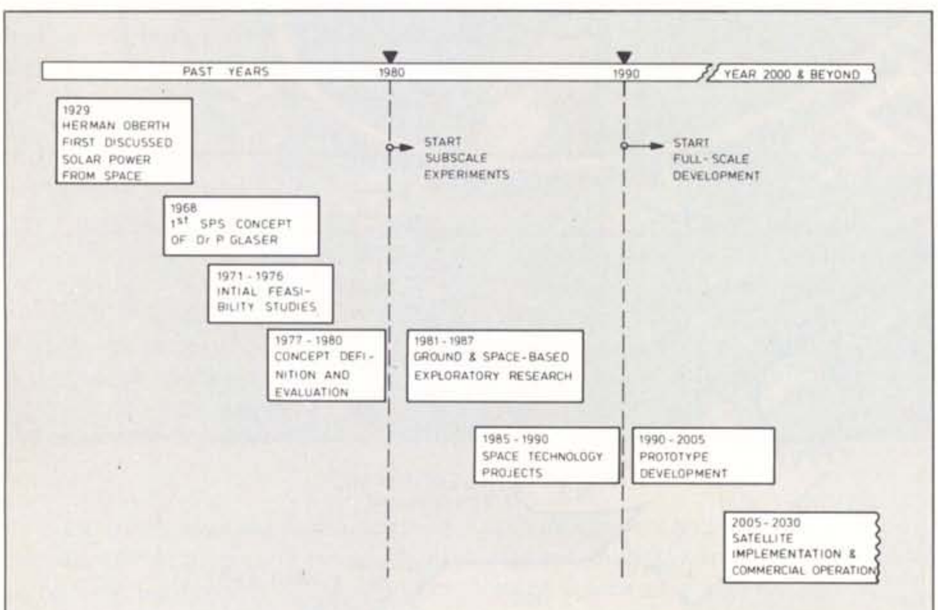


Figure 8 – Organisation of SPS system definition and evaluation in the USA

Figure 9 – Calendar of past and anticipated SPS activities





environmental requirements;

– and, last but not least, whether the technical solutions, conversion efficiencies and cost goals can be achieved in time.

If the results of preliminary studies should confirm that the SPS is of potential interest to Europe, it will be necessary to expand the activities and to embark on a more intensive evaluation of the SPS option, including some terrestrial tests to support the system studies, to define the SPS development and operation phases, and to initiate supporting space experiments that will provide the information needed to decide whether a full development programme should be started. Figure 9 shows a tentative time frame for those investigations.

In planning European activities, it has to be recognised that the SPS cannot be treated as an extension of the present European space programme, but must be seen rather as part of a European energy research effort. Due to its enormous cost, an SPS programme is beyond the means of individual European countries and can only be considered in terms of a cooperative venture, possibly on a worldwide basis. Because of the great potential benefits, however, Europe should itself invest some money to evaluate the SPS concept in sufficient detail to make an independent judgement and to be in a position to identify its 'stake' in such a venture should a cooperative development become a possibility.

To illustrate the possible economic impact of a European SPS, it might be noted that forty 5 GW satellites presently assumed for an ESA trade-off study could produce some 1.6×10^3 TWh of electrical energy per year, corresponding to an annual income of more than 40 thousand million dollars at 2.5 cent/kWh.

Conclusions

The SPS could be a promising concept for producing a significant part of Europe's electrical energy needs by the conversion of solar energy in space. In the next century solar-power satellites could possibly make a contribution to the European energy supply similar to that from fast-breeder nuclear reactors or nuclear-fusion reactors. The SPS appears to be feasible technically, but a considerable effort will be needed to demonstrate its engineering, economic and environmental viability.

Technology-verification investigations for concept and cost validation must go hand-in-hand with the technical, social, economic and environmental assessment studies. Many years of exploratory activities will be necessary before a definite answer as to the viability of the SPS will be possible, perhaps in the late 1980s or early 1990s.

Aside from technology transfers to new terrestrial energy-generation systems, the SPS appears to represent the only direct contribution that the European space community could make to the relief of the world energy shortage.

Applicability of European Space Systems and Technology to Solar Satellite Power Systems*

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As an extension to the foregoing discussion on the solar Satellite Power System's potential as a European energy source, a set of technological disciplines are presented here that could prove critical when assessing the feasibility of the solar SPS and any subsequent development programme. Both existing and developing European space systems and technologies could play a substantial role in any early SPS research programme. This article does not strive to list comprehensively all possible SPS research issues, but attempts rather to identify those European technologies applicable to the near-term studies and concept-technology verification investigations that will be needed if SPSs are to become a reality in the 1990s.

* Based on a presentation at the 30th IAF Congress in Munich. The technological work addressed encompasses items funded both by ESA and by national space agencies.

Introduction

As mentioned in the previous article (page 8) the current US Department of Energy/NASA reference system for SPS evaluation is founded on a set of technological requirements that are comparatively well defined. It assumes a photovoltaic energy-conversion system combined with a microwave energy-transmission system operating at 2.45 GHz.

Relevant space technologies in Europe

Electrical to microwave conversion

Studies in the United States on the conversion of DC power to microwave power for transmission to earth indicate that of all amplifier tubes that could be employed, only klystrons and amplitrons are likely to achieve efficiencies in excess of the 80% that represents one of the goals of the SPS programme. However, solid-state microwave power devices are also being investigated as an alternative. In early microwave transmission experiments intended only to demonstrate technical feasibility, other existing amplifier technologies may be employed. Two examples are travelling wave tubes and semiconductor devices developed and evaluated in Europe in recent years for telecommunications satellites, and the pulsed travelling wave tubes and klystron amplifiers generating peak RF powers of up to 10 kW and 500 W (continuous wave) that are being studied for Europe's proposed Synthetic Aperture Radar (SAR) system designed to deliver earth-observation data. Tests on power tubes have already shown that lifetimes of 30 years can eventually be anticipated.

Bipolar transistors and Field-Effect Transistors (FETs), the natural competitors for power tubes, have been assessed at device and circuit level to determine their technological and RF-performance qualities. Bipolar power transistors can already deliver 5 W at 3 GHz, while an amplifier using high-performance microwave FETs developed in the UK can provide 35 dB stable gain at low intermodulation and distortion levels, together with low complexity/mass and good reliability.

In addition to the above development efforts, there have already been a number of hardware demonstrations of microwave generators providing some, albeit modest, background from which to start the design work for initial SPS energy-transmission experiments.

Microwave power transmission and control

In this domain, the critical technical requirements for SPS operation are related to transmission efficiency and microwave phase control. Space experiments are needed to demonstrate that the microwave beam can be formed and pointed with sufficient accuracy. The radio-frequency characteristics of the transmitter will also have a strong bearing on the severity of the environmental impact of high-power microwave beams.

Microwave power transmission experiments can be accomplished with large-scale extensions of technologies that have already been used in communications satellites. Highly focussed beams are sent from these

Figure 1 – Meteosat's electronically despun antenna

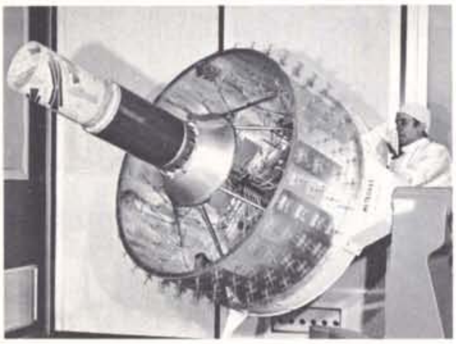
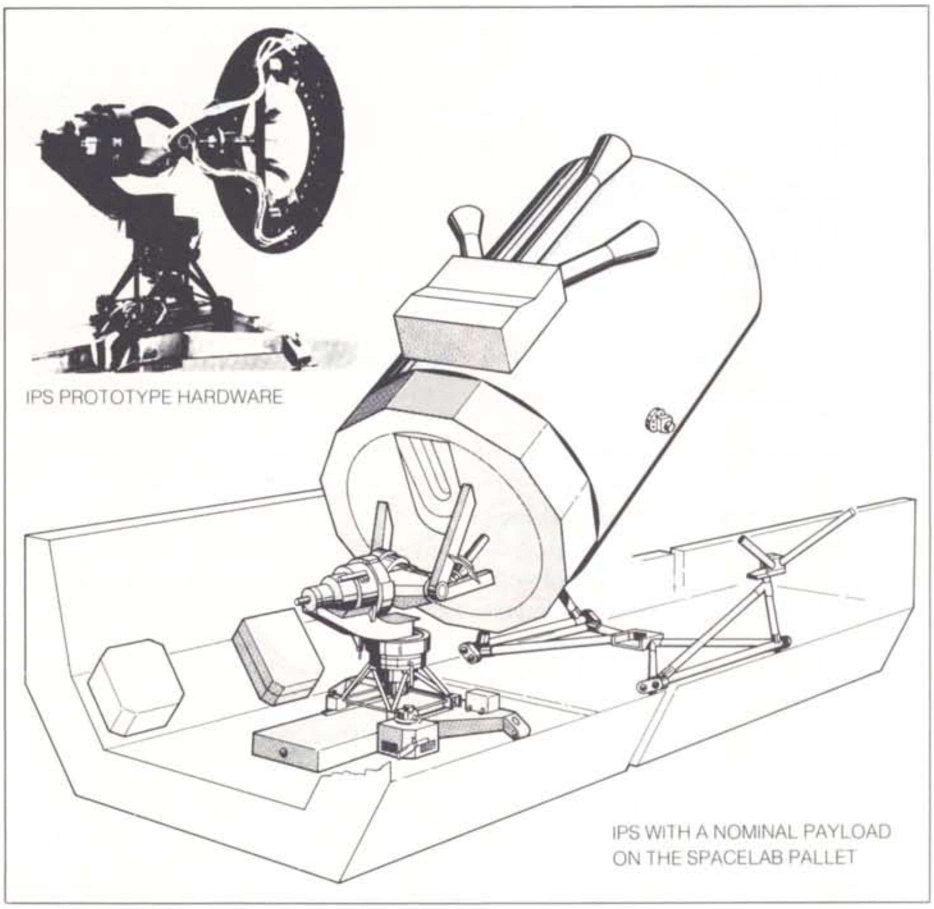


Figure 2 – Spacelab's Instrument Pointing Subsystem (IPS)



satellites to earth receiving antennas, and large antenna dishes on the earth send highly directional signals to space vehicles.

Figure 1 shows Europe's first electronically despun antenna, which is carried by ESA's meteorological satellite Meteosat. An S-band beam is formed by excitation of the five columns that face the earth at any given moment. Fine scanning is provided by progressive variation of the amplitude illumination distribution. The Spacelab Instrument Pointing Subsystem, shown in Figure 2 mounted on the Spacelab Pallet, will provide arc-second pointing accuracy mechanically for payloads weighing up to 2000 kg. An increase in capacity to 6500 kg is already projected. Both technologies can provide useful elements for future key SPS technology-verification experiments.

Space structures

The very large dimensions of the SPS's slab-like space segment will require an open structure to achieve an extremely low mass, and probably a distributed control system to balance the low frequencies and to control inherently slow processes. Although the structural technology needed represents a technological challenge, it can be viewed nevertheless as an evolution of the basic technologies associated with current aircraft and space vehicles. A major difficulty in the design and development of such a large structure is the impossibility of system simulation testing on the ground.

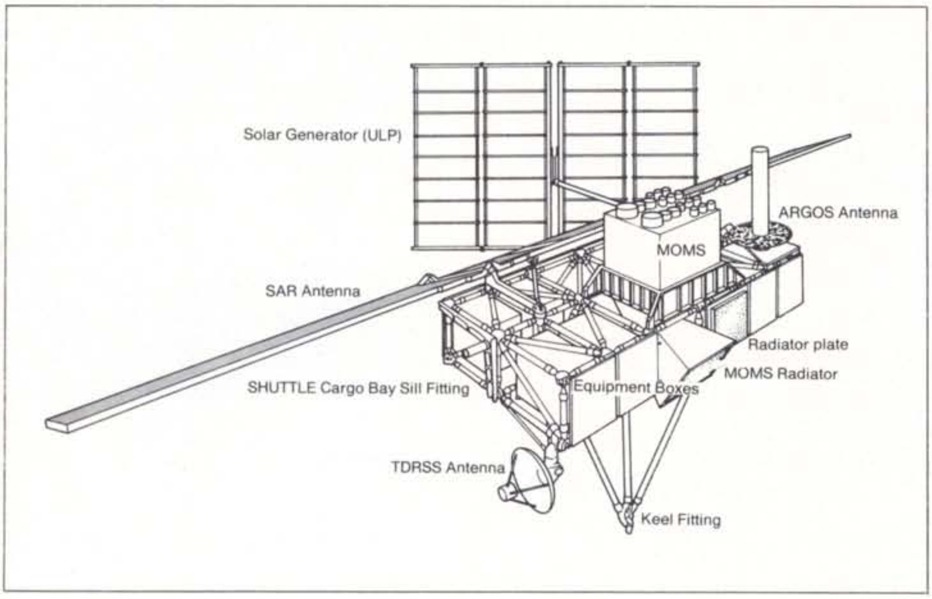
Some Shuttle-compatible lightweight support structures have already been investigated in Europe. At present this effort is mainly aimed at providing support structures and their subsystems for Spacelab follow-on missions and free-flying pallets. One example is the Shuttle Pallet Satellite (SPAS) concept developed in Germany (Fig. 3). The realisation of this modular payload-support structure, consisting primarily of tubular carbon-fibre composite truss elements and titanium spheres, has already reached a relatively advanced stage, and flight hardware is expected to be ready in 1980/1981.

The hardware concepts currently being investigated will not, of course, meet the requirements for an SPS, since they are based on ground assembly and have therefore to withstand mechanical loads that are higher than in the case of in-orbit assemblies by several orders of magnitude. The experience gained from this type of mission can, nevertheless, support the numerical characterisation of SPS structural performance, and the technological work (basic tools, analysis techniques and software) that is under way can be applied to assess the construction requirements for the increasingly sophisticated structures needed in early SPS technology-verification projects.

Solar-energy conversion

Major development requirements for the SPS energy-conversion system centre on the need for advanced solar cells and blanket manufacturing methods that will allow low-cost arrays, easily deployed in space and capable of operating for 30 years (nominal) at geosynchronous

Figure 3 – Carrier for a Space Shuttle pallet satellite



altitude, to be produced.

Over the last 15 years, European industry has accumulated considerable experience and ability in the design, development and manufacture of solar arrays for a broad range of space applications. With potential applications in several key projects, the 4 kW solar array developed for the Space Telescope (Fig. 4) is of particular interest, because it is the first deployable and retractable array designed specifically for a Shuttle-launched and recovered mission.

Studies of 10–50 kW and high-voltage arrays (up to 2000 V) that could serve as a power source for free-flying manned and unmanned spacecraft are presently being conducted under ESA contract. The 200–500 kW of power required for an early experimental space construction base could possibly evolve from this technology. The full- scale SPS would, however, call for extensive use of in-orbit construction techniques, which could be supported by European systems derived from Spacelab.

Silicon solar cells manufactured in Europe could meet the technical requirements of early technology projects, although production costs are still very high. One possible impetus towards lower cost might stem from Europe's development work on solar cells for terrestrial use. Both Germany and France are presently engaged in research and development programmes in the field of terrestrial solar generators, with price goals of some $3/W at panel level for 1985.

Economically viable full-scale SPS development will require still much more advanced solar cells to provide low-cost units ($0.2/W) with a consistently high efficiency of at least 17% at 25°C, light in weight with low degradation rates, and the possibility to perform in-situ annealing. More than that, the assembly of a 5 GW SPS would call for totally automated fabrication methods capable of producing in the order of millions of square metres of blanket annually. This clearly implies a need for new technologies and a very high growth rate in solar-cell production capacities.

Attitude and orbit control
Most of the control concepts on the US DOE/NASA reference SPS have already been employed on conventional European satellites or have been studied in Europe, albeit on a smaller scale. Space-qualified sun, star and earth sensors are already available and advanced Charge Coupled-Devices (CCDs), sensors and gyros are already being developed for future ESA programmes.

Electric-propulsion systems delivering thrusts in the millinewton range have been studied in the UK, France and Germany. Their initially widespread development goals have been narrowed progressively with a view to achieving the first practical application for north-south stationkeeping by electric propulsion. The mercury radio-frequency ionisation (RIT) concept developed in Germany is now being pursued intensively to qualify it for an early test flight (Fig. 5).

Figure 6 shows another new candidate electric-propulsion technology being developed in Europe. The attractive aspects of this concept, based on ion field emission, are its mechanical simplicity and the fact that higher thrust levels can be achieved by clustering the requisite number of emitter modules, all fed in parallel from a common propellant tank and all energised in parallel by a common power supply.

Thermal control
Because of the size, function and location of the SPS, its thermal design will be rather demanding. The transmission antenna, for example, will generate hundreds of megawatts of waste heat, which must be dissipated to space. This can be accomplished through highly efficient thermal radiators. Several requirements must be met in this case, including a 30 year lifetime, with in-space assembly and maintenance capability, and high-reliability system start-up after eclipse periods. The SPS technology-verification experiments will already require advanced, active thermal control subsystems.

High-density heat dissipation is already called for on a smaller scale on existing communications spacecraft and on

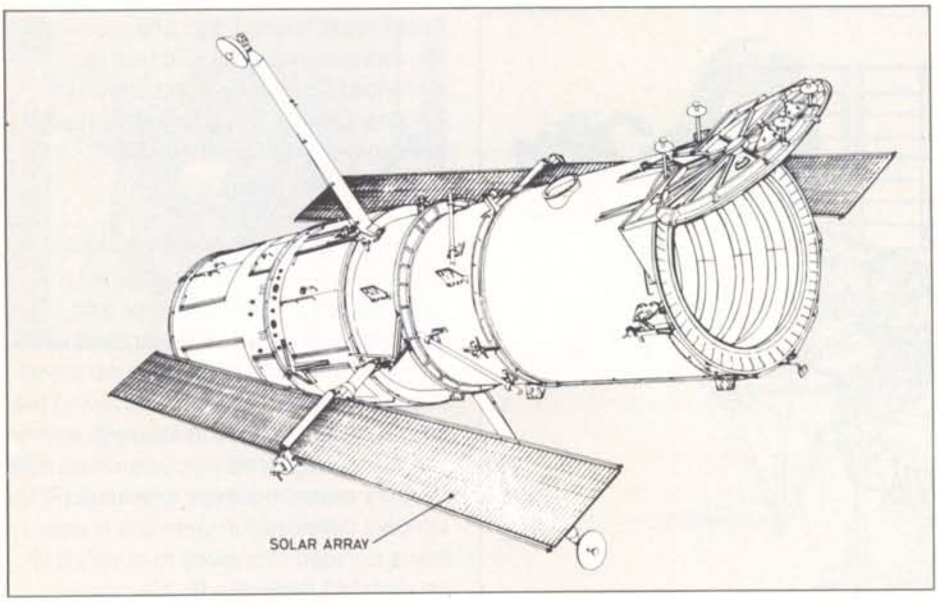


Figure 4 – Space Telescope, with its two 4 kW solar arrays deployed

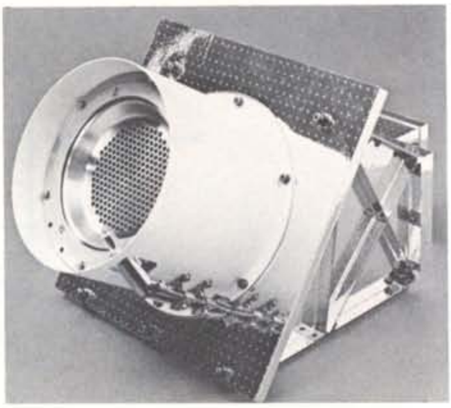


Figure 5 – The RF ion engine (RIT 10) for spacecraft stationkeeping

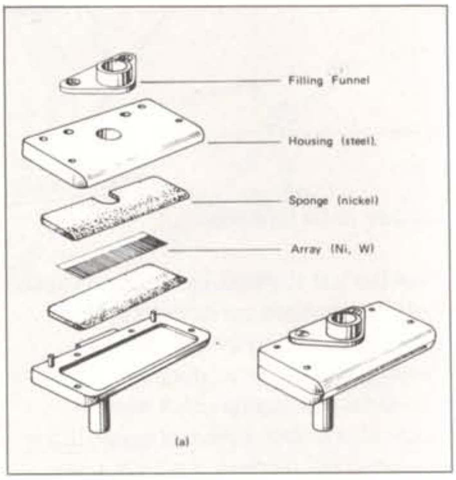


Figure 6 – An elementary Field-Emission Electric Propulsion (FEEP) module

Spacelab, which has several pieces of cold-plate-mounted equipment (Fig. 7). Long lifetimes, extending to seven years, are also one of the design requirements for space communications systems.

The SPS is expected to require additional selected developments in the thermal-technology area, to produce stepped increases in capability, with in particular:

- high-density cold plates and thermal distribution methods
- high-efficiency heat-transport systems
- thermal umbilicals (flexible heat pipes, fluid lines and loop connects/disconnects)
- radiators
- solar-concentrator blankets with high reflectivities and low degradation rates
- analytical tools and ground-test methods.

The tools and test methods are already well developed for today's complex scientific and applications spacecraft, but considerable improvement in data management and computational speed is nevertheless essential for the designing of very large space systems.

The development and thermal analysis of SPS subsystems will also entail significant departures from present-day test techniques. Special integral techniques (thermal/structural/attitude control) may be required in dealing with the effects of thermally induced distortions on SPS stabilisation.

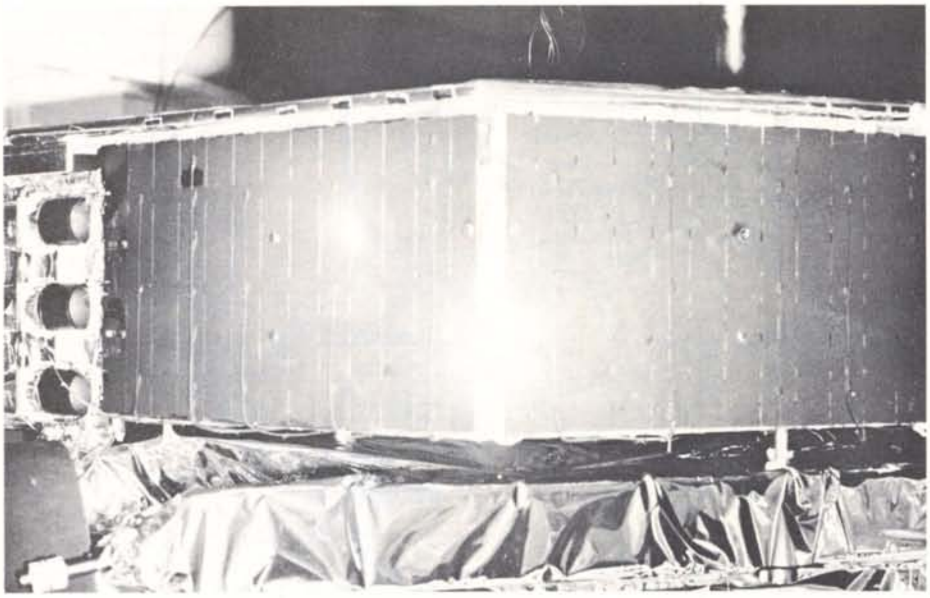
Ground stations
The studies for the SPS microwave reception and conversion system needed on the ground can be divided into three areas:
(i) rectenna power collection
(ii) grid interface, and
(iii) structural support and site design.

The rectenna power-collection system will consist of billions of receiving elements (typically a half-wave dipole in front of a metallic reflector, with a microwave filter, a barrier diode and rectifier circuits), is novel and represents a critical element in the application of microwave free-space power transmission. Many European countries have derived relevant experience from high-gain spacecraft antennas and from military and civil radar antennas. A good deal of phased-array work has already been performed at different frequencies from L to X-band, and in terms of electrical design and analysis low-noise receivers for radars do not differ essentially from those for rectenna systems. Development work for ESA's Marots, Meteosat and OTS spacecraft has generated high-performance front ends for 1.5, 2.2 and 14 GHz regimes. The state-of-the-art within Europe at component level can therefore be described as fair and, although developments are needed, much of the available technology is quite applicable for early space-to-space power-transmission experiments.

Technologies not readily available in Europe
As suggested in the foregoing paragraphs, many of the technical developments required by the SPS technology-verification experiments could

Figure 7 – Technology model of a Variable Conductance Heat Pipe (VCHP)

Figure 8 – Projected development scenario for Europe's Ariane launch vehicle



benefit from existing or planned European space technology. However, that statement needs careful qualification! A complete baseline SPS is yet to be defined, and in a number of cases the requirements are not well understood at this point. For instance, alternative power-transmission options, particularly laser systems or even solid-state microwave devices (which are admittedly not nearly so well defined as klystron microwave devices), could drastically change not only the space segment and ground-receiver characteristics, but the entire system concept also. A limited systems-engineering effort concentrating on those areas that are major cost factors or contain the greatest technical uncertainty is needed to identify and analyse design and technology options. Thereafter the applicability of European space technologies could be determined more reliably and 'bright spots' for these technologies could be identified.

As far as technology requirements for the SPS reference concept and for some other promising options are concerned, the following technologies are not yet under serious study in Europe:

- alternative solar-energy conversion systems (gallium-arsenide cells, closed thermal heating systems, photo-electrochemical cells)
- alternative power-transmission routes (various laser options)
- electric-propulsion systems suitable for primary propulsion
- processes for in-space construction.

This list will certainly grow. As pointed out above, Europe has good bases for developing many of the requisite technologies, but the necessary scaling up of current technologies by many orders of magnitude will certainly lead to a few surprises and many new technological problems will arise.

Applications for Ariane and Spacelab

All the studies of possible SPS configurations published so far have identified the development of low-cost transportation systems as crucial to project success. Although the present Space Shuttle is a first step in this direction, an order-of-magnitude reduction in the cost of launching payloads into low earth orbit is still required, together with an increase in payload masses and volumes by a factor of 10 to 20.

While it is not proposed that Europe, with its limited resources, should consider the development of a complete transportation system for the SPS at this time, it should perhaps be noted that several exploratory studies of large, re-usable ballistic launchers were carried out in Europe in the 1960s.

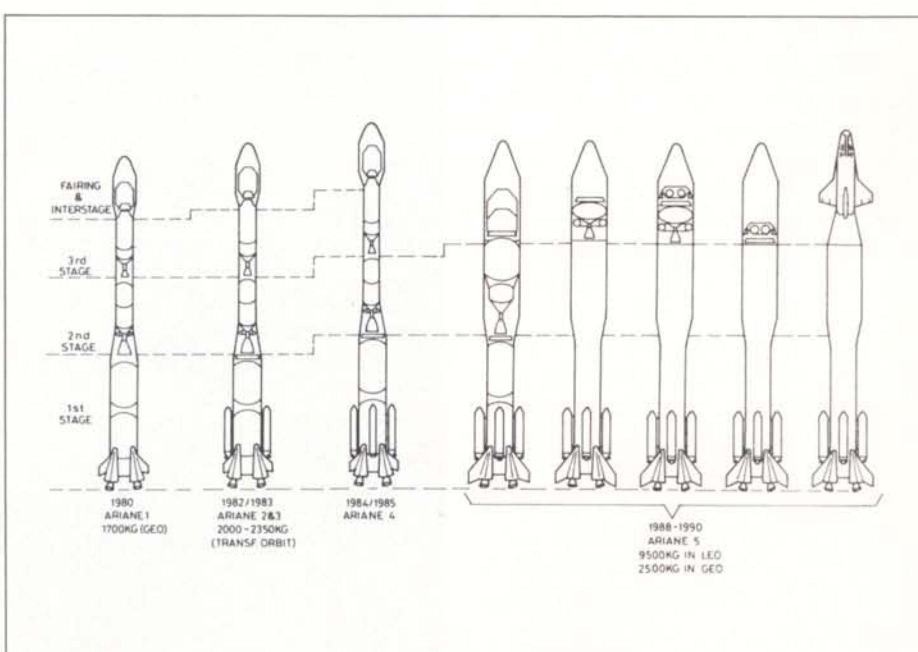
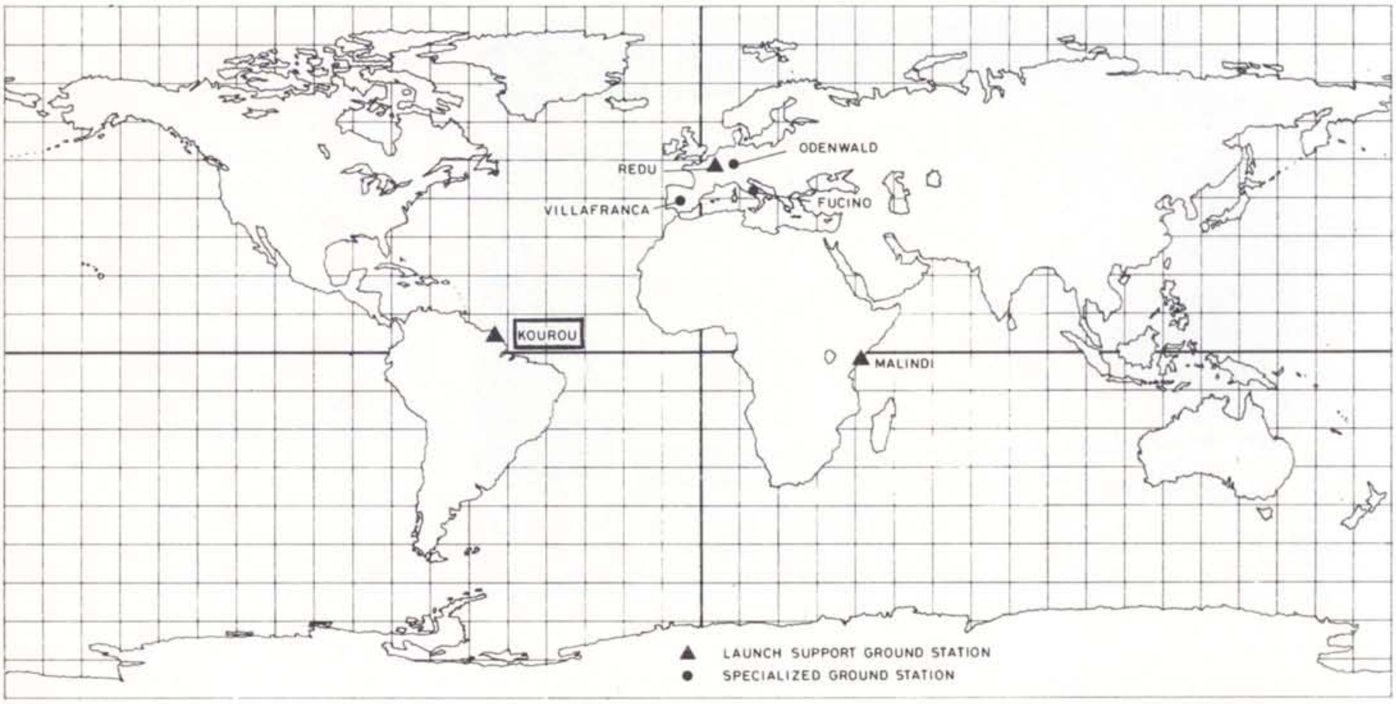


Figure 9 – European launch site, Kourou, French Guyana

Figure 10 – Concept for an experimental space platform



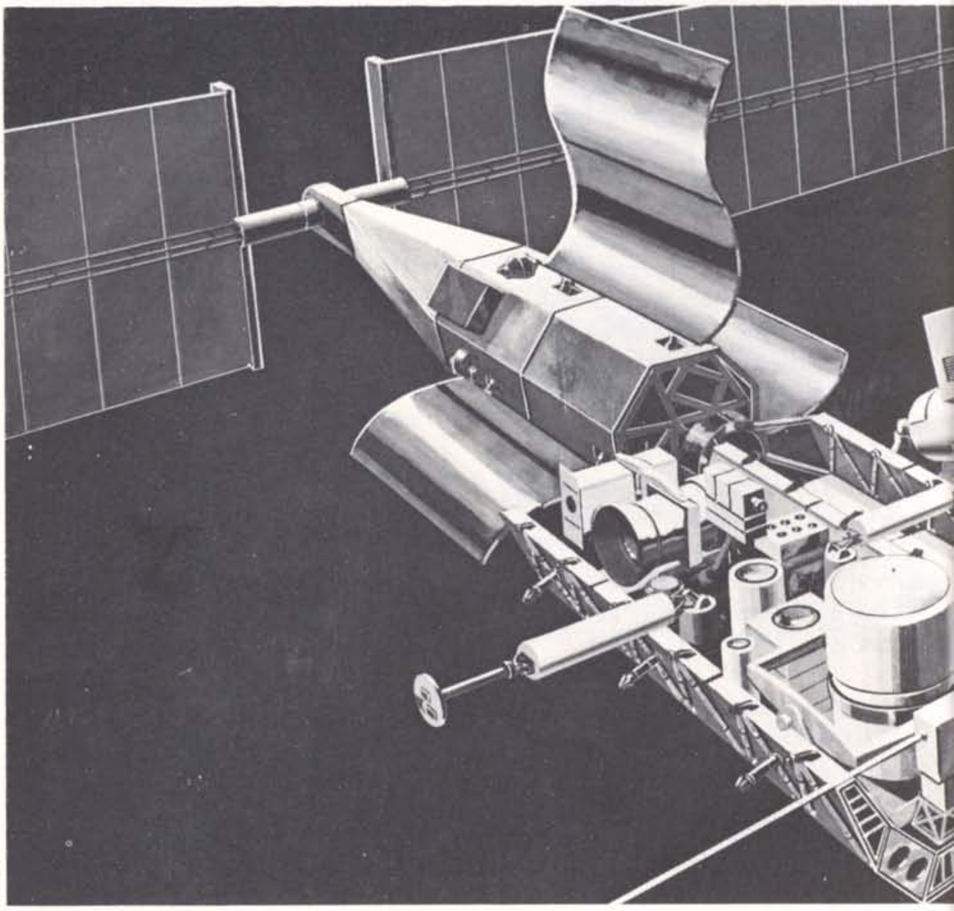
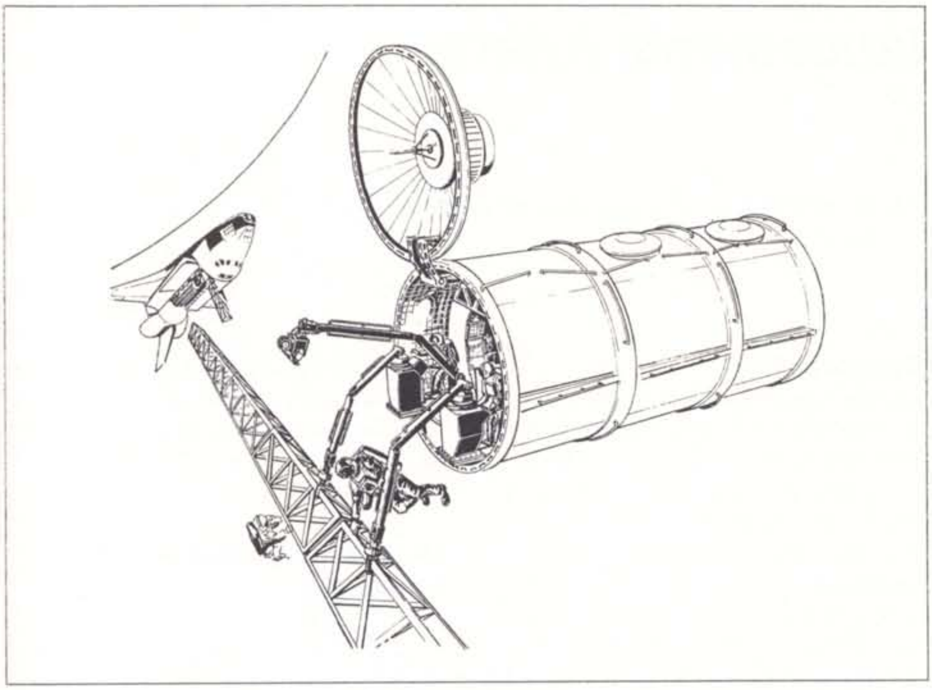


Figure 11 – Spacelab-derived construction maintenance and repair module



Ariane technology, including upgraded Ariane vehicles, could contribute to an SPS technology-verification programme, particularly if the more advanced Ariane concepts currently being discussed are realised in the meantime (Fig. 8). The Ariane launch site at Kourou, French Guyana, is ideally situated for launches into geostationary orbit. The low latitude and low population density associated with this site could represent substantial advantages for an SPS programme (Fig. 9).

There are two competing technologies under consideration for performing the transfer between the low-earth and geosynchronous orbits, namely advanced chemical and electric-propulsion systems. The former have the advantage of employing more conventional technology and allowing shorter transfer times, whereas the latter require orders of magnitude less propellant but involve long mission times. The chemical systems could profit from the continued development of Ariane's upper stages.

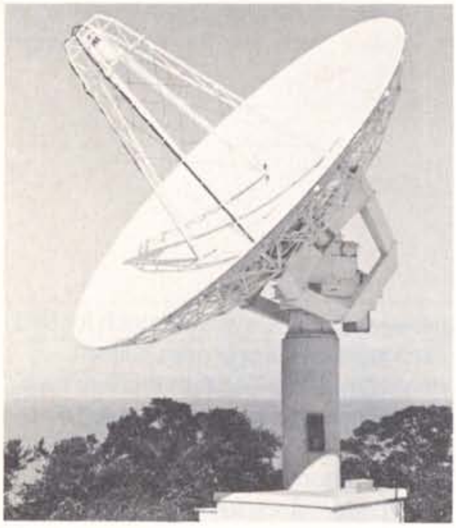
The feasibility and system compatibility of the electric-propulsion approach for SPS purposes are still unproven. Some development work on ion-thrusters and magnetoplasmadynamic propulsion systems operating with inert gases (xenon, argon) is going on in Germany. Early performance tests in space could quantify their potential for orbit-raising and transfer applications on unmanned vehicles.

Spacelab-derived systems may well find applications in the realisation of the SPS concept, as free-flying experimental space platforms (Fig. 10), crew-transport modules and maintenance and repair vehicles (Fig. 11) for example, while crew living and working quarters may evolve from early low-earth-orbit platforms, themselves employing extensively Spacelab-derived systems.

Conclusions

Any synopsis of the European space systems and technology applicable to Satellite Power Systems must necessarily be incomplete at this time; SPS concept definition is expected to evolve considerably in the next few years and many new technology requirements are expected to emerge. Nevertheless, Europe already has an array of interesting space technologies at its disposal which it could apply to advantage in the early study and technology-verification efforts that will be needed to assess the full implications of an SPS programme and hence ensure some degree of initiative in defining potentially attractive 'Europeanisations' for a cooperative SPS development programme.

The technologies that have been identified here as having application to the SPS have all been developed for other European space projects. It is probable that technology investigations undertaken to support the SPS assessment would, in turn, find application in other future space projects and, quite possibly, also in new terrestrial energy systems.



Les systèmes de localisation et de télémesure au service des lancements Ariane

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Le but de cet article est de souligner le rôle essentiel des systèmes sol de localisation et de télémesure dans le cadre des lancements Ariane. Il décrit ensuite les moyens mis en oeuvre au Centre Spatial Guyanais (CSG) et dans les stations aval pour assurer la couverture totale de la trajectoire propulsive. L'accent est mis sur la complémentarité de ces deux systèmes et le traitement en temps réel des informations*.

Contexte général

L'implantation et la détermination des caractéristiques d'un système spécifique est fonction des besoins de la 'mission', au sens large. Dans le cas particulier du lanceur Ariane dont l'objectif nominal est la mise en orbite de satellites géostationnaires, le véhicule doit assurer, avec une précision maximale, l'injection sur orbite de transfert (200/36 000 km) du composite charge utile/moteur d'apogée. En partant de la table de lancement, la trajectoire du véhicule est optimisée sur l'énergie dépensée, sous forme d'ergols, pour atteindre ce but. Elle est alors programmée à bord du lanceur qui devra la suivre avec précision (inclinaison 0,034°/longitude 12 km/grand axe ellipse 60 km) grâce à son propre système de guidage (centrale inertielle/calculateur/équipements de pilotage et senseurs divers) et ce, malgré les perturbations rencontrées.

De ce point de vue, les systèmes sol sont parfaitement passifs et ne peuvent donc intervenir pour assurer des corrections de trajectoire éventuellement nécessaires. Par contre, il est essentiel que du sol, on puisse suivre en temps réel et retracer l'évolution du lanceur et le comportement des différents systèmes embarqués, et ce dans un double but:

(i) établir un bilan général de la performance lanceur,

(ii) assurer la sauvegarde des personnes et des biens, par destruction du véhicule, au cas où sa trajectoire deviendrait dangereuse[1].

Tel est donc le besoin, exprimé en termes généraux, qui justifie les deux systèmes de localisation et de télémesure, qui sont de ce double point de vue, parfaitement complémentaires.

Missions des systèmes localisation/télémesure

A ce stade, il nous paraît souhaitable, pour une meilleure compréhension des rôles respectifs, d'analyser avec quelque détail les fonctions de chacun des systèmes. Pour ce faire, nous prenons l'exemple concret du tir L01, premier tir de qualification du lanceur Ariane.

Missions principales du système localisation

(i) En temps réel
- acquisition et enregistrement des données de localisation (585 interrogations/seconde)
- visualisation des données de trajectographie sur tables traçantes
- désignation d'objectif au profit des autres moyens de poursuite
- établissement du diagnostic de satellisation (environ 30 minutes après le décollage – précision ± 1000 km sur apogée et ± 10 km sur périgée).

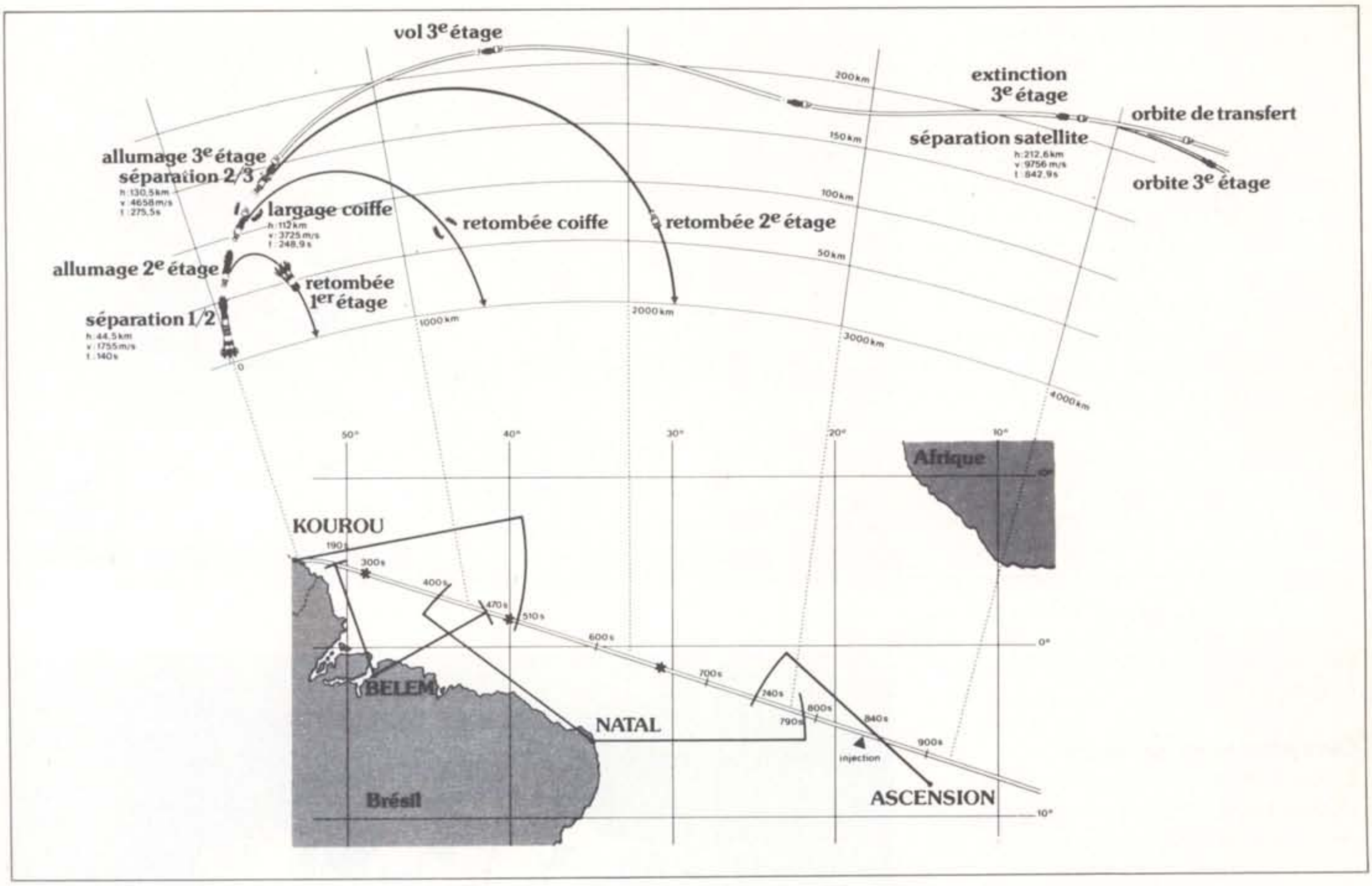
(ii) En temps différé
- traitement des données pour l'établissement des listings et bandes de désignation
- analyse du fonctionnement des moyens de mesure du CSG
- restitution des mesures optiques et radio-électriques

* Je remercie le Centre Spatial Guyanais, et notamment le Chef de la Division Opérations, pour la collaboration apportée à la rédaction de cet article et la mise à disposition des documents photographiques.

[1] Une trajectoire non nominale ou dangereuse ne permettrait de toute façon pas la réalisation de la mission.

◄ *Antenne Stella de réception de télémesure (site Cayenne-Montabo).*

Figure 1 – Trajectoire type d'Ariane pour une mission géostationnaire avec implantation des moyens de couverture.



– élaboration de la trajectoire de synthèse du lanceur (précision à l'injection: ± 100 m en position et ± 1 m/s en vitesse).

Missions principales du système télémesure (TM)

– Acquisition des informations TM émises par le lanceur et la capsule technologique (CAT). (7 équipements TM à bord, débitant plusieurs milliers d'informations/seconde).
– Restitution, en temps réel, par le CSG et les stations aval des événements et de certains paramètres clé (séparations d'étage, attitude du véhicule, braquage des moteurs, pression des réservoirs et des chambres de combustion).
– Restitution, en temps différé, de toutes les informations reçues (total ~ 1300 paramètres différents).

Le détail et les chiffres cités donnent une idée plus concrète de la complexité des tâches accomplies par ces deux systèmes à l'occasion d'un lancement.

Implantation et caractéristiques des moyens

La trajectoire imposée au lanceur et les paramètres d'émission des équipements embarqués fixent essentiellement l'implantation des moyens de localisation et de télémesure. Leurs missions respectives fixent les caractéristiques techniques des équipements mis en place.

La Figure 1 représente une trajectoire type Ariane pour une mission géostationnaire. On réalise facilement que l'étalement de cette dernière (plus de 4000 km avant injection) et l'altitude qui conditionne la visibilité radio-électrique, demandent un déploiement géographique des moyens au sol. La solution retenue, permettant d'assurer une couverture totale de la trajectoire, est illustrée sur la Figure 1.

Elle se compose essentiellement des matériels suivants, répartis sur les sites de Kourou, de Cayenne, de Salinopolis, de Natal et de l'Ile d'Ascension (Fig. 2):

– Radars d'acquisition: A1-A2-type Adour
– Cinéthéodolites infrarouge (Fig. 3)
– Radars hautes performances: B1-B2-Béarn-FPQ (Fig. 4)
– Stations et antennes de réception TM.

Quelques caractéristiques essentielles de ces matériels sont reprises dans le Tableau 1.

La Figure 2 montre en outre le recouvrement des différents sites qui

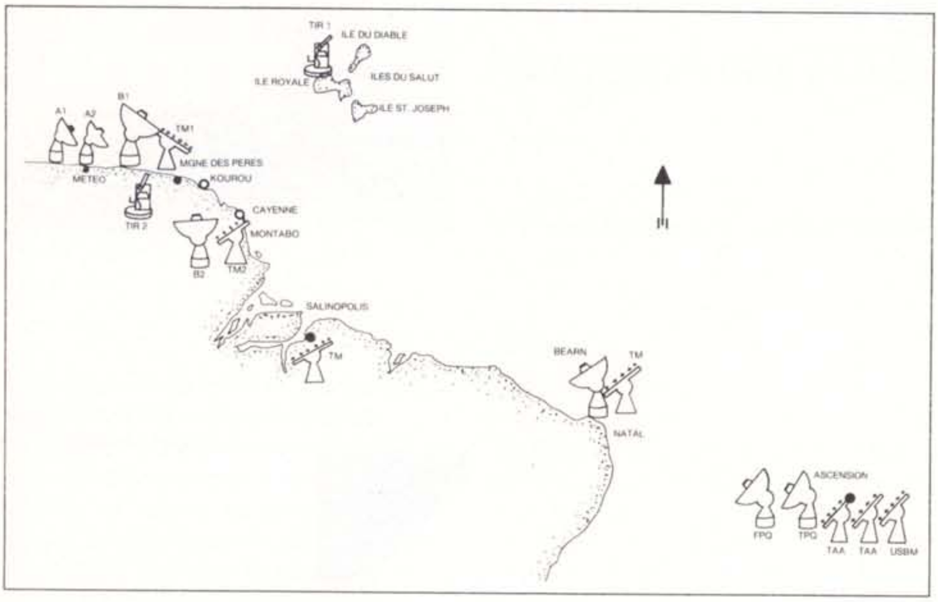


Figure 2 – Ensemble des moyens de localisation et de télémesure du CSG et des stations aval.

Figure 4 – Antenne du radar Bretagne de localisation (site Montabo).

Figure 3 – Cinéthéodolite infrarouge.

prennent le lanceur en poursuite tout au long de sa trajectoire.

Les systèmes en opérations
La complémentarité des systèmes de localisation et de télémesure, qui tous deux poursuivent le lanceur en temps réel, exige une étroite coordination des moyens respectifs.

La prise en charge du véhicule, en séquence par les différents sites jusqu'à l'injection en orbite, impose aussi une coordination très étroite de ces derniers de façon à ce que le site suivant puisse avoir fait l'acquisition de l'objectif avant que le site précédent en ait perdu la visibilité.

Afin de résoudre ces deux problèmes avec un maximum de fiabilité, le CSG a mis en place un dispositif qui permet la *synchronisation* totale des moyens et des sites. Les données d'acquisition du lanceur (site/gisement/distance) relevées par les moyens (radars Adour ou Bretagne) de la base de lancement sont traitées en temps réel par ordinateur et transmises aux autres moyens qui peuvent alors prendre l'objectif par asservissement direct sur le moyen principal désigné; cette opération porte le nom de *parallaxage*. Il en est de même tout le long de la trajectoire; c'est ainsi par exemple que la station Natal est pointée sur un point de rendez-vous avec le lanceur, avant même que celui-ci soit dans sa zone de visibilité. De même, chacune des antennes radar ou TM peut, s'il le faut, asservir les autres, ce qui permet de pallier la déficience d'un signal répondeur ou télémesures du véhicule. La redondance ainsi créée, nécessaire pour la sécurité des opérations, donne en outre une bonne souplesse aux systèmes en permettant des opérations en modes dégradés suite à la panne toujours possible d'un moyen spécifique.

Cette synchronisation des moyens et des sites est contrôlée entièrement et directement par le CSG, pour l'ensemble des stations. Elle a fait l'objet d'un entraînement très poussé des équipes concernées (Voir: Le programme de qualification opérationnelle du CSG, *Bulletin ESA*, no. 20, nov. 1979, pp. 41-43).

Deux *chaînes de calculs* complètes traitent les données de localisation en parallèle. Outre les opérations de parallaxage, les sorties alimentent les tables traçantes du Centre de Contrôle et de la Salle Sauvegarde, permettant une visualisation en temps réel de la trajectoire

Figure 5 – Centre de Contrôle avec, au milieu, les tables traçantes de trajectographie.

du lanceur (Fig. 5). Pour la fonction sauvegarde, ces deux calculateurs donnent aussi à chaque instant le point d'impact prédit du véhicule, en fonction de sa position et des paramètres de bord, de propulsion notamment (précision de 200 m à 3 km suivant la distance du lanceur). Si le lanceur dépasse les limites prévues, le responsable Sauvegarde envoie l'ordre de destruction. A ce jour, sur plus de 50 tirs d'engins, principalement du type fusées-sondes, une seule destruction a été provoquée.

Les différents sites TM traitent aussi directement un certain nombre de paramètres reçus. Ces paramètres, considérés comme les plus significatifs, sont sélectionnés pour chaque lancement et, après traitement des données TM correspondantes, sont visualisés sur enregistreurs graphiques permettant un suivi en temps réel de leur évolution (système de contrôle visuel immédiat – CVI).

Tableau 1 – Caractéristiques principales des équipements Localisation et Télémesure

Radar Bretagne (BR)

Modes:	poursuite sur répondeur ou en écho de peau ou mixte
Fréquence:	5450 à 5825 MHz
Diamètre:	3 m
Lobe:	1,2°
Gain:	42,5 dB
Puissance moyenne:	470 W
Portée nominale:	4096 km
Précision:	
– angulaire	± 0,1 mrd
– distance	± 10 m

Cinéthéodolites infrarouge (TIR)

Modes:	poursuite sur rayonnement IR, ou par désignation ou manuelle
Télescope, ouverture:	400 mm
Distance:	500 m à l'infini
Précision angulaire:	± 5''

Antenne de Réception TM (Stella 43)

Modes:	poursuite automatique sur émission ou par désignation ou manuelle
Fréquence:	bande E (2200 - 2290 MHz)
TM:	FM/FM - PCM/FM
Antenne, diamètre:	10 m
Gain:	> 43 dB
Précision de pointage:	< 0,2°

Conclusions

Nous avons vu le rôle essentiel des systèmes de localisation et de télémesure sur le plan performances du lanceur et sauvegarde.

La synchronisation des moyens et des sites est indispensable pour assurer la continuité de la poursuite et la redondance nécessaire.

Le traitement en temps réel des données de localisation et de certains paramètres TM est l'outil indispensable à la sauvegarde des personnes et des biens, outre qu'il permet un contrôle direct de la mission.

Nous espérons avoir démontré au lecteur que les deux systèmes de localisation et de télémesure forment un tout indissociable et indispensable pour la réalisation des objectifs imposés pour un lancement Ariane.

The System of Geostationary Meteorological Satellites during the Global Weather Experiment*

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The Global Weather Experiment is a major exercise organised by the World Meteorological Organisation (WMO) and the International Council of Scientific Unions (ICSU). The participants include virtually all of the 147 member states of WMO and the Experiment has been 'operational' from 1 December 1978 until 30 November 1979. During this operational year an unprecedented number of observing systems were deployed in order to provide the most effective data set for the use of atmospheric and oceanographic research groups during the coming years. This article outlines the role played by the global system of geostationary meteorological spacecraft during the operational year.

* Latest status of Meteosats-1 and 2 reported on page 53.

Purpose and scope of the Global Weather Experiment

The objective of the operational year of the Global Weather Experiment has been to gather meteorological and oceanographic data on the scale needed to resolve a number of unknowns about the atmosphere. The current routine observing systems are quite inadequate in most areas of the world to describe the atmosphere in sufficient detail to provide a satisfactory basis for making forecasts or even to validate forecasts once they have been made. There are, of course, data-rich areas of the world, such as Western Europe and North America, where this statement is less true than for the tropics and southern hemisphere, but nevertheless it is increasingly apparent that accurate forecasts for Europe (for example) extending to more than three to five days certainly need data from the tropics and even from the southern hemisphere.

The Experiment provides a year-long data base which will be used for improving forecasting techniques and will also be used ultimately to help define an optimum composite observing system, so that the advances made in understanding the meteorological processes can eventually be put to routine use. Other objectives include the assessment of the ultimate predictability of weather systems and the investigation of the physical mechanisms underlying the observed fluctuation in climate on time scales of up to a few years.

To achieve these objectives an enormous world-wide effort has been organised, to deploy additional observing systems especially for the operational year, to coordinate the introduction of new satellite observing systems in time for the start of the Experiment, and finally to ensure that data from all new and existing observing systems are brought to central data centres in a suitable format, so that they can be readily accessed and used.

Even a brief description of the total observing system is outside the scope of this article, but it is relevant to list some of the major sources of data:

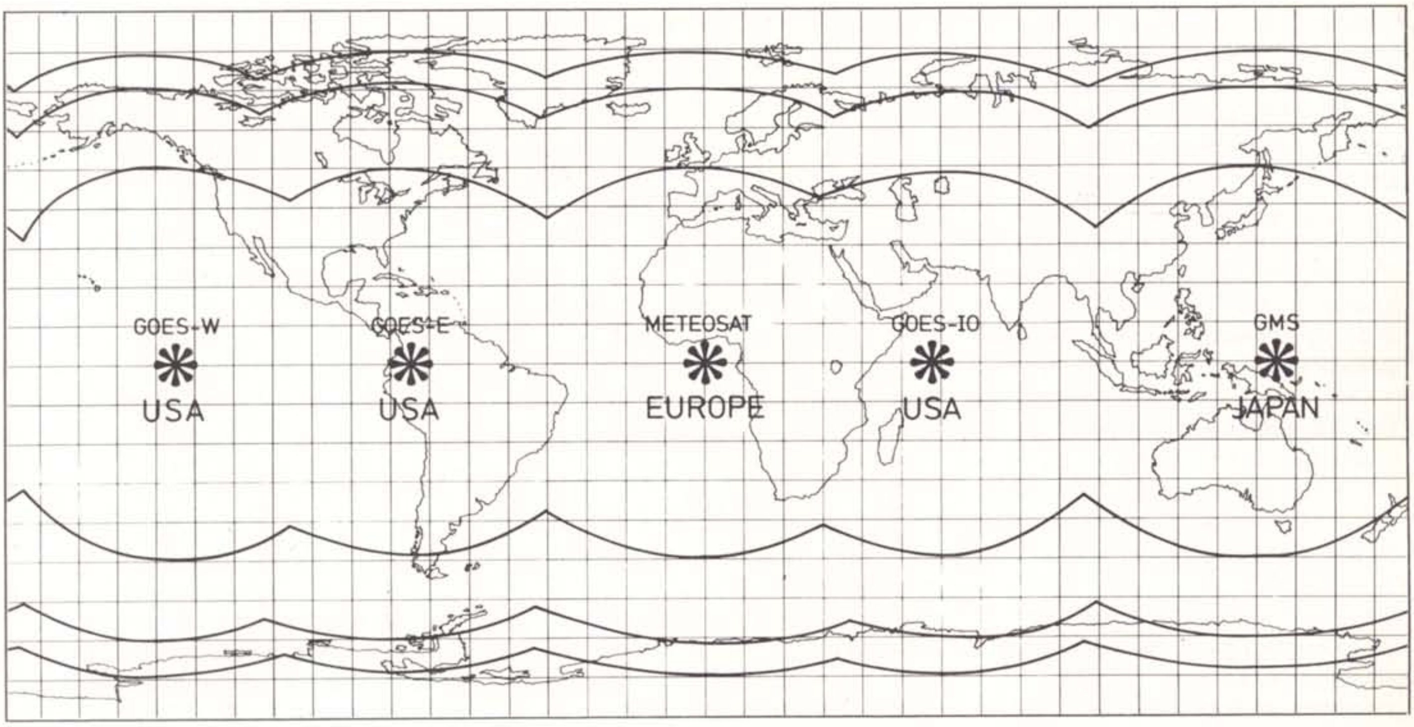
- the normal World Weather Watch surface-based stations providing routine information
- four polar-orbiting meteorological satellites
- five geostationary meteorological satellites
- special aircraft, releasing parachute-borne instruments
- specially deployed ships
- free-floating high-altitude balloons
- buoys drifting in the ocean
- commercial aircraft and ships equipped with meteorological and oceanographic instruments.

The programme is by far the most ambitious international research undertaking ever, and the purpose of this article is to describe the system of geostationary meteorological satellites which became operational ready for this Experiment.

The geostationary meteorological satellites

A system of five spacecraft in geostationary orbit, and more or less

Figure 1 — Coverage of the geostationary satellites. The three boundaries indicate (in order of distance from the equator) the approximate coverage areas for the computation of cloud winds, the useful area for images, and the telecommunications coverage, respectively



equally spaced around the equator, can provide an almost total global view of the earth, with only the polar regions excluded (and these areas are covered adequately by the system of polar-orbiting satellites). Such an observing system came into being for the first time ever for the operational year, with three spacecraft provided by the USA, one by Japan and one by ESA (Table 1).

These five spacecraft were operated throughout the year, and although they were provided by different organisations the system as a whole has been

Table 1 — Spacecraft locations (all over the equator) during the Global Weather Experiment

Operator	Spacecraft	Longitude
USA	Goes-E	75°W
USA	Goes-W	135°W
USA/ESA*	Goes-IO	58°E
ESA	Meteosat	0°
Japan	GMS	140°E

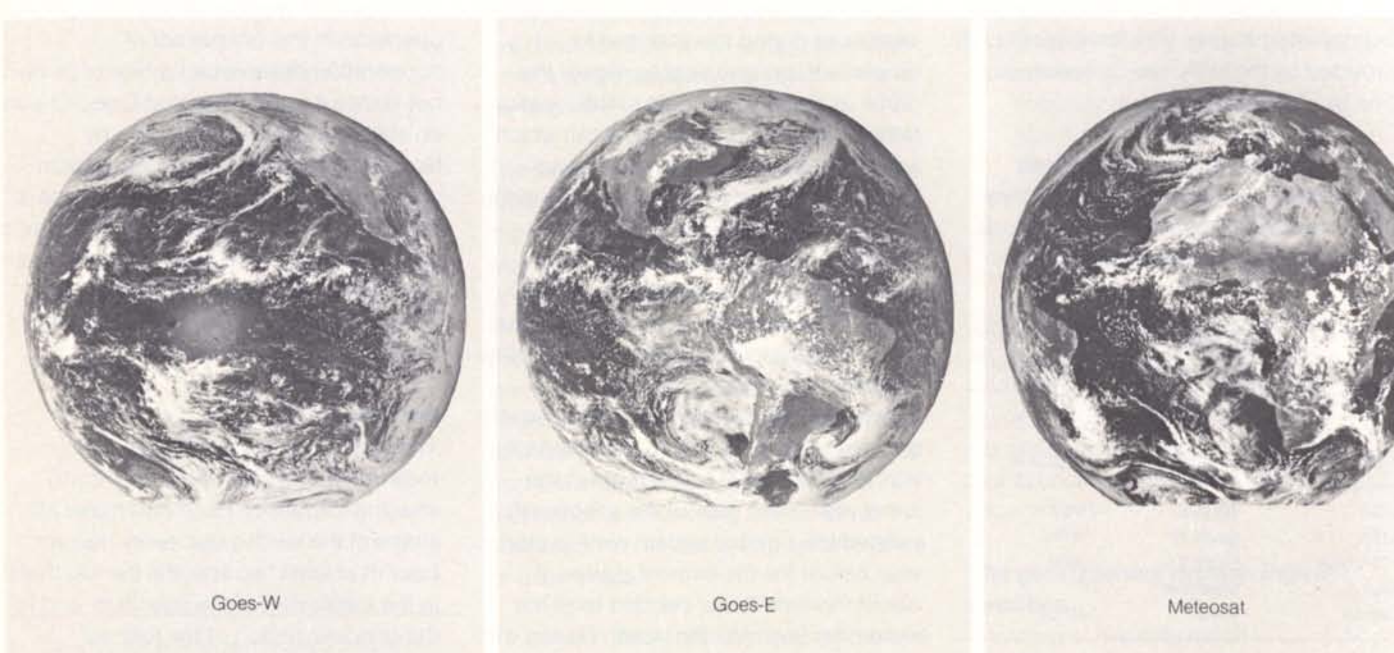
* See text

coordinated so that the services provided are compatible, even though the spacecraft themselves are different and have some individual features that are not uniform. The USA's Goes system is comprised of two types of similar spacecraft, Goes and SMS, both of which were used during the year, but for simplicity it is convenient to regard the name as being applicable to the location rather than the precise spacecraft which was being operated at any particular moment. This system had its origins in the ATS satellite in 1966, and SMS-1, launched in May 1974, was the first satellite of the Goes programme. The Goes-E and Goes-W locations (east and west) were therefore occupied long before the start of the Global Weather Experiment. Japan's GMS was placed into orbit on 14 July 1977, and ESA's Meteosat was launched on 23 November in the same year. Thus, four of the spacecraft needed for a global system were in orbit a year before the Experiment started. At about this time it was decided to fill the remaining gap over the Indian Ocean with a Goes spacecraft (available as an in-orbit spare). Under a joint programme, the USA agreed to provide the spacecraft and a transportable ground station and ESA undertook to operate the Indian Ocean satellite, designated Goes-IO, for the duration of the experiment. The story of how this final spacecraft was brought into operation in this unique act of cooperation deserves an article of its own, but suffice it to say here that Goes-IO was on station and in full operation by November 1978 and the global system was complete (albeit temporarily since at the end of the Experiment and one year of operation the Goes-IO project came to an end. Since 1 December 1979 there has been no meteorological geostationary satellite over the Indian Ocean).

Imaging

The primary function of these meteorological satellites is their earth-imaging capability. Each can make full scans of the earth's disc every half an hour in at least two spectral bands; that is in the visible part of the spectrum and in the 'window' region of the thermal infrared, at around 11 μm. This part of the

Figure 2 — Examples of images from the five geostationary meteorological satellites on 15 October 1979 (visible spectrum)



spectrum is to a great extent immune from atmospheric attenuation and is therefore used to view the earth, sea and clouds throughout the twenty-four hours. In addition to these two channels, Meteosat also has its so-called 'water-vapour channel' – an infrared channel at 6 μm, in the absorption band of water vapour. This channel cannot be used to see the earth's surface, but it is indicative of the amount and height of water vapour in the upper atmosphere.

The three satellites have different radiometers, but the overall characteristics of the visible (VIS) and 11 μm (IR) channels are similar and the resulting images compatible (Table 2).

Table 2 — Characteristics of the earth-imaging systems

	GMS	Goes (E, W & IO)	Meteosat
Number of scan lines for full-disc infrared	2500	1750	2500
Resolution (km) at subsatellite point:			
visible	1.25	1.0	2.5
infrared	5	8	5
water vapour	–	–	5
Spectral response (μm)			
visible	0.55 – 0.75		0.4 – 1.1
infrared	10.5 – 12.5		10.5 – 12.5
water-vapour	–		5.7 – 7.1

The actual number of images taken depended strongly on the operational requirements of the various agencies concerned, and consequently full-disc images were not acquired every half hour. Each satellite can, for instance, be operated in such a way that partial earth scans are made more frequently. This is of use for tracking hurricanes or for the production of special-area cloud-wind vectors. In other cases the frequency of operation was required to be less frequent than at half hourly intervals, so it would be incorrect to assume that each spacecraft generated 48 images each day. Nevertheless, the system worked throughout the year and although in some instances there were temporary problems, these were overcome and an enormous amount of image data was acquired. All of these images were transmitted to the appropriate ground station in digital form, and since each image contains some 2×10^8 bits of information, this part of the operation alone generated over 10^{13} bits of digital information during the operational year, assuming about thirty full images per satellite per day. These images have been stored in both digital and photographic formats and can be made available to researchers.

Cloud wind vectors

The frequent images from the five satellites have been exploited to compute the velocity of clouds. It has been determined that clouds normally – but not always – follow the atmospheric motion quite closely, and this product has proved to be a valuable source of information on the dynamics of the atmosphere. The process is in principle quite simple – a sequence of images are carefully registered one with the other so that all coastlines are aligned; the movement of clouds is then apparent and may be measured. The next stage is to determine the cloud height, and this measurement is derived from the infrared radiance of the cloud, which is converted into a Planck equivalent temperature and then into a height by reference to an atmospheric profile, since temperature normally decreases monotonically with height in that part of the atmosphere in which clouds occur.

Image data from all five satellites have been used routinely for these determinations, at different centres around the world (Table 3).

Table 3 – Producers of cloud wind vectors

Computing centre	Satellite(s)	Frequency (per day)	Period(s)
European Space Operations Centre (ESOC)	Meteosat	2	all year
Japanese Meteorological Satellite Centre (JMSC)	GMS	2	all year
National Environmental Satellite Service (NESS)	Goes-E,W	3	all year
University of Wisconsin	Goes-E,W	1	all year
University of Wisconsin	Goes-IO	2	all year
Laboratoire de Météorologie Dynamique (Paris)	Goes-IO	1	Jan. 17-18 Feb. 1-10 May 16-June 30
DFVLR (Munich)	Goes-IO	2	Jan. 5-March 5

The seven centres involved in this activity use different processing systems to achieve the same objective. They include fully automatic computer techniques, man/machine interactive processes, as well as the use of film loops and mechanical-optical systems. This variety of technique might give rise to concern that the results are mutually inconsistent, and in order to check on this possibility a number of comparisons have been made.

Goes-IO

GMS

The wind vectors produced by different data producers have been compared in the overlap areas, and the cloud winds have also been compared with conventional wind measurements. These experiments indicate that in spite of the different systems in use, the resulting wind vectors are compatible, both with one another and with conventional data. Furthermore, it has been demonstrated that these cloud winds have a measurable positive impact on weather forecasts, so that already this new system has proved to be of benefit.

Wind vectors are computed in near real time by the three satellite operators

Figure 3 — The distribution of image data in near real time is illustrated by this Wefax picture of the Indian Ocean. It started as a Goes-IO image received at an ESA ground station in Spain. From there it was sent back via Goes-IO in stretched form, and received at CMS in France for format conversion and retransmission via Meteosat to user stations. In this example the user station was the University of Dundee, in Scotland

(ESOC, JMSC and NESS) and distributed globally with a delay of only a few hours over the meteorological telecommunications system. Thus wind data from four of the satellites are available operationally and have been used on a daily basis as an input to forecast models and for briefing of aircrews, for example. The other data producers have worked in non real time and their winds have not been used operationally, but all winds from all seven producers have been written on magnetic tape in a special data format and mailed to a data centre in Sweden as an input to the Global Weather Experiment. Each centre produced from 200 to 700 wind vectors for each determination, one to three times each day, and the total number of wind vectors produced was well in excess of one million.

A significant advantage of this method of determining wind vectors is that it can be utilised in data-sparse regions, such as the southern oceans and equatorial regions, where there has previously been very little information on wind patterns. This in itself is of major importance to the Global Weather Experiment. An area of particular interest is the Indian Ocean, because of the monsoon regime, which affects large areas of Asia. Special efforts have been made by the three research institutes involved to compute as many winds as possible over this area, for periods that coincide with intense observations by other systems during peaks in monsoon activity

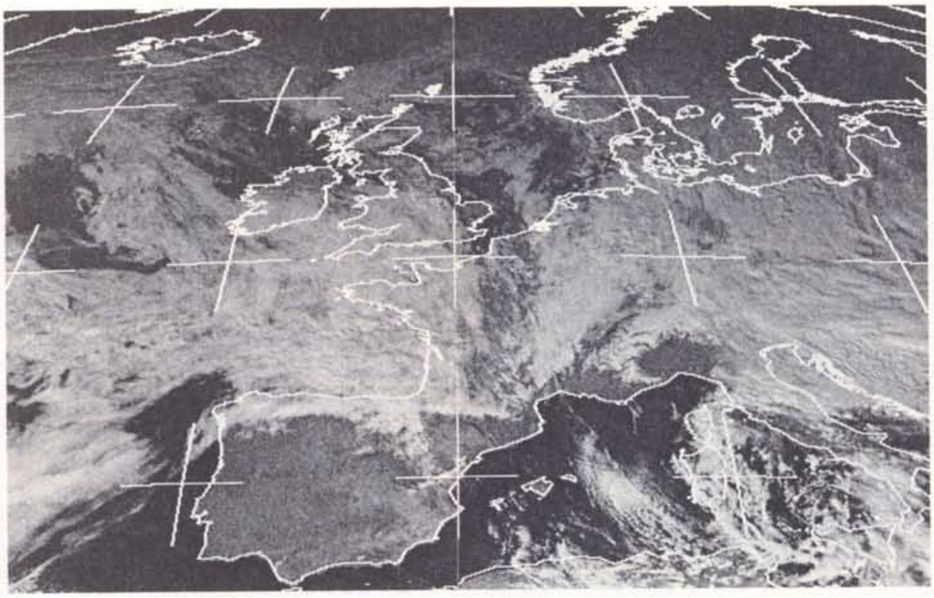
Image distribution
All the satellites relay their data to their ground station. These data can be read by other stations, but in addition the operators re-transmit image sectors in analogue format (Wefax) so that low-cost user stations can receive processed image data in a convenient form. This service is available from all satellites except directly from Goes-IO, and has been in operation throughout the year, so that local forecasting units have had quick, cheap access to the geostationary image data. These pictures have also been used to route research aircraft into meteorologically active areas and have thus contributed directly to the research programme. Goes-IO did not support Wefax directly, but special arrangements were made to provide this service indirectly and thus give routine information over the vital Indian-Ocean area. The Goes image was received at the Centre de Météorologie Spatiale (CMS) in France and relayed to Meteosat as a Wefax transmission. CMS does the same for Goes-E, so that for the duration of the Global Experiment, the Meteosat user has been able to receive images from three satellites, with a field of view stretching from the west coast of America to the Bay of Bengal, at least four times per day. This particular feature of the Meteosat operation is unique. It should also be pointed out, perhaps, that in addition to Wefax, images are also distributed in other, nonstandardised ways, including a landline distribution for Goes-E and W, a high-resolution facsimile service from GMS and the high-resolution digital service from Meteosat.

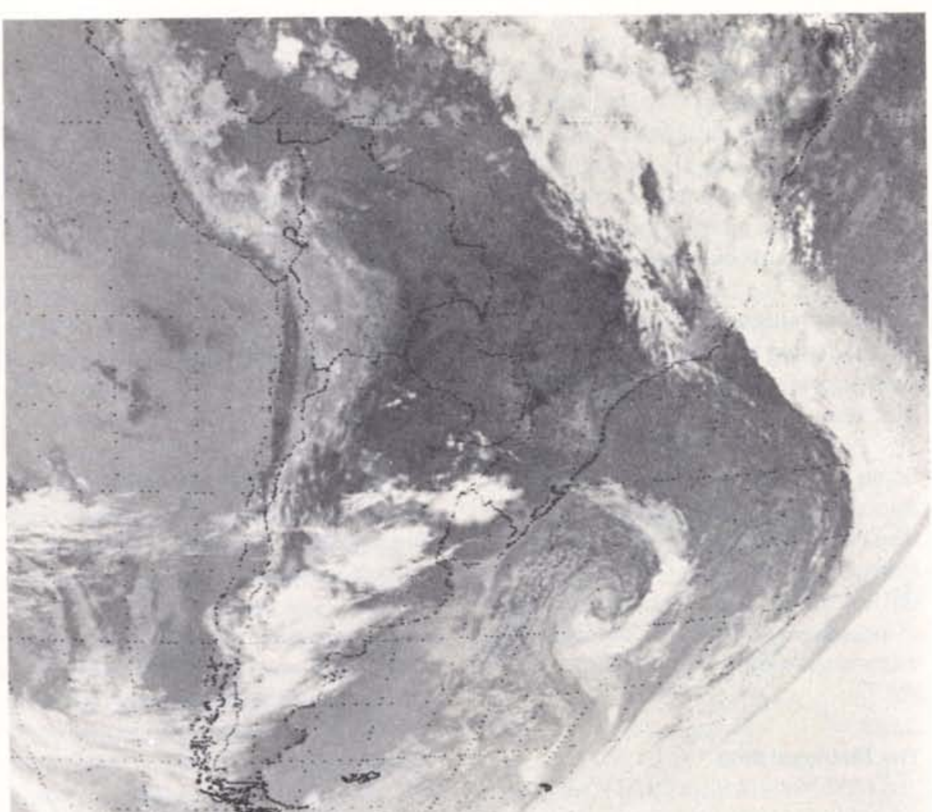
The number of user stations exceeds 100 for Meteosat alone, and there is no doubt that this operation has contributed significantly to the conduct of other operations during the Experiment.

Data-collection system
Another feature of the system has been the possibility to relay data from environmental data-collection platforms to the corresponding ground station, from where they have been relayed to the meteorological community. This system is coordinated so that mobile platforms (ships, aircraft, etc.) can move from one satellite field of view to another without interruption in service. The system

Figure 4 — A Wefax picture of Europe transmitted to Meteosat user stations. The coastlines were added at the central ground station at ESOC (Germany) and the picture was received by the Swiss Meteorological Service. A similar Wefax service is operated by the USA and Japan for the Goes-E, Goes-W and GMS satellites

Figure 5 — In addition to direct Wefax broadcasts from Goes-E, images relayed from Goes-E to CMS in France are reformatted and sent via Meteosat to Meteosat user stations. For this picture of South America the coastlines were added in the USA, and the user station was the University of Dundee, in Scotland





is not available on Goes-IO, but has been in operation on the other four satellites throughout the period of the Experiment and has certainly demonstrated its effectiveness as a new data-collection system. Routine weather messages have been collected daily from ships, aircraft and land stations and relayed in near real time to the meteorological community.

The system was utilised for only a fraction of its ultimate capacity of many thousands of platforms, but has nevertheless demonstrated that the system works on a near-global basis. An interesting example of this aspect of the system is the American Asdar project, whereby twenty B747 Jumbo Jets have been equipped with automatic devices for relaying meteorological data. These platforms generate a weather report eight times each hour and send them to satellites within their field of view for relay to the ground station and the user community. This has taken place completely automatically, and on a typical day some 400-500 weather reports were transmitted through each of the four satellites involved. The coverage area for this system extends to more than 80° from the subsatellite point, so that each satellite is covering nearly half the world's surface.

Conclusion

The global system of geostationary meteorological satellites was in operation ready for the start of the world's first Global Weather Experiment and has demonstrated its effectiveness in the main missions of the system. Images have been generated, distributed and stored routinely. Cloud-motion vectors have been produced routinely for all five satellites, and the international data-collection system has been demonstrated on four out of the five. In addition, the image data have been used for production of other meteorological parameters on a satellite-by-satellite basis (examples: cloud analyses, sea-surface temperatures), and the total system has made a significant contribution both to the Global Weather Experiment and to the routine work of operational meteorologists.

Unfortunately, the global system does not yet exist on a permanent basis. Goes-IO has returned to the USA location, and Meteosat-1 ceased to transmit image data one week before the end of the experiment after two years of successful operation.

Some Research Uses of Meteosat and Early Results*

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Apart from the operational utilisation of Meteosat data by meteorological services for weather analysis and forecasting, there are a wide range of possible applications for the data within various scientific research communities. An overview of a number of Meteosat's research applications has been built up on the basis of the frequent and numerous contacts that have taken place between the users and the Agency during the many seminars and demonstrations that have been held since the Meteosat-1 launch in November 1977. Promising results have already been achieved by research groups working in such fields as meteorology, oceanology, ecology and climatology, and many of these research activities will continue to be pursued with the next generation of meteorological data to be produced by Meteosat-2, which will be launched later this year.

* Latest status of Meteosats-1 and 2 reported on page 53.

The utilisation of Meteosat data is still a very young field of research for three main reasons. Firstly, Meteosat-1 has presented the European and African scientific communities with their first opportunity to work with a geostationary environmental satellite stationed permanently overhead and producing remote-sensing observations with a very high repetition rate (half an hour between images over the same area). Secondly, there is a certain inertia to be overcome before any new data source can be fully utilised. Last but not least, the utilisation of such data often implies the use of very sophisticated and expensive equipment, a lot of computer programming, and the need for qualified and experienced people to work on these difficult problems. Despite these and other natural start-up constraints, Meteosat data is already being widely used, as it is hoped this summary will illustrate.

Some of the applications that will be discussed here were presented by the researchers themselves during the first Meteosat Scientific User Meeting, held in ESOC in June 1979; others are the result of individual contacts and discussions with researchers during seminars, visits, etc.

The Meteosat data

The radiometric sensors that have been operating on Meteosat-1 since its end of 1977 launch and which will be duplicated on Meteosat-2, to be launched later this year, are designed to operate in three distinct spectral ranges:

- 0.4 – 1.1 μm visible (sunlight reflected by bodies)
- 10.5 – 12.5 μm infrared (thermal infrared)
- 5.7 – 7.1 μm water vapour (water-vapour infrared absorption band)

The on-ground resolutions for each channel are 2.5, 5.0 and 5.0 km at the subsatellite point (0° latitude, 0° longitude). Two visible sensors provide the higher visible resolution, but one of the two must be switched off when water-vapour data are needed. Since the spacecraft are designed to spin at 100 rpm, their radiometers scan the earth's surface at the same rate from east to west, and from south to north in 25 min via a stepped telescope movement.

These raw data, transmitted by Meteosat-1 in digital form on a half hourly cycle, have been received directly at the central ground station at ESOC, as well as at some user stations with the necessary sophisticated receiving equipment, such as the Lannion Space Meteorology Centre (CMS), operated by the French Meteorology Service (Fig. 1).

Images preprocessed in ESOC have been relayed via the satellite to standard user stations in both digital and analogue forms. Over 400 image sectors have been retransmitted each day in this way to over 100 user stations in Europe, Africa, India and the USA. In addition users have been supplied with magnetic tapes or photographic images by ESOC from the Meteosat archive. There have thus been three sources of data available for research use – direct reception, retransmissions from ESOC, and retrievals from the archive – and all are being exploited by the research community.

Meteorological parameters (cloud winds, sea-surface temperatures, etc) computed at ESOC from the basic image data are also being used for research, as explained later, although these parameters are not ideally suited for some projects because they are designed to be of maximum value to operational meteorologists, e.g. the resolution is about 200 km. For this reason wind vectors have also been computed at other centres, and sea-surface temperatures to much higher resolution have also been computed elsewhere (Fig. 2). This in itself represents a research effort in addition to the physical research that can follow once these data have been derived.

Research applications of the data

It is very difficult to delineate the scientific research being undertaken with Meteosat data into sharply defined categories, mainly because the doctrines involved are becoming more and more specialised and interdisciplinary at the same time. It is possible however, to classify the main activities under synoptic meteorology, numerical weather prediction, climatology and radiation budget, and hydrology and agriculture.

Synoptic meteorology

The use of Meteosat images to study cloud evolution, perturbation motions and characteristic atmospheric patterns (such as hurricane development, lee waves, jetstreams, monsoons, etc) has clearly been the most common field of investigation in the national meteorological services and institutes. The image sequences are a novel indicator of cloud development, for example, and can be used to extract cloud-motion vectors either automatically or manually (see ESA Bulletin No. 20, pp 14-19).

A very promising field of research is in progress at Munich University's Meteorologisches Institut where an attempt is being made to extract vectors over cloud-free areas using Meteosat water-vapour data. With the help of some assumptions to take into account the dynamical background to water-vapour motion in the atmosphere, such as convection or wave situations, the displacements of some water-vapour contours have already been determined

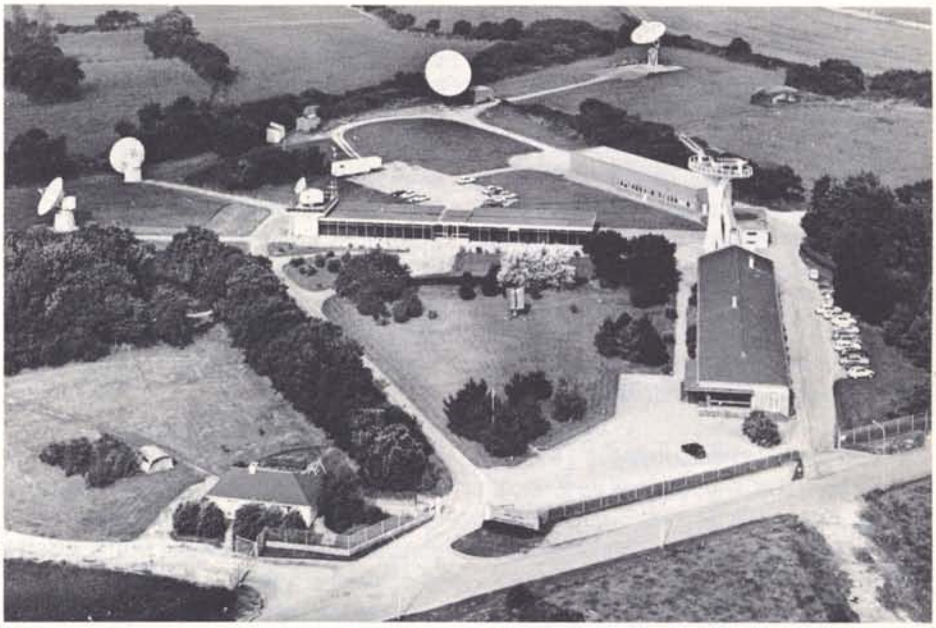


photo cms

Figure 1 – Meteorological satellite reception facilities at CMS, Lannion (France)

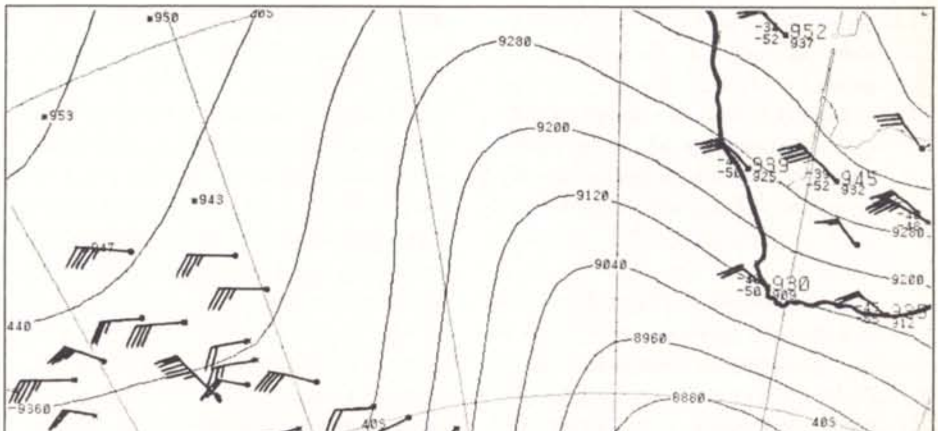


Figure 2 – Sea-surface wind vectors calculated twice daily as an operational product by a Meteosat user. Two enhanced thermal-infrared images, 30 min apart, are used as an information base

interactively from two consecutive water-vapour images taken three hours apart. The diffuse vapour patterns have to be properly enhanced in order to track their locations on a small scale. Heights have been attributed by calculating emission functions with high precision for several atmospheric models, and the results show that these water-vapour contour vectors relate approximately to the mean motion of an atmospheric level between 400 and 500 mb for middle latitudes, depending on the mean atmospheric conditions.

At Laboratoire de Météorologie Dynamique (LMD), in France, various groups have been working on dynamic and synoptic studies using Meteosat data, including:

- convective-cloud-evolution studies, in which growth or dissipation is expressed in terms of a 'convection index', derived from the relative evolution of a quantity proportional to the cloud volume contained in a given picture area (from successive images); these measurements can be compared with in-situ measurements such as radar data;
- cloud-motion studies, carried out using three different techniques, fully automatic, interactive and optical, the last being the most frequently used. ESOC cloud-motion vectors have been compared with those obtained with the optical correlator, called a 'nebulometer', for three specific time periods, with good results;
- water-vapour image comparisons with synoptic phenomena observed from the ground; these show relationships between dark patterns on the water-vapour image at mid latitudes in Europe and profiles of water-vapour content and temperature deduced from an analysis of the synoptic field. Relationships between different kinds of water-vapour patterns and meteorological phenomena such as fronts and jet streams are also being investigated.

The meteorological-film project group at the central institute for film and video activities at the Freie Universität, Berlin, has been studying wind extraction from cloud displacements using a sequence of three digital Meteosat infrared images and applying several enhancement techniques. Cyclone development has already been studied, and emphasis is presently being put on mesoscale motion field analysis to obtain a detailed picture of one particular cyclone.

Numerical weather prediction
Because space meteorology is a very young science but is growing very quickly, meteorological satellites have been considered by some as the final solution to all weather-prediction problems, whereby the ground observing system would become redundant. At the same time, many have held more negative attitudes towards the advantages that could be expected from satellite data. As usual, the truth has proved to lie somewhere in between. It has now been recognised that the ground observation system will always be necessary, at the very least as a calibration tool for satellite data, but that the newer satellite data are becoming more and more important to the users.

A very careful analysis of the impact of satellite data on numerical weather prediction has been carried out at the European Centre for Medium-Range Weather Forecasting (ECMWF) in Reading, in the course of the Global Weather Experiment. The Experiment, which was 'operational' from 1 December 1978 until 30 November 1979, consisted of making two different forecasts over the same period, one based on all available data – conventional and satellite – and the second made without satellite data. The conventional-plus-satellite data forecast included temperature soundings from the Tiros-N and NOAA-5 polar orbiters and cloud-motion vectors from the five geostationary satellites including Meteosat (see article on page 26).
The data-assimilation experiments started on 13 January 1979 and the observations were analysed every six hours. Although the forecast differences were rather small during the first couple of days, they became substantial after eight days. That particular weather situation provided an example of successful prediction of a characteristic blocking high-pressure pattern over the Atlantic. The blocking high on day 8 was not predicted in the case of no satellite data.

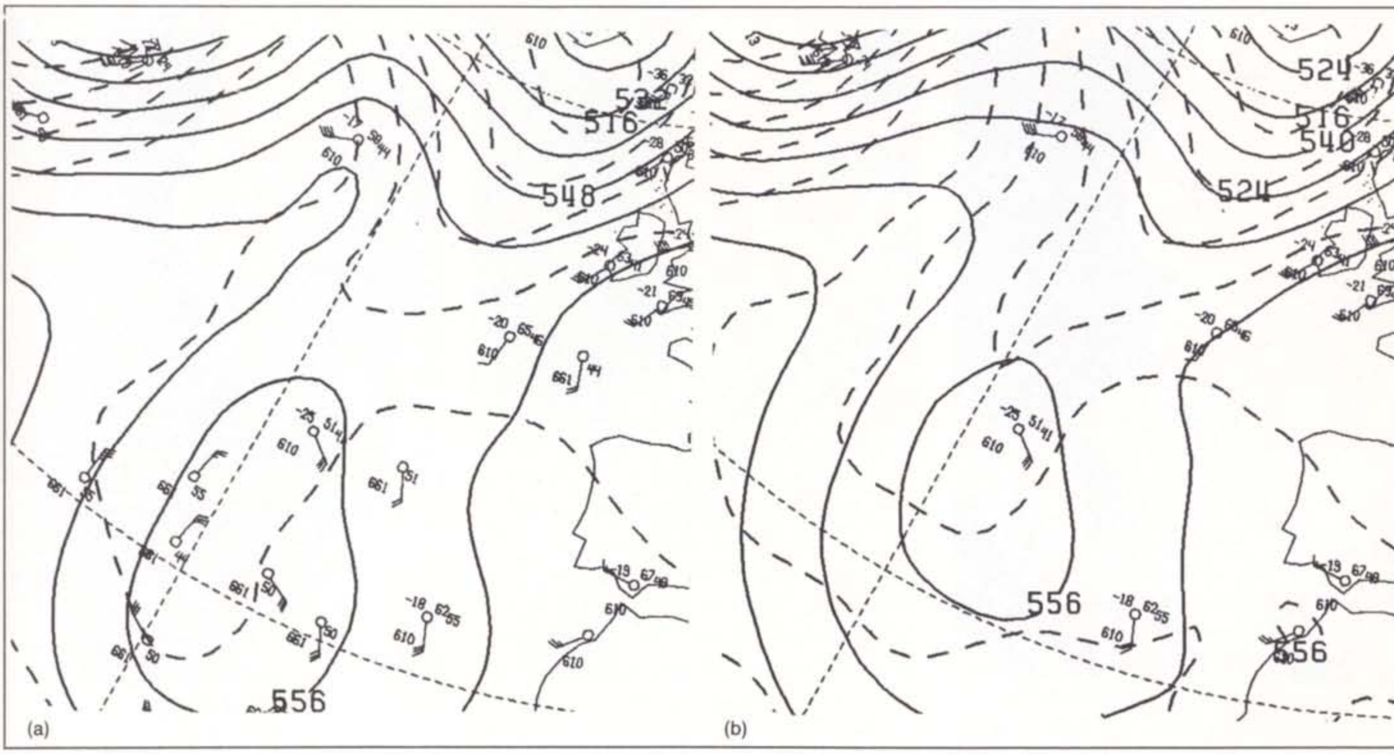
The results of that exercise suggest that it may be necessary to extend the integrations to more than three days and it may also be that the cloud wind observations are carrying more information than the satellite temperatures derived from polar-orbiter satellites such as Tiros-N.

A similar experiment has been carried out at the Swedish Meteorological and Hydrological Institute (Fig. 3). Aside from considerations concerning the impact of the particular numerical model used, a number of other facts emerged here when comparing results with and without satellite data, and with and without radiosonde data; namely

- if radiosonde observations are removed from the data set, a lot of information is lost about short waves; when satellite observations are taken away, almost no information about the short waves is lost, but the loss of information about the longer waves is significant:
- the satellite data over ocean areas are particularly valuable;
- the effective use of satellite data is strongly dependent on the data-handling design of the numerical analysis scheme, and consequently users have to make special efforts to take maximum advantage of these new data.

Climatology and radiation budget
Although it is too soon to expect conclusive results within these fields of research, after just two years of Meteosat operation, some tentative conclusions are

Figure 3 – Geopotential analyses (500 mb) over the Atlantic for 16 January 1979 at midday
(a) Analysis from SAT-experiment (conventional + satellite data)
(b) Analysis from NOSAT-experiment (no satellite data)
Satellite wind observations, including Meteosat cloud motion vectors, are indicated by '661' and the height of these winds are given in centibar. Radiosonde observations are indicated by '610'



suggested by the users' reports.

Particular interest has been shown in the water-vapour-channel data by scientists, with whole-earth-disk images being made available in that band several times per day for the first time.

Various groups at Laboratoire de Météorologie Dynamique are working on Meteosat water-vapour data and one has been investigating the use of water-vapour radiance values to improve two-dimensional infrared/water-vapour histogram performance in distinguishing high, semitransparent clouds from medium-level opaque clouds. To improve the method, cirrus radiation has been measured at the same wavelengths with LMD's scanning radiometer ARIES, on board a NASA aircraft. Applying the experience gathered, a better water-vapour channel calibration is being constructed by comparing the radiometer data with the values obtained by a transmission model applied to radiosonde data.

First results of studies on water-vapour radiation in cloud-free areas have already shown a possible relationship between the emergent energy and the amount of water vapour above 500 mb, as well as between that energy and the layer that contributes most to the radiance, the layer's height generally varying between 5 and 7.5 km.

The same data-calibration problems are being investigated by researchers at DFVLR's Institut für Physik der Atmosphäre, in Oberpfaffenhofen (Germany) where a comparison between Meteosat data and high-altitude aircraft data has been carried out to study diurnal variations in radiation-budget components with high spatial resolution.

Ground-truth measurements to derive in-orbit calibration values for Meteosat data have been performed by a team from Hamburg University's Meteorologisches Institut. Some preliminary results from the comparison of the Meteosat-derived data with these ground- truth measurements have shown promising agreement between sea- surface-temperature values measured in- situ and those derived from Meteosat infrared data, and they also indicate a possibility for calibrating Meteosat visible data.

Within the field of global-radiation determination and cloud statistics, there are a number of groups working at the Institut für Geophysik und Meteorologie at Cologne University. Radiative-transfer computations for realistic atmospheric models have been made to determine the absorption and reflection properties of the earth-atmosphere system, with the aim of deriving diurnal variations in global radiation, radiative balance and cloudiness by using high-resolution processed Meteosat visible and infrared images. Investigations of deep cumulo-nimbus clouds around the tropics have also been carried out because of the role these clouds play in the vertical transport of mass energy and water vapour.

At the Laboratory for Planetary Atmospheres at University College London, studies have been made of the

Figure 4 – Dynamics of the frontal edge of the southern Benguella upwelling regime. Three chronological Meteosat images, enhanced in the ocean temperature part of the thermal-infrared spectrum, show the growth and eventual instability of the upwelling front during March 1978 (courtesy of J R E Lutjeharms)

17 MARCH 1978

22 MARCH 1978

24 MARCH 1978

earth's radiation budget based on Meteosat data. The diurnal radiative properties of the earth's atmosphere-surface system have been investigated by measuring the diurnal variation in the infrared channel radiance and the reflected visible radiance from the digital images. One of the first results to emerge was that the diurnal mean values evaluated from sun-synchronous satellites can be affected by errors over certain types of surface, due to the impossibility of measuring some parameters more frequently than once per day.

A team at the University of Munich's Meteorologisches Institut has been studying atmospheric turbidity from scattered radiation measurements using special sets of Meteosat images, for which the amplification gain of one of the two visible channels was set to a particular value. Each image was therefore formed by a sequence of couples of horizontal lines, one with the normal gain value, the other with a very high gain value. The extraction of turbidity parameters from the images is performed in a complex fashion to take into account the optical and physical properties of both aerosols and atmosphere. The method appears promising, particularly for future air-pollution-monitoring applications.

Studies of the ground's thermal behaviour can provide useful information about subsoil characteristics and soil moisture. The CITHARE project, carried out at the Centre National d'Etudes Spatiales (France), was conceived mainly to produce soil thermal inertia and humidity cartography over Africa from geostationary-satellite imagery. Extraction of reflected solar flux and emitted thermal radiation at half hourly intervals from Meteosat images has allowed data on soil radiation dynamics and thermal inertia values to be computed. Together with albedo, these data seem to be an aid in the further preparation of geological maps.

Studies of the equatorial ocean-current system kinematics and dynamics have been started at Cologne University also using Meteosat-derived sea-surface temperatures and near-surface cloud-motion vectors.

Extensive use of Meteosat data is also being made by several scientific teams working in oceanology. A number of phenomena not previously noted have been observed, and in other cases the regular acquisition of Meteosat images has facilitated the extended study (in time) of known features of the circulation. Daily contrast-enhanced thermal infrared images have been studied at a National Research Institute for Oceanology (Fig. 4). Observations of upwelling regimes off the Southwest African coast are very important for atmosphere/ocean interaction studies and for economic-benefit appraisal, e.g. for the local fishing industry. It has been clearly recognised that the satellite imagery of the upwelling has revolutionised oceanological thinking on its extent and dynamical characteristics, particularly for the southern upwelling front in this region. Fairly successful correlations between the extent of upwelling and wind stress have been made using enhanced infrared Meteosat images.

Hydrology and agriculture

Many researchers have been working on

the application of Meteosat data to hydrological activities, one of the most interesting topics being the quantitative evaluation of precipitations by cloud-analysis techniques.

At Laboratoire de Météorologie Dynamique radar experiments have been used for ground truth in trying to find a relation between Meteosat cloud observations and precipitations; doppler radars have also been employed. An attempt to correlate Meteosat and radar data on the formation of squall lines and thunderstorm activity has been made at the National Physical Research Laboratory in one South African country.

Meteosat/radar image-processing equipment is planned by the Swiss Meteorological Service. Data from 33 automatic weather stations, two digital meteorological radars, and Meteosat pictures received and digitised by an analogue receiving station, are to be processed and combined by a minicomputer, and then disseminated to users. The data are also to be used to estimate temperatures, cloud liquid-water contents, rain intensities and cloud-top heights.

The British Meteorological Office is also mounting an ambitious programme to merge Meteosat and radar data on interactive displays with animation facilities, to provide high-quality short-period forecasts of clouds and rainfall.

Several teams working in conjunction with the United Nations Food and Agriculture Organisation (FAO) have been applying Meteosat data in hydro-meteorological research for agriculture. The most important projects involve the estimation of precipitation from satellite images, and the application of image monitoring to areas with significant environmental hazards and disasters, such as the desert-locust problem.

As far as the rainfall evaluation from satellite images is concerned, a number of different techniques have already been developed, the two most attractive being attributed to R.A. Scofield and V.J. Oliver (USA), and to E.C. Barrett (UK). The first technique, designed for convective clouds, is based mainly on the anvil growing speed and on the temperatures at the top of stormy clouds. The second technique is more general in its application and is useful for evaluating the rainfall from both convective and frontal clouds. It implies a manual interpretation of the satellite image, which leads to the extraction of a cloud parameter related to each possible rain-generator cloud pattern on a grid. A regression model is available for every kind of climate; by entering the cloud parameter and rainfall data of one station within the whole area covered by the grid, it is possible to estimate the amount of rainfall for each grid point where those clouds are present. If no stations are available, a climatological curve can be used. The method has been verified in the USA and it works satisfactorily. It has been used mainly to establish whether or not it was raining in a selected zone and how much rain was falling, in order to improve knowledge of precipitation for large areas where no stations are present. The application of the method to Meteosat images is being studied by FAO scientists.

Finally, as reported in ESA Bulletin No. 20, a research group of the University of Bayreuth in Germany has been using Meteosat images for ecological studies of desert plants on the southern border of the Namib desert in South Africa. A comparison of satellite images and the physiological and climatological data collected in-situ showed that the plants use a surprising mechanism to survive for several months in the absence of a ground water supply: they are able to increase the water-vapour content in their young leaves or shoots by drawing from cold and humid air under certain weather conditions.

Validation exercises and training facilities

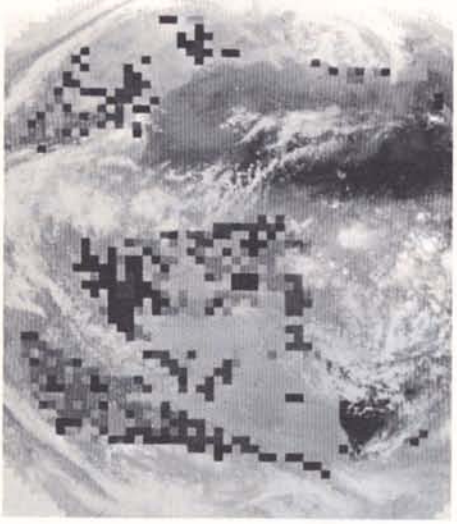
Though not precisely a field of research, studies performed by European meteorological services in cooperation with ESA to validate some satellite meteorological products merit mention here, particularly those for the cloud-motion vectors and sea-surface temperatures. Because all satellite-derived data are the final product of a very complex remote-sensing and processing chain, such verification exercises are absolutely necessary to establish confidence in the product and to improve its quality.

As far as the Meteosat cloud-motion vectors are concerned, several validations have taken place since April 1978 using a number of techniques, ranging from a comparison with data from co-located radar-tracked balloons, to that with winds derived from numerical models. The results have been satisfactory, the cloud-motion vectors appearing to be similar in quality to both the conventional winds and other satellite-derived winds.

This kind of study is very important and useful to the meteorological services also, because it can be considered an operational exercise through which the user gains confidence with the data and improves his expertise in using them. Facilities like films, movie loops and video cassettes, prepared with the express purpose of training students and young scientists can also be classed as a form of 'applied research' in the exploitation of Meteosat data.

Conclusion

The aim of this article has been to present an overview of just some of the many and varied research uses to which Meteosat data is being put, and the list that has been given is by no means exhaustive. In preparing this first and incomplete review, there have been extensive borrowings, sometimes verbatim, from the reports of Meteosat's users; due acknowledgement is made for all of these inputs.



Operational Production of Sea-Surface Temperatures from Meteosat Image Data*

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Although the sun is the fundamental source of energy that drives the earth's atmosphere, it must be remembered that the atmosphere is predominantly transparent to solar radiation and therefore the effective source of energy is the earth's surface, where solar radiation can be converted into thermal energy. Because the thermal capacity of the surface layers of the oceans is considerable, and the major part of the earth's surface is covered by water, global measurements of Sea-Surface Temperature (SST) are extremely important to meteorologists, particularly for numerical prediction models.

This article describes how the basic infrared radiance measurements made by the Agency's Meteosat spacecraft are being translated into sea-surface temperatures using an automatic computerised processing system, the manual editing process that takes place before the data are disseminated to the user, and an analysis of the first results compared with conventional ship measurements.

Prior to the advent of meteorological satellites SST data were only available from a sparse array of weather ships located at preselected positions, and from merchant ships sailing the world's shipping routes. There were therefore vast expanses of ocean for which very little information was available. Meteorological satellites carrying infrared radiometers have changed this situation substantially and data from polar-orbiting satellites have now been used to determine SSTs for some years. However, because infrared radiometers cannot 'see' through clouds, the coverage of SST data from such satellites is rather restricted.
The latest generation of geostationary satellites, such as Meteosat, have the advantage that, because they view the same area almost continuously, the probability of obtaining an unobstructed view of a particular area of sea surface is considerably increased. Meteosat now has the ability to provide the meteorological and oceanographic communities with SST measurements twice per day at over 2000 possible locations, with a grid spacing of about 200 km.

Automatic processing
Infrared images covering the Meteosat field of view consist of an array of 2500 × 2500 picture elements (pixels). After reception of the image, an image-conditioning process is applied which has the effect of translating the raw image into an ideal image, which can then be used for the determination of meteorological parameters. Before the calculation of these parameters, the image is subdivided into segments (32 × 32 IR pixels), which are centred at fixed geographical locations and which form the basic unit to be processed. Only segments within a 50° great circle arc of the subsatellite point are processed and the aim is to produce a sea-surface temperature for each 'sea' segment every 12 h. The temperature obtained is a skin temperature which is affected by atmospheric absorption; it is the determination of the atmospheric-absorption parameter that is one of the primary objectives of the entire automatic processing.

The processing can be divided into several stages, the first of which is common to all meteorological products derived from Meteosat images. It comprises a multispectral analysis of the segmented data by applying a cluster procedure to two-dimensional histograms and then identifying the peaks of the histogram with the aid of an interpretation table. The analysis is carried out for all available segments satisfying a given quality threshold and for all available radiometric channels. The first step of the analysis consists of constructing two-dimensional histograms for the infrared (IR)/visible (VIS) and IR/water vapour (WV) channels and defining all the peaks present in the histograms by considering them as a superposition of several Gaussian surfaces. For a given peak in the IR one-dimensional histogram, the mean value and its associated standard deviation are calculated and the contribution of the VIS data to the two-dimensional histogram is isolated by using the maximum and minimum radiance values of this IR peak. An analysis is then performed on the one-

* Latest status of Meteosats-1 and 2 reported on page 53.

Figure 1 – Two-dimensional histogram of visible and infrared radiances from a two-band image.

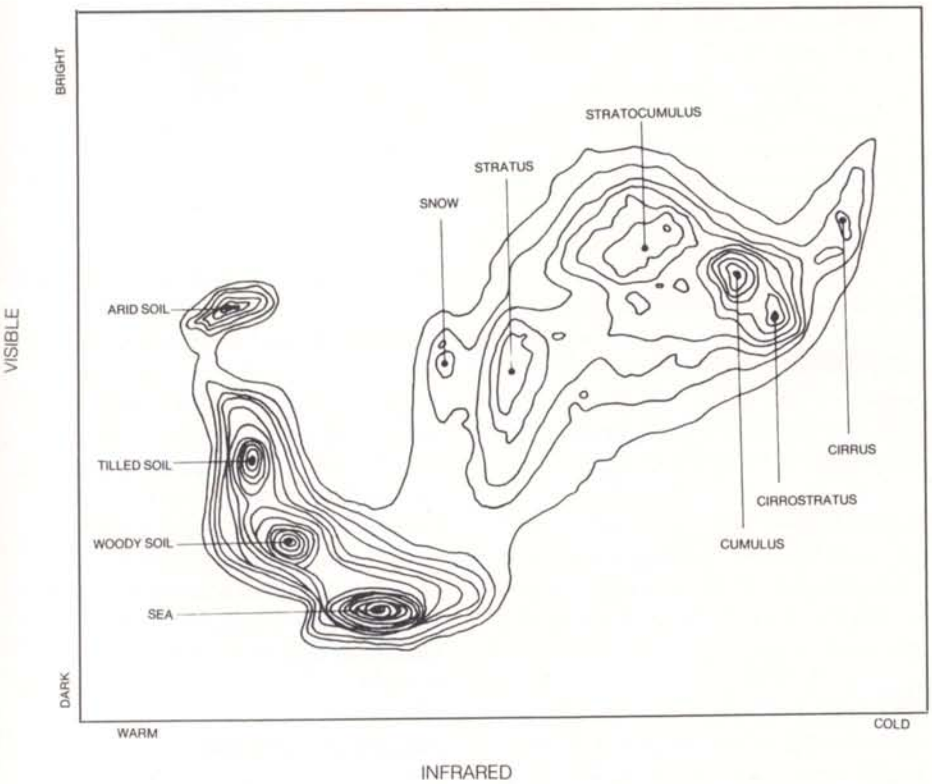
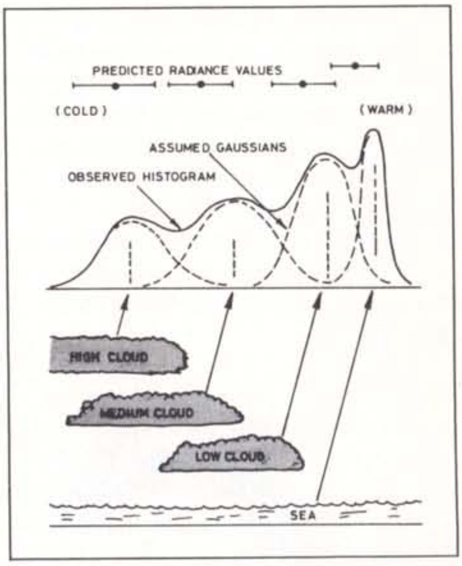


Figure 2 – Idealised schematic of the one-dimensional histogram analysis concept. The segment description gives the predicted radiances at the top of the diagram. The real segment yields an observed histogram, which is processed to produce the underlying Gaussians. These are then tied to the predicted values and hence to the physical sources



dimensional VIS histogram, which is created as a projection of the isolated portion of the two-dimensional histogram, to determine the VIS mean value and standard deviation of the recognised cluster. Having described the cluster in this way, it can be subtracted from the two-dimensional histogram to leave a residual histogram. This process is carried out for each peak found in the IR/VIS histogram. For the purpose of SST determinations, the WV channel is only used to distinguish between those peaks where the sea surface is under a completely cloud-free sky and those where it is under a very thin layer of upper cloud.

After each cluster has been extracted, its source of radiation is identified by comparison with a predefined interpretation table which contains the radiance characteristics of the objects that can be expected to be present within that segment, i.e. sea, land and clouds. This table is a function of climatology and a learning process is also involved. If a peak does not correspond to any reflector given in the interpretation table, it is merged into the remaining peaks in such a way that the mean value of the peaks is not altered. After completion of this analysis, each cluster present in the segment is identified and its radiance characteristics are known.

For any reflector identified as the sea, it is necessary to correct the raw radiance value to account for any contribution from other sources. First, if sunglint is present in any segment an adjustment is made based on known parameters for that segment. Secondly all segments have to be corrected for attenuation. This correction is based on a look-up table assigned to each segment and selected from a series of 58 look-up tables, which are in fact a set of previously defined model atmospheres. The actual table used for a segment is determined by comparison with the forecast atmospheric characteristics for that segment. The forecast profile is obtained from the USA National Weather Service's global twelve-hour grid-point forecast. At this juncture the sea-cluster description and its associated corrected IR radiance value are known. These SST intermediate results are generated every hour for each 'sea' segment, but in practice the temperatures derived are made available only twice per day. Because of the large amount of data to be processed and the difficulties involved in separating the sea from other reflectors, it is necessary to perform a manual quality control of the automatically calculated results prior to coding, dissemination and archiving.

Manual editing

The manual editing of the SST results is undertaken by trained meteorologists using the MISS IDA system (Meteorological Interactive Software System for Image Data Analysis)* available at ESOC (Darmstadt). The purpose of the quality control is to allow the deletion from the data set of any anomalous results calculated by the automatic processing, and it is performed twice per day, nominally for 00 UT and 12 UT. Up to twelve generations of SST

* Described in detail in ESA Journal No. 3, 1979, pp 215-232.

results may be available at any one time, but the operator only controls the latest eight sets of results extracted in the 12 h window immediately prior to the nominal times. Since the diurnal variation in sea-surface temperature is small, the final data set produced is effectively a combination of results from the previous eight hours, although only the latest acceptable result is presented for each segment.

The SST results calculated on the mainframe computer are formatted into product-independent records for transmission to the MISS IDA system, and manual editing is performed on each set of available hourly results over the whole area where SST calculations have been made. The meteorological operator is provided with a considerable amount of information to help him in his analysis, some of which is automatically displayed, such as

- the number of segments for which a result has been calculated
- the maximum and minimum radiance values within a set of results (raw values and values corrected for atmospheric absorption)

Other information can be selected for display as necessary; for example

- the area of sunglint within an image
- the area of segments that have been processed.

The meteorologist has available facilities for both spatial and temporal analysis of the SST results in relation to the prevailing meteorological situation. The comparison between the results and IR or VIS images is achieved by superimposing the two data sets and scaling them on a common resolution. The superposition of results on images that have a better resolution is possible by making use of various facilities (e.g. a zoom effect) available in the image-display hardware. During the analysis the operator checks, for each set of results,

- the consistency of the SST results with cloud-free areas (low stratus cloud or fog is difficult to detect automatically)
- areas where sunglint occurs (incorrect sea clusters may be generated in these areas)
- results in segments containing sea and land (these can be contaminated by land radiances).

Throughout this checking process the operator can delete temperatures that appear incorrect, either for individual segments or for areas, simply by moving a cursor to the offending results and validating their choice with a light pen.

In parallel with the image-results comparison, the operator also performs a spatial analysis by comparing adjacent results in order to detect anomalous gradients.

The processing described above is performed on individual sets of SST results ordered in a reverse time sequence, i.e. the latest result set is processed first. This procedure is followed by a temporal analysis. As previously mentioned the temperature of the sea surface does not change quickly with time and therefore combining results computed on different images will improve both the quantity and quality of the disseminated data. The temporal analysis is performed by creating an animation loop with low-resolution, black-and-white earth images as a background superimposed with colour-coded SST results.

The animation is of only two steps, whereby the operator can compare a given set of results with a summary of all previously (later in time) accepted results. Commencing with the two latest sets of results, R_1 and R_2, the summary will consist of all accepted results from R_1 plus any results from R_2 that were not available for R_1. This summary is then animated against the results for R_2 and the operator is able to detect, and delete, those results from R_2 that are inconsistent with the results from R_1, on either a temporal or spatial basis. The same technique is repeated for each further set of available results by first combining it into the summary of all previously accepted results and then making the comparison.

At the end of this editing sequence, one is left with a set of results in which the latest acceptable result for each segment is both spatially and temporally consistent with its neighbours. At this point the operator has produced as complete an SST coverage as the data allows. The data is finally transmitted back to the mainframe computer where it is automatically coded into a standard World Meteorological Organisation (WMO) format for transmission in real time over their Global Telecommunications System (GTS) to all interested users.

Analysis of first results

Before discussing the results of the comparison of Meteosat SSTs with ship measurements, it is worth considering the types of SST data available to the meteorological community. Although the coverage by ship measurements on any particular day (Fig. 3) is limited, over a period of a few days a reasonable picture can be obtained. It is known, however, that for a given location the departure of the measured sea-surface temperature from climatology is small, usually only 1-2°C. These departures are nevertheless important, since the portion of the sea sampled by the ship's bucket has a heat capacity comparable with that of a significant portion of the atmosphere above it. Infrared-radiometer measurements, on the other hand, are representative only of the top few microns of the sea and one should not a priori expect ship and radiometer measurements to agree. In fact they appear to be reasonably well correlated, although it cannot be overemphasised that in order to be of use to meteorologists the satellite measurements must be demonstrated to be consistent with ship temperatures.

Figure 3 – Sea-Surface Temperature (SST) measurements received during a 24 h period, from ships within the Meteosat area

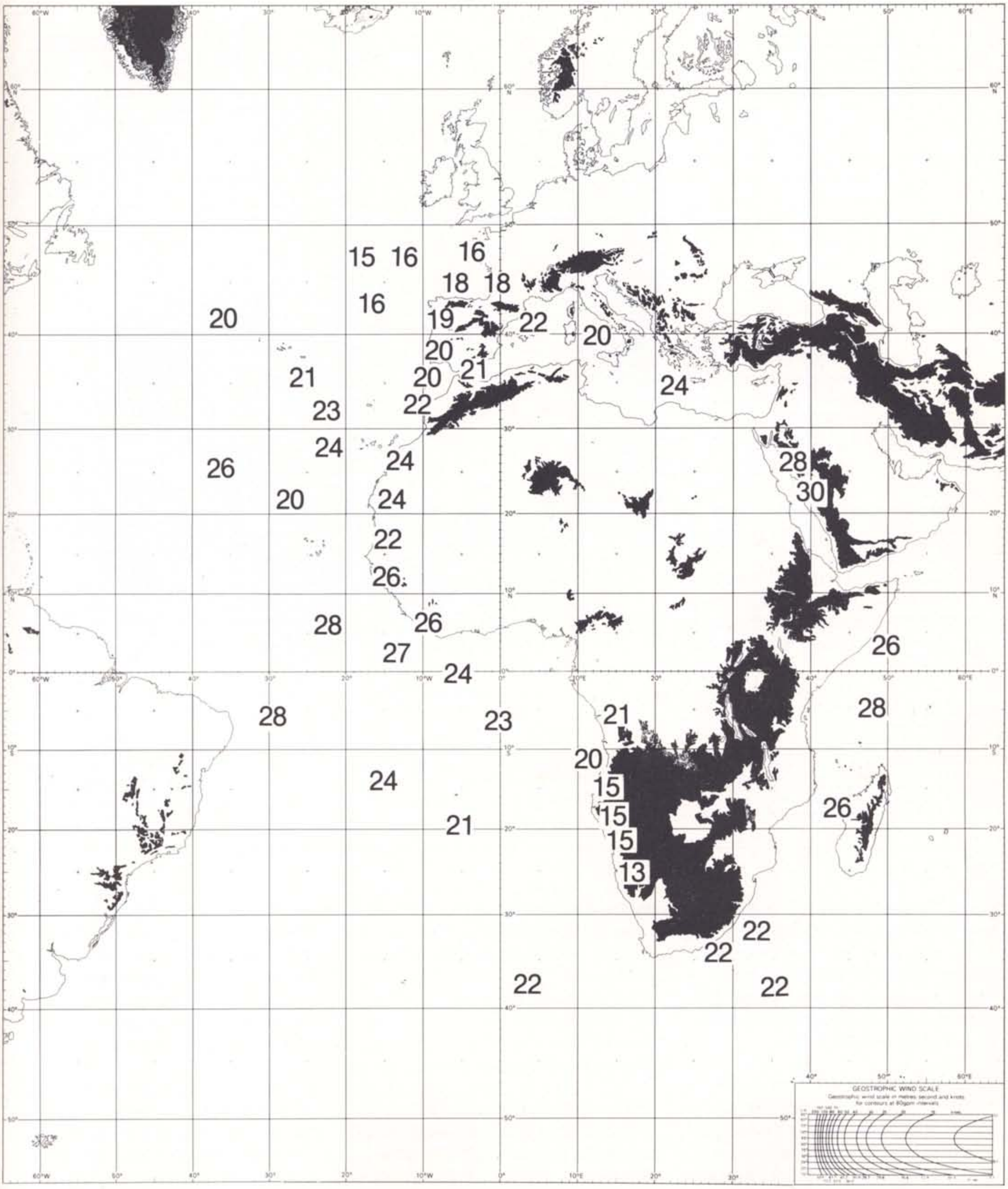


Figure 4 – Meteosat Sea-Surface Temperatures for 9 October 1979 at 12 UT (temperatures in whole degrees)

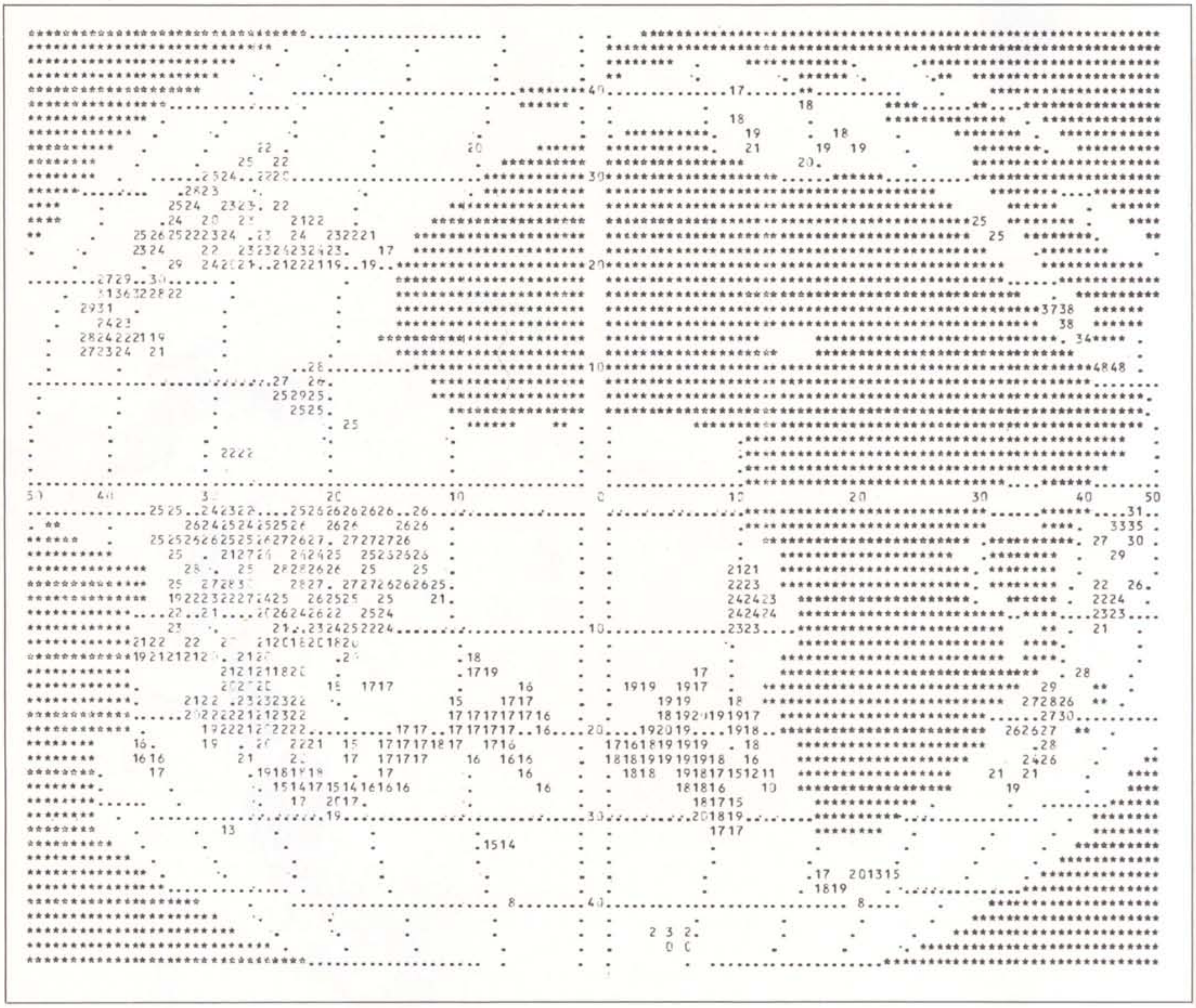


Figure 4 shows the output from a typical run of the Meteosat sea-surface temperature program. It is apparent that the satellite data is spatially coherent, which is encouraging, and that the coverage is a considerable improvement on that of the ship data.

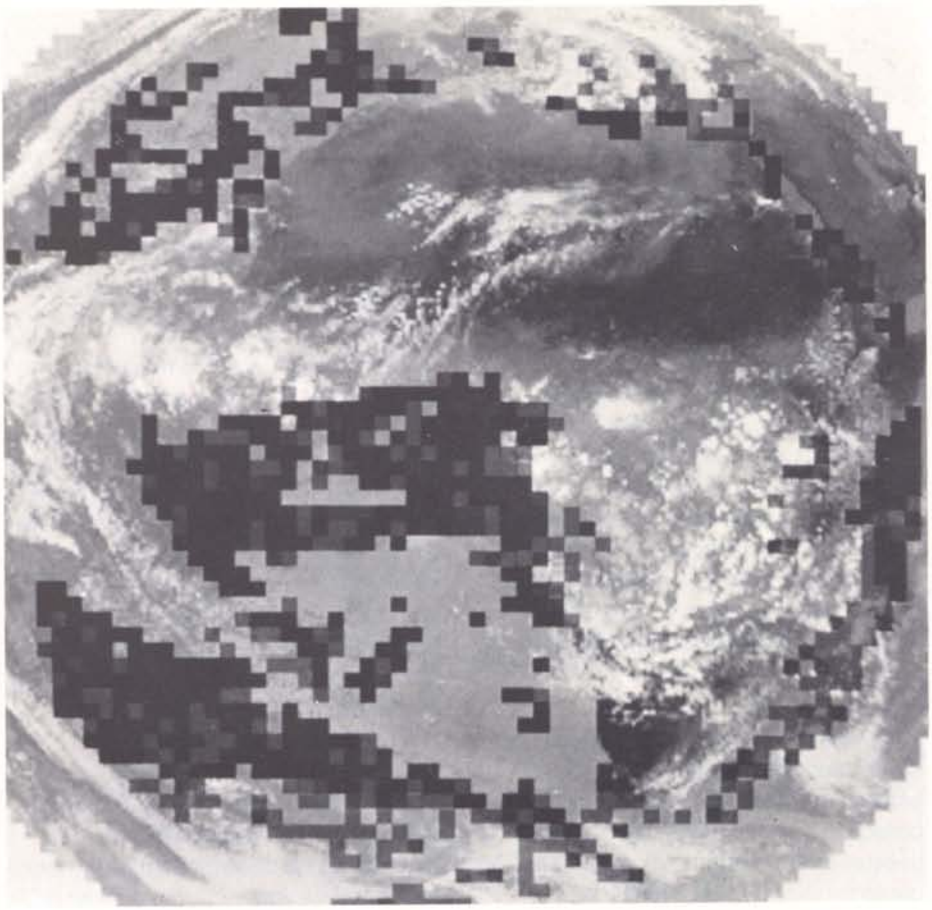
In comparing ship and satellite measurements, the ship data must be within the same segment as the satellite data or in one of the eight neighbouring ones, and within 24 h of it. For the data obtained during the first two weeks of October 1979, the field of differences (satellite minus ship) gave the following statistics:

Size of sample: 135
Mean: −1.07
Standard deviation: 2.26

The bias error can be attributed partly to an error in the absolute calibration of the radiometer and partly to the fact that occasionally a peak in the IR histogram is attributed to sea when in fact it is cloud, resulting in a sea-surface temperature that is much too low (such results should be eliminated during quality control, but with the large amount of data to be checked it is inevitable that some anomalies will go undetected).

The error in the absolute calibration of the radiometer is more difficult to explain because the calibration coefficient is calculated using ship SST measurements in such a way that the bias error should

Figure 5 — A representation of the positions at which sea-surface temperatures have been calculated from Meteosat images. The colours on the original product indicate the time of the determinations and the latest determination at a given location is always indicated.



be minimal. Of course, if the same set of ship measurements were used to calibrate the radiometer as were used to validate the data, one would get zero bias and this would be one way to proceed, using a different calibration coefficient for each run of the SST program. This is not done because it is considered that the internal black body on Meteosat provides a more reliable measure of the variation in performance on a day-to-day basis. The absolute calibration coefficient is therefore calculated offline and is used for a period of a few months, with a variable 'relative' calibration coefficient derived from the on-board black body.

However, during the period of the analysis Meteosat has been in eclipse around midnight each night and this has added a further complication. During eclipse periods the performance of the radiometer undergoes a diurnal variation, which means that SSTs generated from a single image at 02 UT are approximately 1°C warmer than those produced at 22 UT the previous day. Calibration using the internal black body takes place twice a day, although not at times that are representative (in terms of the diurnal variation) of the times when SSTs are calculated. This effect is a possible source of bias error, although it would account for less than 1°C.

Reducing the standard deviation to near zero is likely to prove more difficult. Contributory factors (in addition to those responsible for the bias error) are errors in the correction for atmospheric attenuation, errors in ship measurements, errors in radiometer measurements and, as mentioned earlier, the fact that the two temperatures are not necessarily compatible anyway. The main improvement that could be expected is a reduction in the atmospheric correction error, although this is not without difficulties.

It may be recalled that one of Meteosat's prime functions has been to serve as Europe's contribution to the First GARP Global Experiment (FGGE), which is an attempt by the world's meteorologists to observe the atmospheric state more accurately than ever before. For the purpose of this experiment certain target-accuracy requirements were laid down for some meteorological products; for SST this target accuracy was 0.2°C. However, the uncertainty in the atmospheric correction implied by the target errors for atmospheric temperature and water-vapour pressure in the atmospheric profile is at least 0.5°C over most of the Meteosat coverage area. It follows, therefore that if meteorologists require sea-surface temperature measurements from satellites that satisfy the FGGE specification, they will have to considerably improve their own ability to determine the atmospheric state.

The Meteosat Data-Collection System and Its Application*

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The systematic collection and processing of environmental data is essential to the acquisition of the knowledge that we need to make better use of our environment. Such activities are not new; they have been going on regularly, even on an international scale, since the early 19th century when synoptic meteorology began. Until the fairly recent past measurements have been limited to locations where humans could actually read instruments. The need for more data, even from inhospitable areas, has resulted in the introduction of automatic data-collection devices in telecommunications contact with the data user, via land lines or radio links. The Meteosat Data-Collection System (DCS) provides a space telecommunications link for the relay of the environmental data being collected.

* Latest status of Meteosats-1 and 2 reported on page 53.

The system
Because Meteosat is a geostationary spacecraft, it provides a link that is permanently available to all compatible data platforms within its field of view (about 80° of great circle from subsatellite point). This is an important advantage over the data-collection systems of near earth-orbiting satellites, to which the platforms are in view for only very limited periods.

The Meteosat Data-Collection System (DCS) has been designed to have the same characteristics as the data-collection systems carried by the other geostationary meteorological satellites presently in operation, namely the American NOAA/NESS Goes series and Japan's GMS spacecraft. This coordinated design approach permits the reports from Data-Collection Platforms (DCPs) carried on ships and aircraft moving from one satellite coverage area to another to be received and transmitted by any of the satellites in the network.

Meteosat is located over the equator and the prime meridian and therefore has line-of-sight contact with the geographical area shown in Figure 1. It is therefore able to communicate with mobile or static DCPs anywhere within this area.

There are three basic types of DCP:
- 'self-timed', which transmit their data at regular intervals based on an internal clock;
- 'interrogated', which transmit their data upon reception of a request signal from the satellite;
- 'alert', which transmit either a small amount of data or a request for interrogation when a particular parameter has been exceeded.

The DCPs transmit to Meteosat on any one of sixty-six 3 kHz reporting channels in the 402 MHz band. After conversion to the 1675 MHz band, the satellite retransmits the messages to its central ground station, in the Odenwald in Germany. There, the signals received are checked for quality before being transmitted to ESOC in Darmstadt for processing and distribution.

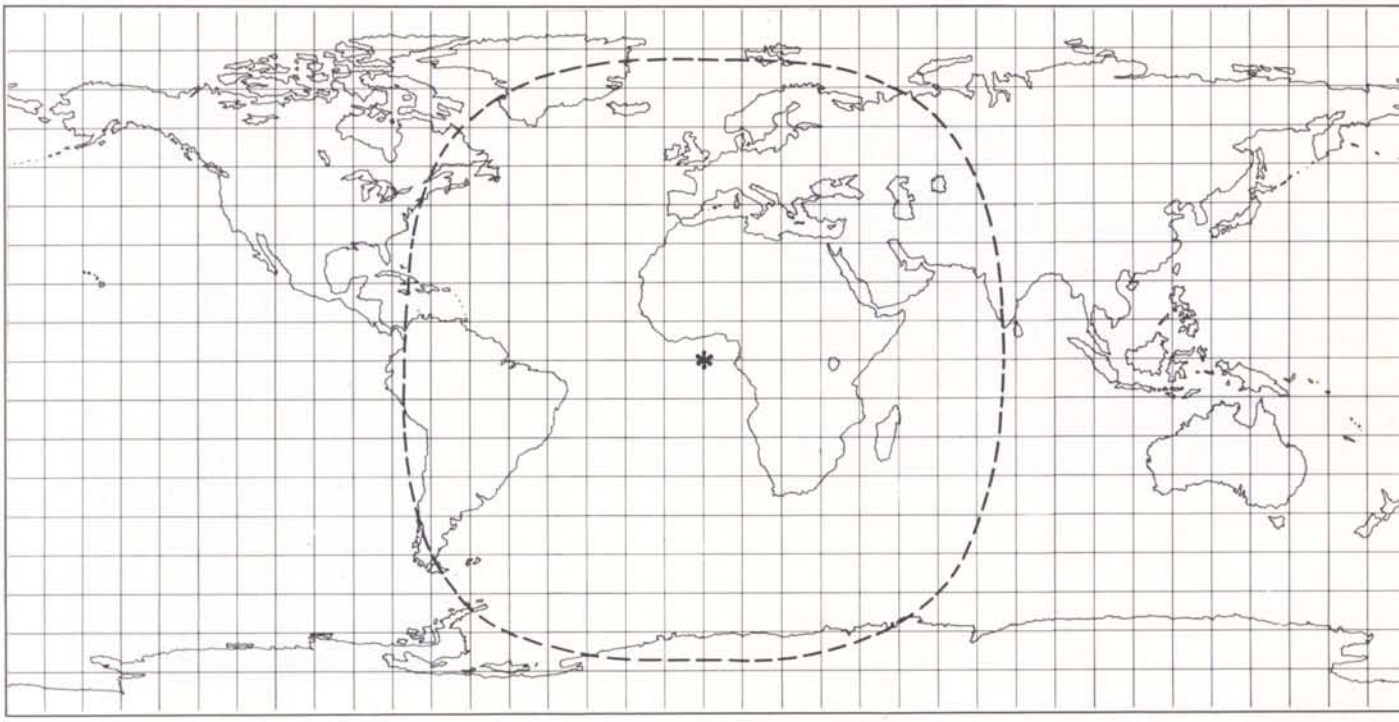
At ESOC, messages from self-timed and interrogated DCPs are collected, processed and disseminated every hour. Any message received from an alert DCP is processed immediately and made available for transmission to the platform's owners.

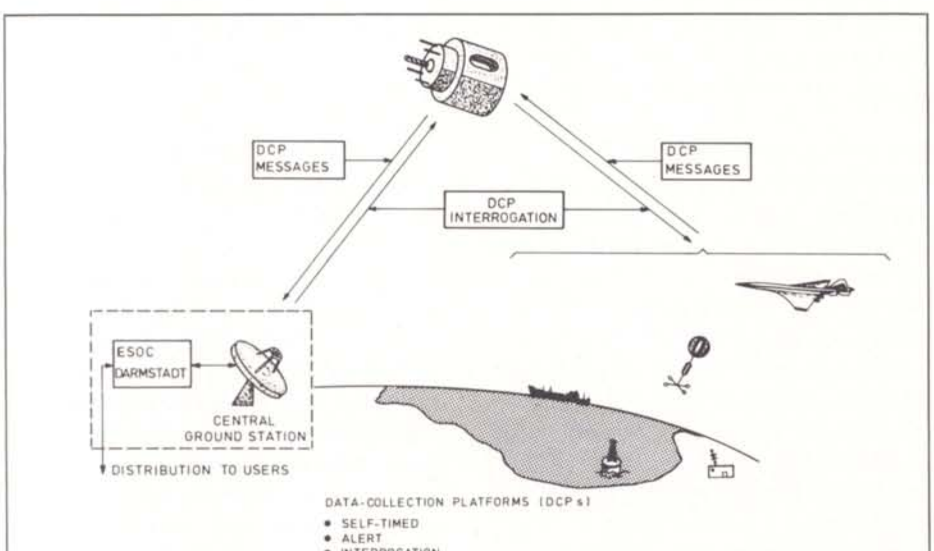
To interrogate a DCP, an interrogation message is generated in Darmstadt and sent to the Odenwald ground station. From there it is transmitted in the 2122 MHz band to Meteosat, which then retransmits the message on one of two possible frequencies in the 468 MHz band. The message includes the unique address of the DCP to be interrogated and only that particular platform will respond by transmitting the data it has collected.

The platform data received in ESOC are provided to the platform owners and others who wish to receive the data, either via the World Meteorological Organisation's Global Telecommunications System (GTS), by telex, or on magnetic tapes for non-real- time applications.

Figure 1 – Coverage area of the Meteosat Data-Collection System (DCS)

Figure 2 – The principle of the Meteosat Data-Collection System





The data-collection platforms

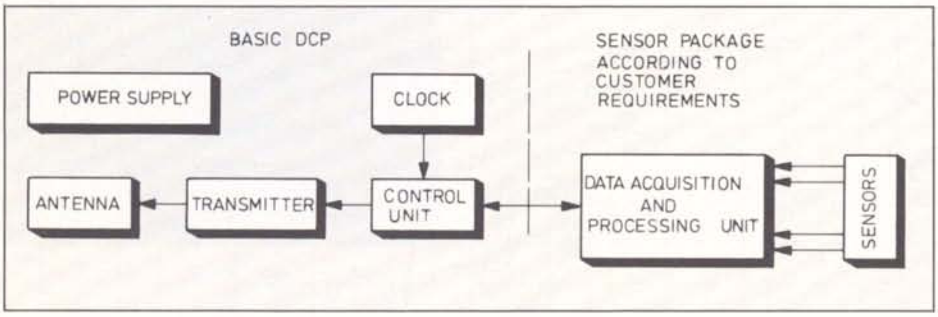
Before a DCP is allowed to use the Meteosat Data-Collection System (Fig. 2), it has to be 'admitted' to the system. This involves allocating an identifying address and reporting frequency to the DCP, and making arrangements for data handling and dissemination. A prerequisite for admission is that the DCP's radio set be type-certified and has therefore undergone a stringent test programme. This ensures that the platform will function successfully within the DCS, and more importantly that it will not cause interference to other system users, even under extreme operating conditions.

For platforms to be used solely within the Meteosat coverage agea, ESA conducts its own certification testing. For mobile DCPs, certification by any of the geostationary meteorological satellite operators is acceptable. Type-certified DCPs are commercially available from several European manufacturers.

The most commonly used type of platform is the self-timed DCP, which consists of the following modules (Fig. 3):

Sensors Data Acquisition & Processing Unit	providing the measurements to be transmitted
Clock Control Unit Transmitter Antenna	providing the radio contact with Meteosat at pre-determined times
Power Supply	either batteries or mains power, depending on location

Figure 3 – Modular composition of a self-timed DCP with data-acquisition facility



The platforms come in various shapes and sizes, but generally they are no more than 50 × 40 × 20 cm³ and weigh less than 20 kg, excluding sensors and antenna. The size of the antenna depends upon the transmitter output power needed from the DCP; with a 5 W transmitter, a 1.5 m-long helical antenna suffices.

The Meteosat DCPs are designed to deliver 100 bits of data every second. Although there are 66 channels available on the satellite, only six are currently in use. Individual messages are allowed to last up to 1 min, which is long enough to transmit up to 100 measurements.

The frequency with which self-timed DCPs make their reports depends on their particular application, but hourly and three-hourly reporting is the most common.

Current applications of the Data-Collection System

The Meteosat DCS can be used to gather a wide range of environmental parameters, but it is especially suitable for recording slowly changing parameters. A number of experimental and pre-operational applications are currently enabling users to assess the system's capabilities and to gain operating experience. The following four examples of current operations might serve to demonstrate the broad range of the System's applications.

Meteorological data collection at remote land sites

The operational weather service of the Danish Meteorological Institute is presently operating a network of meteorological observing stations in Greenland. The information gathered, in addition to being important to the local population, provides the air traffic on the North-Atlantic and polar routes with essential weather data. Two types of station are in use: a complex manned type requiring a utilities infrastructure, 220 V power supply, etc., and a purely automatic type. The latter are intended to be visited only once per year for maintenance purposes, are completely self contained, and can be operated in locations far from human habitation.

A manned station located near Danmarkshavn (76 N 18 W) has been relaying its data via the Meteosat DCS since mid-1978. The unmanned automatic stations are a newer development and the first two were installed in the summer of 1979 at Aputiteq (67 N 32 W) and near Kap Cort Adelaer (62 N 43 W). Both types of station provide three-hourly reports of air pressure, air temperature, air humidity, wind speed and wind direction. These reports are processed at ESOC and disseminated via the GTS to all meteorological centres that wish to receive them.

Meteorological and sea-state monitoring

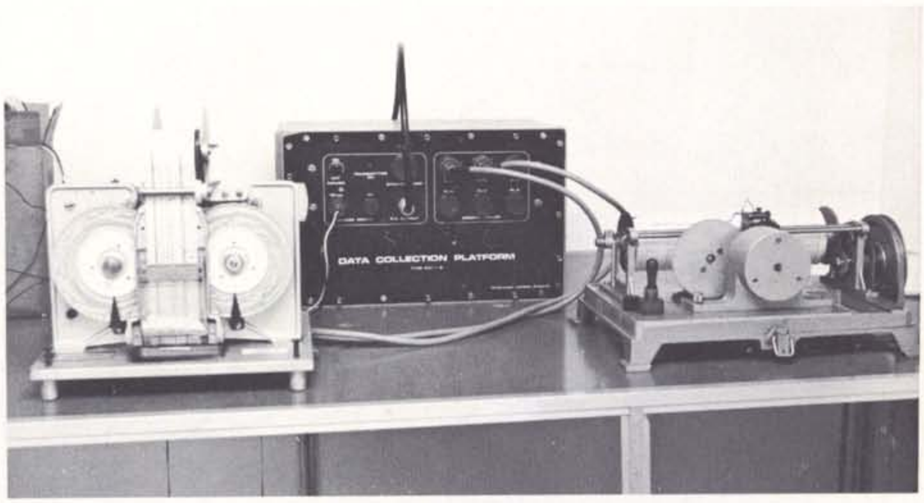
The German Hydrographic Institute (DHI) is operating a measurement network in the North and Baltic Seas. As a part of this network, a buoy that uses a Meteosat DCP for data transmission is to be anchored at 55° 05′ N and 6° 20′ E, making it the most remote station in the DHI network. The buoy itself is rather large, with a draught of 10 m, a diameter of 10 m, and a weight of 60 t (Fig. 4). It was originally conceived for use in a wide variety of oceanographic research projects, but its robustness makes it particularly suitable for permanent ocean-monitoring applications. The platform transmits air temperature and pressure, wind direction and speed, sea-surface temperature, water conductivity, depth and wave characteristics, as well as information on its own technical status (housekeeping). Except for the wave characteristics, the parameters undergo data reduction on board so that only averaged and maximum and minimum values are transmitted. The buoy transmits five minutes of data every three hours and, after some processing at ESOC, the measurements relayed to the DHI, the German Marine Weather Office (Seewetteramt), and to other users.

Figure 4 – North-Sea buoy carrying a Meteosat DCP

photo dhi

These data have several applications, in:
- forecasting sea conditions
- improving forecasting methods
- improving current-flow and wave-generation knowledge in the German

Figure 5a, b – Typical DCP installation for river monitoring



Bight and continental-shelf areas
- supporting fishery research and marine traffic.

They can also provide a basis for decisions concerning the dumping of waste products at sea and other questions of environmental protection.

Hydrological monitoring
The effective management of freshwater resources continues to be one of mankind's most pressing needs. Even areas with abundant rainfall require considerable information on precipitation, flow rates of rivers, etc. to ensure that their population's needs are met.

A pilot study has been initiated by the UK Water Data Unit to examine the effectiveness of using the Meteosat DCS for the transmission of hydrological parameters (Figs. 5a, b). Five DCPs have been installed:
- at Bewdly on the River Severn (rural area)
- at Derby on the River Derwent (urban area)
  Both of these DCPs are connected to level meters, which make measurements every 15 min.
- at Blackwell Bridge on the River Rother
  This DCP is connected to ultrasonic discharge-gauging equipment, which measures water flow rate (m^3/s) at 30 min intervals.
- at Cirencester
- at Loch Quoich, Scotland
  Both of these DCPs are connected to rain gauges, which provide measurements every 15 min. The Loch Quoich installation supports the control of a hydroelectric power station.

Although the five platforms make frequent measurements, transmissions to Meteosat are normally made only at a fixed time every day, when all the measurements of the previous 24 h are transmitted. After processing at ESOC, the data are transmitted via the GTS to provide the user with a daily record. Under normal conditions, this daily reporting is sufficiently frequent. Exceptionally, however, conditions can develop which require a rapid reaction on the part of the user. For this reason, all the Water Data Unit DCPs have an alert mode, so that when a measurement exceeds a predetermined level a warning is transmitted on a separate alert frequency. These alert messages are processed immediately at ESOC and routed to the user.

Meteorological data collection from aircraft
The ASDAR (Aircraft to Satellite Data Relay) programme is an example of the use of DCPs in mobile applications, a use that would probably not have been realised without international coordination of system design specifications. The National Oceanographic and Atmospheric Administration (NOAA, USA) is conducting this pre-operational programme to collect weather data from aircraft, using specially developed, air-certified platforms installed on wide-bodied Boeing 747 transport aircraft (Fig. 6). These platforms store data from the standard aircraft avionics systems and transmit them hourly during the flight. A special stripline antenna has been developed because, for obvious reasons, the conventional DCP directional antenna cannot be used in this application. The lack of directionality of this strip antenna has to be compensated by increased transmitter power, namely 80 W compared with the 5 W necessary for a fixed DCP installation.

Every hour, each ASDAR platform transmits one message containing eight stored reports (Table 1) identifying

Figure 6 – ASDAR DCP messages during the week 12-18 November 1979
..... Typical observation points
⑤ Number of times route flown during the week

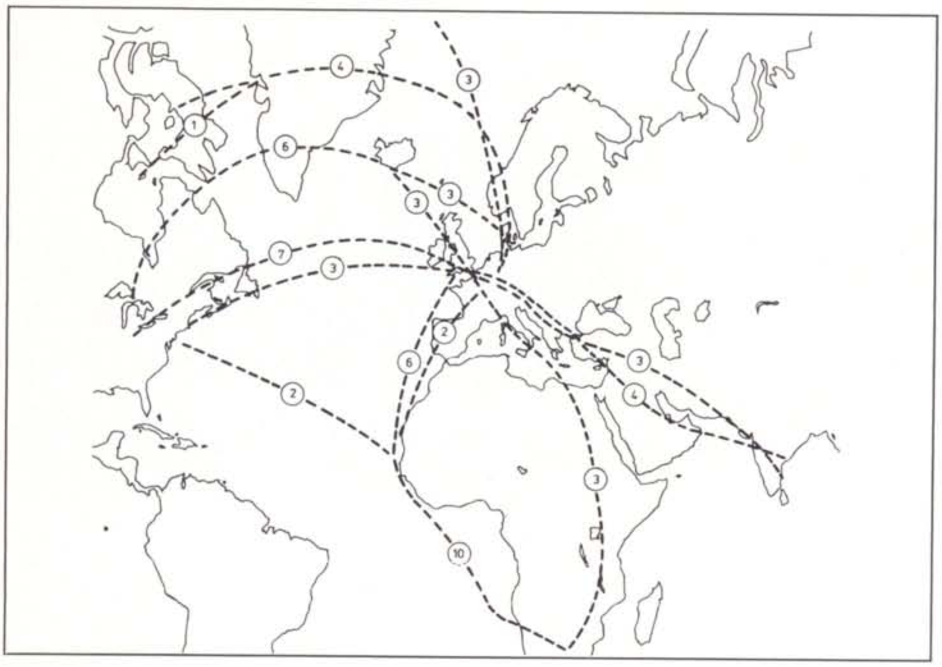


Table 1 – Example of ASDAR reporting

Aircraft identification PanAm/KLM	Aircraft position (degrees and minutes) latitude	longitude	Time of measurement (hour and minutes UT)	Flight level (hundreds of feet)	Outside temperature (minus deg. centigrade)	Wind direction (degrees of azimuth)	Wind speed (knots)
PA001Z	57 02 N	29 05 W	13 02	F 350	MS 37	259	081
PA001Z	57 04 N	27 32 W	12 54	F 350	MS 41	269	089
PA001Z	57 05 N	25 59 W	12 47	F 350	MS 37	279	086
PA001Z	57 05 N	24 27 W	12 39	F 350	MS 41	288	093
PA001Z	57 05 N	22 56 W	12 32	F 350	MS 41	295	096
PA001Z	57 03 N	21 26 W	12 24	F 350	MS 40	305	099
PA001Z	56 59 N	19 56 W	12 17	F 350	MS 43	310	110
PA001Z	56 54 N	18 26 W	12 09	F 350	MS 43	314	106
KL002Z	42 15 N	21 26 E	13 04	F 368	MS 48	308	011
KL002Z	42 52 N	20 19 E	12 56	F 368	MS 49	294	010
KL002Z	43 29 N	19 11 E	12 49	F 368	MS 50	293	014
KL002Z	44 09 N	18 04 E	12 41	F 368	MS 51	282	020
KL002Z	44 52 N	17 00 E	12 34	F 368	MS 51	276	025
KL002Z	45 32 N	15 51 E	12 26	F 368	MS 52	256	033
KL002Z	46 09 N	14 38 E	12 19	F 368	MS 53	246	037
KL002Z	46 53 N	13 36 E	12 11	F 368	MS 53	239	045

- the aircraft carrying the DCP
- aircraft position (latitude and longitude)
- time
- flight level (hundreds of feet)
- air temperature
- wind direction and speed.

ASDAR messages can be received by all the geostationary meteorological satellites and after retransmission to the ground stations they undergo standard processing before distribution on the GTS. The data can be used by all meteorological agencies concerned with forecasting for air transport.

Meteosat has been receiving ASDAR reports regularly since March 1978 and in the interim 20 aircraft have been equipped. Typically over 2000 messages per month are received and distributed by the Meteosat DCS.

The above examples of the DCS operations serve to illustrate the possibilities of the system. Important among the other platform installations are those on merchant ships. Several test programmes already carried out have demonstrated the DCS's effectiveness for marine use. This would seem to be a particularly fruitful area for DCS activity because, in the recent past, reductions in the size of ship's crews, coupled with poor reliability of high-frequency radio links, have considerably decreased the number of ship's weather reports available to the meteorological agencies.

Conclusions

The Meteosat Data-Collection System provides a reliable method of relaying low-speed environmental data from any location within the satellite's coverage area to a central point, from where it can be distributed to the platform's owner or to a community of users. The DCPs themselves are small and simple, conventional techniques being used in their construction. This results in relatively inexpensive units suitable for deployment in observation networks.

Several self-timed and alert platforms have already been purchased and put into operation by users. The interrogatable DCPs, however, have not yet found such favour with users, probably because these platforms are rather more expensive than the other types. A number of users are nevertheless currently studying the use of interrogatable DCPs for specialised applications.

Programmes under Development and Operations*

Programmes en cours de réalisation et d'exploitation

In Orbit / *En orbite*

	PROJECT	1979 – 1984	COMMENTS
SCIENTIFIC PROGRAMME	COS-B	OPERATION	1/2 YEAR ADDITIONAL OPERATIONAL LIFE POSSIBLE
	GEOS 1	OPERATION	LIMITED DATA ACQUISITION FROM 'OAKHANGER' STATION
	ISEE-2	OPERATION	2 YEARS ADDITIONAL OPERATIONAL LIFE POSSIBLE
	IUE	OPERATION	4 YEARS ADDITIONAL OPERATIONAL LIFE POSSIBLE
	GEOS 2	OPERATION	HIBERNATION MODE DURING LAST HALF OF 1980
APPL. PROG.	OTS 2	OPERATION	2 YEARS ADDITIONAL OPERATIONAL LIFE POSSIBLE
	METEOSAT 1	OPERATION	

Under Development / *En cours de réalisation*

	PROJECT	1979 – 1984	COMMENTS
SCIENTIFIC PROGRAMME	EXOSAT	MAIN DEVELOPMENT PHASE; LAUNCH; OPERATION	
	SPACE TELESCOPE	MAIN DEVELOPMENT PHASE; FM TO USA; LAUNCH	LIFETIME 11 YEARS
	SPACE SLED	DEF. PHASE; MAIN DEVELOPMENT PHASE; FSLP LAUNCH	
	ISPM	DEF. PHASE; MAIN DEVELOPMENT PHASE; LAUNCH	LIFETIME 4.5 YEARS
	LIDAR	DEF. PHASE	
APPLICATIONS PROGRAMME – TELECOM. PROG.	ECS	MAIN DEVELOPMENT PHASE; LAUNCH F1; DELIVERY F2; OPERATION	LIFETIME 7 YEARS
	MARITIME	MAIN DEVELOPMENT PHASE; LAUNCH A; B READY FOR LAUNCH; C READY FOR STORAGE; D READY FOR STORAGE; OPERATION	LIFETIME 7 YEARS
	L-SAT	DEFINITION PHASE; MAIN DEVELOPMENT PHASE; LAUNCH; OPERATION	LIFETIME 7 YEARS
APPLICATIONS PROGRAMME – E.O.P.	METEOSAT 2	INTEGR.; TESTING; LAUNCH; OPERATION	
	SIRIO 2	MAIN DEVELOPMENT PHASE; LAUNCH; OPERATION	
	ERS 1	PREPARATORY PHASE; DEFINITION PHASE; MAIN DEVELOPMENT PHASE	LAUNCH END 1985
SPACELAB PROGRAMME	SPACELAB	MAIN DEVELOPMENT PHASE; FU I AT NASA; FU II AT NASA; FLIGHT 1; FLIGHT 2	
	SPACELAB - FOP	PRODUCTION PHASE; INITIAL DELIVERY; INTEGRATION; FINAL DELIVERY	
	IPS	MAIN DEVELOPMENT PHASE; FU DEL. TO NASA	
	IPS - FOP	PRODUCTION PHASE; DELIVERY	TENTATIVE SCHEDULE ONLY
	FIRST SPACELAB PAYLOAD	EXPERIMENTS DEVELOPMENT/TESTING; INTEGRATION; FSLP LAUNCH	
ARIANE PROGRAMME	ARIANE	DEVEL. PHASE; LO 1; LO 2; LO 3; LO 4	
	ARIANE PRODUCTION	MANUFACTURE; L5; L6; L7; L8; L9; L10; PROVISIONAL OPERATIONAL LAUNCHES	

* Reporting status as per end November 1979/Bar valid per end December 1979.

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

Cos-B

Au cours des quatre derniers mois de l'année 1979, Cos-B a procédé à deux observations de cibles galactiques proches et à deux observations d'objets extragalactiques. Il s'agissait pour la première des deux cibles de la nébulosité du Taureau, observation qui a permis de compléter la couverture du ciel aux latitudes galactiques moyennes. Cette observation a été suivie d'une nouvelle observation (la troisième) du pulsar des Voiles (PSR 0833-45). Maintenant que la liste des sources de rayonnement gamma détectées par Cos-B s'établit à 29, il est encore plus évident que cet objet présente une brillance gamma exceptionnelle, étant trois fois plus brillant que son concurrent le plus proche. (Ceci est dû à sa position fortuite à proximité du système solaire % 1500 années-lumière seulement les séparent % sa luminosité gamma intrinsèque n'est en effet pas exceptionnelle.) Il peut donc faire l'objet d'une étude beaucoup plus détaillée que les sources typiques, comme le montrent les résultats publiés à la suite des deux premières observations de Cos-B. Depuis ces observations, les radio-astronomes ont enregistré une nouvelle variation transitoire de la fréquence de pulsation ('glitch') dont il sera intéressant de déterminer si elle a influé sur l'émission du rayonnement gamma.

Les dernières cibles extragalactiques observées ont été l'objet BL Lac Mk 421 et la radiogalaxie variable Cen A, qui figurait également parmi les premiers objectifs de Cos-B. Ces dernières observations ont commencé à la mi-décembre et se prolongeront au cours de l'année prochaine. La mission Cos-B se poursuivra en 1980 sous la forme d'un projet spécial en dehors du cadre du programme scientifique obligatoire. Au moment où nous publions ces lignes, l'Allemagne et les Pays-Bas se sont engagés à apporter le soutien voulu pour six mois d'opérations et on a bon espoir de pouvoir disposer d'un complément de ressources suffisant pour permettre la poursuite des opérations jusqu'à la fin de l'année. Aucun changement dans les performances du satellite ou de l'expérience n'ayant été signalé récemment, la poursuite de la mission apparaît tout à fait possible techniquement.

Geos

Expérience de dynamique de Geos-1
En mai 1979, une modification d'orbite importante a été opérée en vue de réduire la durée des longues éclipses dont Geos-1 devait être l'objet pendant la période d'été. On avait envisagé à l'origine d'effectuer cette correction en faisant fonctionner de façon continue l'un des petits propulseurs axiaux (pendant environ 45 mn). Des simulations sur calculateur du comportement dynamique du satellite au cours d'une telle manoeuvre ont cependant montré que celui-ci deviendrait très rapidement instable (après environ 5 mn), la composante, selon l'axe de rotation, du vecteur 'vitesse angulaire' ayant tendance à s'annuler et l'angle de nutation tendant vers 90°. La manoeuvre prévue fut donc effectuée par un propulseur radial en mode pulsé, ce qui n'entraîne aucune instabilité mais prend beaucoup plus de temps (environ 9 h).

Comme la prévision du calculateur avait révélé un phénomène très intéressant de dynamique susceptible de présenter un grand intérêt pour d'autres satellites (p. ex. l'ISPM), il a été décidé d'effectuer avec Geos-1 une expérience de dynamique ayant pour objet de vérifier les prévisions théoriques. Cette expérience a eu lieu en deux phases, les 27 et 28 septembre. Deux manoeuvres ont été effectuées, par application d'une poussée continue de la part du propulseur axial inférieur pendant respectivement 82 et 181 s. L'état dynamique du satellite a été suivi grâce aux deux accéléromètres de bord. Les résultats de ces expériences ont confirmé les prévisions théoriques avec une précision tout à fait satisfaisante, en particulier en ce qui concerne la décroissance prévue de la vitesse de rotation. Une description détaillée des expériences et de leurs aspects théoriques a été publiée dans le nº 4 (1979) du Journal de l'ESA.

Geos-2
On a effectué, depuis septembre, des manoeuvres de modification d'orbite et d'orientation et procédé en particulier à un déplacement du satellite en longitude de 37° Est, emplacement conjugué à Kiruna, jusqu'à 15° Ouest, position très proche de l'intersection de l'équateur géographique et de l'équateur magnétique. On a en outre fait tourner de 180° l'axe de rotation du satellite pour éviter l'ombre des mâts sur le réseau solaire au cours de l'hiver 1979/1980.

Depuis décembre, la procédure de restitution de l'orientation magnétique a été modifiée. L'ESOC utilise désormais les axes transversaux du magnétomètre à bobine exploratrice et le seul détecteur selon l'axe de rotation du magnétomètre à noyau saturé. La qualité des données est régulièrement vérifiée par comparaison avec la mesure de la gyrofréquence de l'expérience active sur les ondes.

Le Conseil a approuvé la prolongation du programme d'expériences de Geos-2 au-delà des deux années de vie utile prévues à l'origine et qui devaient s'achever en juillet 1980. Cette décision entraînera une mise en sommeil du satellite de juillet à décembre 1980 et sa réactivation en 1981 pour opérer en corrélation avec la nouvelle installation EISCAT.

ISEE

La mission continue de se dérouler de façon satisfaisante.

Dans le courant de l'année, les chercheurs des équipes scientifiques d'ISEE-1 et -2 ont demandé que les véhicules spatiaux soient placés à de faibles espacements, dans le but principalement d'étudier de plus près certains phénomènes intéressant la magnétogaine et la magnétopause. Il n'a pas été possible de réaliser de très faibles espacements, les plans orbitaux des deux satellites ne coïncidant pas; on savait par ailleurs que les plans orbitaux s'écartaient l'un de l'autre à une vitesse croissante. On a donc procédé à une série de manoeuvres de grande envergure pour réaligner les orbites et on en a profité à l'époque pour faire en sorte que, pour quatre orbites, les axes de rotation des véhicules spatiaux fassent entre eux un angle de 60° afin de réétalonner les magnétomètres. Ces manoeuvres ont été exécutées en octobre et novembre, à l'aide d'ISEE-2 exclusivement, sur la base de calculs effectués par l'ESOC; elles se sont déroulées sans incident et ont été parfaitement réussies. Le 11 décembre a eu lieu le 'rendez-vous', les véhicules spatiaux n'étant plus alors distants que de trois kilomètres à l'apogée (la distance de trois kilomètres avait été délibérément choisie pour éviter une collision). Il reste à bord suffisamment d'ergols pour trois autres années de manoeuvres normales d'espacement.

Cos-B

During the last four months of 1979, Cos-B made two observations of nearby targets in the Galaxy and two of extragalactic objects. The first of the former was the Taurus cloud complex providing additional sky coverage at medium galactic latitudes. This was followed by a third observation of the Vela pulsar (PSR 0833-45). Now that the list of gamma-ray sources detected by Cos-B extends to 29 members, it is even more evident that this object is exceptional in its gamma-ray brilliance, being three times as bright as its nearest rival. (This is due to its chance proximity – a mere 1500 light years – to the solar system: its intrinsic gamma-ray luminosity is not exceptional.) It can therefore be studied in much greater detail than the typical sources, as has been demonstrated by the published results of the first two Cos-B observations. Since they were made, radio astronomers have recorded another 'glitch' in its pulsations and it will be interesting to discover what effect this may have had on the gamma-ray emission.

The latest extragalactic targets are the BL Lac object Mk 421 and the variable radio galaxy Cen A, which was also one of the earliest targets of Cos-B. This latter observation was started in mid-December and will extend into the new year. The Cos-B mission is continuing in 1980 as a special project outside the mandatory scientific programme. At the time of writing, Germany and the Netherlands have committed sufficient support for about six months' operations and it is confidently expected that sufficient further resources will become available to permit continuation to the end of the year. There has been no recent change in the performance of either the spacecraft or the experiment, so that such a continuation appears to be completely feasible from a technical point of view.

Geos

Geos-1 dynamic experiment
In May 1979, an orbit manoeuvre for Geos-1 was planned in order to reduce the maximum eclipse durations expected during the summer period. It was initially intended to perform this manoeuvre by applying continuous thrust from one of the axial thrusters (duration about 45 min). However, computer simulations of the dynamic behaviour of the spacecraft during such a manoeuvre revealed that it would become unstable very rapidly (after about 5 min), the spin component of the angular-velocity vector tending to zero and the nutation angle tending to 90°. The planned orbit manoeuvre was therefore performed by a radial thruster in pulsed mode, which does not lead to any instability, but takes much more time (about 9 h).

Since the computer prediction showed a very interesting phenomenon in spacecraft dynamics that can be of vital interest for other spacecraft (e.g. ISPM), it was decided to perform a dynamic experiment with Geos-1 with the aim of verifying the theoretical predictions. This experiment was conducted in two steps on 27 and 28 September. Two manoeuvres were made with continuous thrust from the lower axial thruster for 82 s and 181 s respectively. The dynamic state of the spacecraft was monitored via the two onboard accelerometers. The results of these experiments confirmed the theoretical predictions with very satisfactory precision, particularly the predicted spin-rate decrease. A detailed description of the experiment and the theoretical aspects have been published in ESA Journal No. 4, 1979.

Geos-2
Orbit and attitude manoeuvres since September have included a longitudinal shift from 37° E, the conjugated location to Kiruna, to 15° W, a position very close to the intersection of the geographic and magnetic equators. A spin-axis reorientation by 180° has also been made to avoid boom shadows on the solar array during the winter of 1979/1980.

Since December, the magnetic attitude reconstitution procedure has been changed. ESOC now uses the lateral axes of the search-coil magnetometer and the only spin-axis sensor of the fluxgate magnetometer. The quality of the data is checked regularly by comparison with the gyro-frequency determination of the active wave experiment.

Council has already agreed to an extension of the Geos-2 experiment programme beyond its originally approved 2 y lifetime, which ends in July 1980. The decision calls for a hibernation between July and December 1980, and a reactivation in 1981 for operations in conjunction with the new EISCAT facility.

ISEE

The mission continues to run well.

Earlier this year the ISEE-1 and -2 investigators asked for small spacecraft separations, chiefly to investigate magnetosheath and magnetopause phenomena more closely. Because of the orbit-plane misalignment of these two spacecraft, very small separations could not be achieved; it was also known that the orbit planes were drifting apart at an increasing rate. For this reason a series of large manoeuvres was used to re-align the orbits and the opportunity was taken at this time to place the spin vectors of the spacecraft at a relative angle of 60° for four orbits to re-calibrate the magnetometers. These manoeuvres were carried out in October and November entirely with ISEE-2, on the basis of calculations made by ESOC, and were smooth and completely successful. On 11 December 'rendezvous' was achieved and the spacecraft were only about 3 km apart at apogee (3 km chosen deliberately to avoid collision). Enough propellant remains for about another 3 y of normal separation manoeuvres.

The subsystems of all three spacecraft are operating nominally, but there are some difficulties with some instruments. The first complete failure of an ISEE instrument has occurred on ISEE-1. On 11 September the 6 V supply line of the medium-energy particle detector dropped to 2 V and could not be brought up again, and so the instrument is dead. Whether this is due to a short or to jamming of the scanning platform of this instrument is not known.

One of the 'high-resolution' energetic-particle detectors on ISEE-3 has been found not to have the anticipated resolution, but fortunately the second instrument carried for the same purpose on this platform is operating better than expected.

Close cooperation between the investigators is continuing; Science Working Team (SWT) meetings are now being held every three to four months, with associated workshops. Investigators are delighted with the outcome of a magnetopause workshop organised in November, a number of papers from which are expected to join soon the large number of ISEE-based papers already in print.

Le fonctionnement des sous-systèmes des trois véhicules spatiaux est nominal mais certains instruments posent des problèmes. La première défaillance complète d'instrument s'est produite sur ISEE-1. Le 11 septembre le circuit d'alimentation 6 V du détecteur de particules de moyenne énergie a vu son rendement tomber à 2 V sans qu'il soit possible de le relever de sorte que cet instrument est maintenant hors d'usage. On ignore s'il s'agit d'un court-circuit ou du 'grippage' de la plate-forme assurant l'orientation de l'instrument.

On a constaté que l'un des détecteurs de particules énergétiques à haute résolution embarqué sur ISEE-3 n'offre pas la résolution escomptée mais il se trouve heureusement que le deuxième instrument installé à cette même fin sur la plate-forme fonctionne mieux que prévu.

Une étroite coopération se poursuit entre les chercheurs; l'équipe scientifique (SWT) tient maintenant des réunions tous les trois ou quatre mois ainsi que des séminaires sur des sujets connexes. Les chercheurs se déclarent extrêmement satisfaits du résultat du séminaire sur la magnétopause qui s'est tenu en novembre et on espère qu'un certain nombre de documents élaborés à cette occasion viendront bientôt grossir l'importante documentation déjà parue sur ISEE.

La durée de vie nominale d'ISEE-1 et -2 s'achève en octobre 1980. Les chercheurs ont sollicité des scientifiques responsables du projet qu'ils demandent une prolongation des opérations couvrant la période restant à courir de la mission d'ISEE-3. Pour ISEE-2, cette requête implique la prolongation des contrats de deux opérateurs de véhicules spatiaux au Goddard Space Flight Center.

OTS

OTS continue de fonctionner conformément aux plans et approche de son deuxième solstice d'hiver. EUTELSAT utilise de plus en plus ce satellite pour des essais et des démonstrations, le programme ESA d'essais orbitaux (OTP) occupant en contrepartie moins de temps; les essais à longs intervalles figurant dans ce programme et les mesures prévues dans le plan d'intéressement ont été menés à bien. Les résultats des essais thermiques effectués au moment de l'équinoxe d'automne ont montré que la dégradation thermique a été très faible au cours de l'année passée. L'analyse des résultats des transmissions d'une des antennes semble indiquer qu'une déformation mécanique s'est peut-être produite au cours du lancement, ce qui n'a qu'une faible incidence sur les expériences de propagation. La puissance totale fournie par les réseaux solaires est actuellement nettement supérieure au profil nominal et la consommation d'hydrazine reste nominale. Si ces tendances se confirment, la vie utile du satellite pourrait être de plus de cinq ans.

Meteosat

Secteur spatial
(Situation au 18 décembre 1979)
A 19 h 13 le samedi 24 novembre, c'est-à-dire le lendemain du deuxième anniversaire du début de son fonctionnement en orbite, le 'Dispositif de protection en cas de sous-tension' (appelé DBU) à bord de Meteosat-1 a coupé l'alimentation des charges non indispensables à la sauvegarde du satellite. Les missions principales de prise d'image et de diffusion ont été interrompues depuis cette date, alors que la mission relative aux plates-formes de collecte de données, dont l'alimentation est exclusivement assurée sur les circuits maintenus, se poursuit normalement.

D'après les essais détaillés auxquels a été soumis le satellite en orbite, le DBU semble présenter des oscillations internes. Dans les premiers jours où est apparu le défaut de fonctionnement, les oscillations n'étaient pas continues et l'on a pu remettre le satellite en service par télécommande pour de brefs laps de temps (~1 heure), avant que la reprise des oscillations ne fasse disjoncter le DBU. Ces derniers temps, les oscillations semblent malheureusement plus stables.

Les essais au sol qui ont été effectués sur montage de table indiquent que des oscillations peuvent apparaître dans le DBU lorsqu'un composant donné se détériore selon un processus particulier. Les essais au sol effectués sur un modèle du satellite ont également montré que de telles oscillations amènent le DBU à disjoncter.

Maintenant que l'origine de la défaillance a été localisée, on essaie de trouver un moyen permettant de s'affranchir du défaut de fonctionnement. Toutes les tentatives ont échoué jusqu'à présent. Les répercussions sur la conception du modèle F2 sont en cours d'analyse.

La nouvelle date de lancement de Meteosat/L03 fournie par Ariane est le 23 septembre 1980.

Le véhicule de qualification a récemment subi avec succès des essais de vibrations conformes aux niveaux modifiés d'Ariane. Le véhicule F2 sera soumis aux essais de vibrations de recette en janvier. Les nouvelles difficultés apparues avec le moteur d'apogée européen (MAGE) ont obligé à passer avec Aerojet un contrat pour un moteur de secours. Le contrat avec Matra pour l'approvisionnement d'un amortisseur de vibrations (VID) est actuellement en cours.

Exploitation
Les vecteurs de vent ont été établis chaque jour et livrés régulièrement aux utilisateurs en temps quasi-réel, ainsi que sur bandes magnétiques à titre de participation à l'Expérience météorologique mondiale. A l'issue de cette expérience d'une année, la contribution du système MIEC/Meteosat se montait à plus de 300 000 vecteurs de vent.

Les températures de surface de la mer et les néphanalyses ont été régulièrement diffusées sur le réseau GTS. Des essais étendus ont été faits en octobre et en novembre sur la diffusion de cartes de l'altitude du sommet des nuages et de cartes météorologiques. Des essais ont également été entrepris sur le renforcement du contraste et la diffusion de formats d'image à des resolutions horizontales différentes.

Démonstration/Expérimentation
La station secondaire d'utilisation de données (SDUS) est récemment rentrée d'Algérie. La DCP ESA se trouve actuellement à bord du navire marchand britannique CP Discoverer. La possibilité de campagnes DCP en Argentine, au Maroc et en Turquie est à l'étude.

Projet GOES-I
Au cours des quatre derniers mois, les signaux infrarouge ont été reçus par intermittence, par suite de difficultés à bord du satellite. Malgré cela, des données précieuses ont été fournies pour

The nominal lifetime of ISEE-1 and -2 ends in October 1980. The investigators have asked the project scientists to apply for an extension to cover the remaining lifetime of ISEE-3. For ISEE-2, this means extension of the contracts of two spacecraft operators at Goddard Space Flight Center.

OTS

OTS continues to operate according to plan and is now approaching its second winter-solstice season. Increasing use of the satellite for tests and demonstrations continues to be made by EUTELSAT, while the ESA scheduled Orbital Test Programme (OTP) occupies correspondingly less time; intermittent long-term OTP tests and incentive-scheme measurements have been carried out as planned. Thermal tests carried out at the autumn equinox indicated very little thermal degradation in the past year. Analysis of the transmission results from one of the antennas tends to point to mechanical distortion of the antenna, possibly during launch, but this is having little effect on the propagation experiments. Total power available from the solar arrays is currently well above the nominal expected profile and hydrazine consumption continues to be nominal. If these trends continue, a satellite lifetime in excess of five years should be possible.

Meteosat

Space segment (status as of 18 December 1979)
At 19.13 h on Saturday, 24 November, one day after the second anniversary of successful operation in orbit, the Undervoltage Protection Unit (the DBU) on-board Meteosat-1 switched off the nonessential loads on the satellite. The main missions of imaging and dissemination have been inoperative since that date, although the Data Collection Platform mission, which operates off only the essential loads, continues to function.

Detailed tests on the satellite in orbit have been made which show that the DBU seems to have an internal oscillation. In the early days of the fault this oscillation was not continuous and it was possible to command the satellite on for a short time ($\sim$1 h) before the oscillation started again and switched the satellite off. Recently the oscillation appears, unfortunately, to have become more stable.

Breadboard tests on the ground have shown that oscillation of the DBU can occur if a particular component fails in its nonpreferred failure mode. Tests using a satellite model on ground have also shown that such an oscillation will cause the DBU to switch the satellite off.

Having identified the cause of the fault, analysis is underway to see if there is any means by which the fault can be bypassed. So far, all attempts have failed. The implications for the design of Meteosat-2 (F2) are being analysed.

The new Meteosat/L03 launch date has now been given by Ariane as 23 September 1980. The qualification spacecraft was recently successfully submitted to modified Ariane vibration levels. The F2 spacecraft will be vibration acceptance tested in January. Further problems with the European apogee boost motor (MAGE) have necessitated placing a contract with Aerojet for a back-up motor. The contract with Matra for the procurement of a Vibration Isolator Device is now under way.

Exploitation
Winds were produced daily and delivered routinely to users in near real time and also on magnetic tape as a contribution to the Global Weather Experiment. At the end of this one-year experiment, the Meteosat/MIEC contribution amounted to over 300 000 individual wind vectors.

Sea-Surface Temperatures (SSTs) and cloud analyses were distributed routinely over the Global Telecommunications System (GTS). There have been extensive trials of the dissemination of cloud-top height maps and of meteorological charts during October and November. Trials on image contrast enhancement and of image format dissemination at various horizontal resolutions have also been undertaken.

Demonstrations/experimental activities
The Secondary Data User Station (SDUS) has recently returned from Algeria. The ESA DCP is now on the British merchant ship 'CP Discoverer'. Possible Data-Collection-Platform (DCP) campaigns in Argentina, Morocco and Turkey are under review.

GOES-I project
The infrared signal was received intermittently for the last four months due to a satellite problem. In spite of this, valuable data were provided to the First GARP Global Experiment (FGGE) monsoon experiment. The satellite was moved back under American control at the end of November.

Space Telescope

Solar array
As reported previously, a new requirement had to be introduced on the basis of overall Space Telescope system attitude considerations, to limit the torque exerted by the solar array on the Space Telescope during slew manoeuvres to very low values. Design efforts and breadboard tests led to the conclusion that a specification 0.1 Nm was technically feasible, and negotiations with NASA resulted in an agreement acceptable to all parties. One result is a four month delay in the solar-array schedule, but delivery is still compatible with NASA need dates. Several technical-interface meetings have been conducted for further detailing of interface agreements. Development tests on subsystems and components have started.

Faint Object Camera (FOC) module
To meet the demanding optical-performance requirements of the FOC, it has proved necessary to redesign the thermal-control electronics to achieve the requisite thermal stability of the optical bench, with the various external temperature-interface and power limitations.

The Preliminary Design Review was held in the second half of October. Although some areas were found to need further work, the review was generally successful. Manufacture of the structural thermal model is proceeding close to schedule.

Photon Detector Assembly (PDA)
The fixed-price contract for the Photon Detector Assembly has been signed. Testing of the structural thermal models of the detector head unit has been carried out as scheduled. The thermal tests demonstrated a satisfactory performance. The vibration test, however, showed that the stiffness of a carbon-fibre tube in the structure of the detector head unit has to be increased, and this work is presently in progress. System development tests have

l'expérience du FGGE (Première Expérience Globale du GARP) sur la mousson. La satellite a été remis sous contrôle des stations américaines à la fin de novembre.

Télescope spatial

Réseau solaire

Comme on l'a mentionné précédemment, il s'est avéré nécessaire, pour des raisons liées à la commande d'orientation du Télescope spatial, de limiter à des valeurs très faibles le couple exercé par le réseau solaire sur le télescope au cours des manoeuvres de pivotement. Les travaux effectués, tant au plan de la conception qu'à celui des essais sur montage de table, ont conduit à la conclusion qu'une spécification de 0,1 Nm est techniquement réalisable; les négociations menées avec la NASA sur ce sujet ont abouti à un accord d'ensemble acceptable à toutes les parties. L'une des conséquences de ce nouvel impératif est un retard de quatre mois dans le calendrier du réseau solaire, mais sa livraison reste encore compatible avec les dates auxquelles la NASA en aura besoin. Plusieurs réunions concernant les interfaces techniques ont eu lieu afin de préciser davantage les accords sur les interfaces. Les essais de développement portant sur les sous-systèmes et les composants ont commencé.

Module de la Chambre pour objets de faible luminosité (FOC)

Afin de répondre aux impératifs de performances optiques très stricts de la FOC, il est apparu nécessaire de revoir la conception de l'électronique de régulation thermique, afin d'assurer la stabilité thermique requise par le banc optique dans les limites à la fois étendues et variables de la température extérieure et compte tenu des restrictions d'énergie électrique.

L'examen de conception préliminaire a eu lieu dans la seconde quinzaine d'octobre. Bien qu'il soit apparu dans certains secteurs identifiés que des travaux étaient encore nécessaires, l'examen a été, d'une manière générale, couronné de succès. La fabrication du modèle 'thermique et structures' se déroule en suivant d'assez près le calendrier.

Détecteur de photons (PDA)

Le contrat à prix forfaitaire relatif au détecteur de photons a été signé. Les essais des modèles 'thermique et structures' de la partie détecteur se sont déroulés selon le calendrier prévu. Les essais thermiques ont apporté la preuve que les performances étaient satisfaisantes. Toutefois, l'essai aux vibrations a montré qu'il fallait augmenter la rigidité d'un tube en fibres de carbone dans la structure de la partie détection, et ce travail est actuellement en cours. Les essais de développement à l'échelon système ont progressé de façon satisfaisante en ce qui concerne le processeur de signaux vidéo assurant l'identification des photons individuels. Ces essais ont conduit à introduire une légère polarisation dans le tube analyseur, afin d'améliorer les caractéristiques du rapport signal/bruit et d'établir un seuil stable. Le calendrier du programme a pâti des grèves qui ont eu lieu au Royaume-Uni et en Italie, ce qui a entraîné des retards d'environ un mois dans les livraisons.

NASA

Le Télescope spatial a été affecté au lancement n° 32 de la Navette, prévu pour le 14 décembre 1983.

Traîneau spatial

Deux examens ont eu lieu au cours des derniers mois; ils ont confirmé la validité de la conception du système Traîneau et de ses sous-systèmes. L'examen de conception du système a eu lieu à l'ESTEC en août et l'examen des opérations du Traîneau, effectué par le SPICE/MSFC, a eu lieu en octobre. Ces examens ont conduit à des recommandations, portant sur des améliorations mineures, qui ont été depuis mises en application dans le programme.

La conception détaillée de tous les sous-systèmes est maintenant virtuellement achevée et la fabrication des pièces à commencé. Un modèle de table de l'électronique du Traîneau a été fourni à l'ESTEC à la date prévue pour les essais en boucle fermée avec un montage qui simule les pièces mobiles du sous-système mécanique. Ces essais ont montré que les performances en boucle fermée sont sensiblement égales à celles qui étaient escomptées, de sorte que les profils d'accélération à enregistrer dans la mémoire de l'électronique pourraient être gelés au moment fixé par le calendrier. Quelques anomalies ont été décelées dans les circuits électroniques et l'on s'attache à les corriger.

Maquette légère du siège du Traîneau fabriqueé par Marshall of Cambridge (Engineering) Ltd. (R-U).

Lightweight Sled seat mock-up made by Marshall of Cambridge (Engineering) Limited (GB).

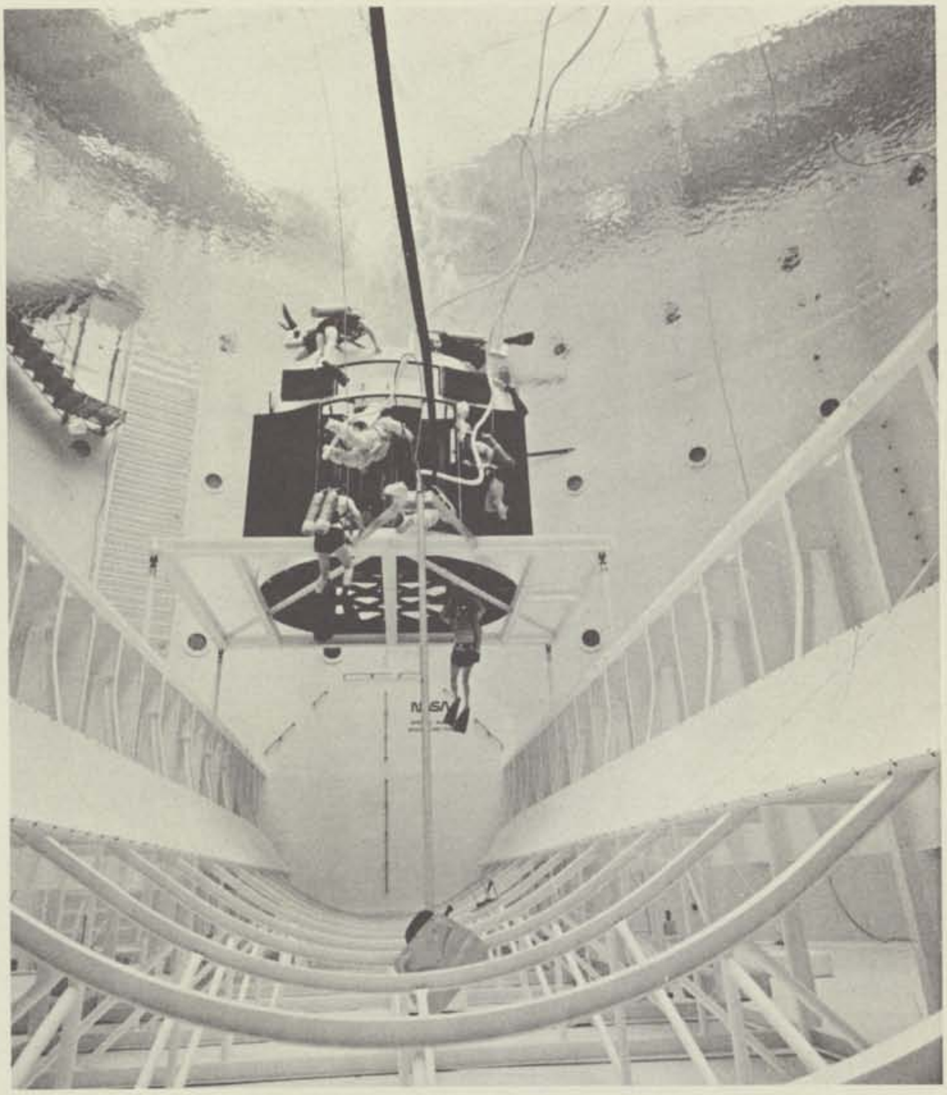
Une maquette légère du siège a été fournie à l'ESTEC pour définition finale des détails du câblage électrique et de l'interface ergonomique. Les essais de plusieurs pièces obtenues dans le commerce, telles que le moteur d'entraînement et certaines pièces de la transmission, ont fait apparaître la nécessité de modifier ces pièces pour les rendre conformes aux normes imposées. Les modifications seront effectuées par l'ESTEC en tant qu'activité supplémentaire, au cours des trois prochains mois.

Les difficultés relatives à l'obtention en temps voulu de pièces et de matériaux adéquats ont causé quelque soucis, le calendrier de ce programme étant très serré. Dans tous les cas, de tels problèmes ont pu être résolus dès qu'ils sont apparus et, dans certains cas, des solutions de rechange ont dû être trouvées afin d'éviter des retards de livraison. Les conséquences de cette situation, et la nécessité d'apporter quelques corrections de conception de détail, sont une source de retard possible dans la livraison des sous-systèmes. On étudie des calendriers possibles, le but étant de ne pas allonger la durée totale du programme.

confirmed good progress with the video signal processing unit for the identification of individual photons. They have also led to the introduction of a light bias in the camera tube to improve the PDA's signal-to-noise characteristics with a stable threshold.

The programme schedule has suffered from strikes in the United Kingdom and Italy, leading to delivery delays of about one month.

NASA
The Space Telescope has been assigned Shuttle launch number 32, currently scheduled for 14 December 1983.



Simulation of the in-orbit replacement of the Agency's Faint Object Camera in the Space Telescope. The test is being performed in the neutral buoyancy facility at Marshall Space Flight Center.

Simulation du remplacement en orbite de la chambre pour objets à faible luminosité dans le Télescope spatial. Cet essai s'effectue en immersion dans le caisson d'apesanteur du MSFC.

Space Sled

Two reviews during the past months have confirmed the adequacy of the design of the Sled system and its subsystems: the Sled System Design Review held at ESTEC in August and the Sled Operations Review conducted by SPICE/MSFC in October. These reviews produced recommendations for minor improvements, which have since been implemented in the programme.

The detailed design of all subsystems is now virtually complete and manufacture of parts has begun. A breadboard model of the Sled electronics unit was delivered to ESTEC on schedule for closed-loop testing with a rig that simulates the moving parts of the Sled mechanical subsystem. These tests showed performance to be roughly as expected, and the acceleration profiles to be stored in the memory of the Sled electronics unit could therefore be frozen on time. A few electronic-circuit anomalies were identified which are being corrected.

A lightweight seat mock-up was delivered to ESTEC for final definition of the electrical harness and ergonomic interface details. Tests on several commercially procured parts, such as the drive motor and some drive transmission parts, have shown the need to modify these parts to bring them to the standard required for the Sled. These modifications will be undertaken by ESTEC as an additional activity over the next three months.

Difficulties with timely availability of parts and materials have proved particularly bothersome for this programme because of the tight schedule. In all cases, these problems have been solved soon after becoming apparent, but occasionally alternatives have had to be found to avoid late deliveries. The net effect of these problems and the need for some detailed design corrections is likely to be a delay in subsystem delivery. Work-around schedules are being investigated with the objective of avoiding any extension in the overall length of the programme.

Experiment development is proceeding normally and interface definition is generally keeping pace with the evolution of design details. The European experiment development schedule contains one incompatibility, in that the French part is to be delivered late, a matter that is being re-evaluated by the parties responsible.

ECS

The ECS programme continues according to plan, with close-out of Critical Design Review actions proceeding satisfactorily. Development problems are being encountered with the travelling wave tubes from one of the two suppliers and steps may have to be taken to safeguard the schedule by accelerating deliveries from the other supplier for the first flight unit.

La réalisation des équipements d'expériences progresse normalement et la définition des interfaces va généralement de pair avec l'évolution des détails de conception. Le calendrier de réalisation des équipements d'expériences européens fait apparaître une incompatibilité en ce sens que la partie française est livrée tardivement. Cette question est actuellement réexaminée par les responsables.

ECS

Le programme ECS se poursuit conformément aux plans et le règlement des mesures à prendre à la suite de l'examen critique de la conception progresse de façon satisfaisante. La mise au point des tubes à ondes progressives de l'un des deux fournisseurs pose des problèmes et il sera peut-être nécessaire d'accélérer les livraisons de l'autre fournisseur pour la première unité de vol en vue d'assurer la tenue du calendrier.

A la demande d'EUTELSAT, deux grandes études techniques sont actuellement entreprises. La première étude a pour but d'accroître les capacités du satellite en période d'éclipse, de cinq à neuf canaux de télécommunication; la seconde porte sur l'analyse des possibilités d'utilisation d'ECS pour la fourniture de services spécialisés aux entreprises.

Marecs

L'examen critique de la conception, qui s'est déroulé début octobre, a abouti à l'approbation de la conception d'ensemble du satellite et il a été décidé de procéder à l'intégration du véhicule spatial Marecs-A sous réserve qu'une solution satisfaisante soit apportée à un certain nombre de problèmes. On prévoit de commencer l'intégration en décembre 1979, après livraison de la structure du module de service. Les essais de l'antenne et de la charge utile du modèle de développement se sont poursuivis et ont donné des résultats satisfaisants. La date de lancement d'Ariane L04 est actuellement fixée au 15 décembre 1980 et le programme du satellite Marecs-A est compatible avec cette date.

En ce qui concerne Marecs-C, la fabrication des unités du satellite qui sont critiques sur le plan des délais a commencé. De plus, les travaux conceptuels pour les deux propositions concurrentielles de stations sol dans l'Océan Pacifique (Japon et Nouméa) se sont poursuivis et l'évaluation technique définitive pourrait intervenir début 1980.

L-Sat

Le 29 novembre, le Comité de la Politique industrielle a approuvé les recommandations de l'Agence concernant le choix de British Aerospace comme contractant principal pour L-Sat, l'attribution du contrat principal de phase B1, une série de quatre contrats d'étude de charges utiles (diffusion TV à 12 GHz, services spécialisés à 12,5 GHz, balises de propagation à 20/30 GHz et répéteur 20/30 GHz) et un contrat pour des études de mission, représentant un total de 1,4 MUC. Le premier de ces contrats devait démarrer à la mi-décembre, la phase B1 prenant fin en avril 1980. Viendra ensuite la phase B2 qui débouchera sur une offre de phase C/D à l'automne, avec comme objectif le démarrage de la phase C/D avant la fin de l'année pour aboutir à un lancement à la mi-1984.

Le programme L-Sat compte maintenant sept participants: la Belgique, le Danemark, l'Espagne, l'Italie, les Pays-Bas, le Royaume-Uni et la Suisse. Le Canada a récemment demandé à participer à ce programme.

Sirio

Les derniers préparatifs et les livraisons sont en cours pour l'intégration du modèle mécanique du satellite Sirio-2. Ce modèle sera soumis à des essais de vibrations et de diagramme de rayonnement RF en février 1980; il sera ensuite remis en état pour devenir le modèle d'intégration, en introduisant des sous-systèmes électriquement représentatifs.

Le concept opérationnel de la phase d'exploitation de Sirio-2 (expériences MDD et Lasso plus un programme de soutien) a été présenté au Conseil directeur du programme de satellite météorologique le 7 décembre pour que des décisions soient prises sur les principes et le financement.

Maquette du satellite Sirio-2

Mock-up of the Sirio-2 spacecraft

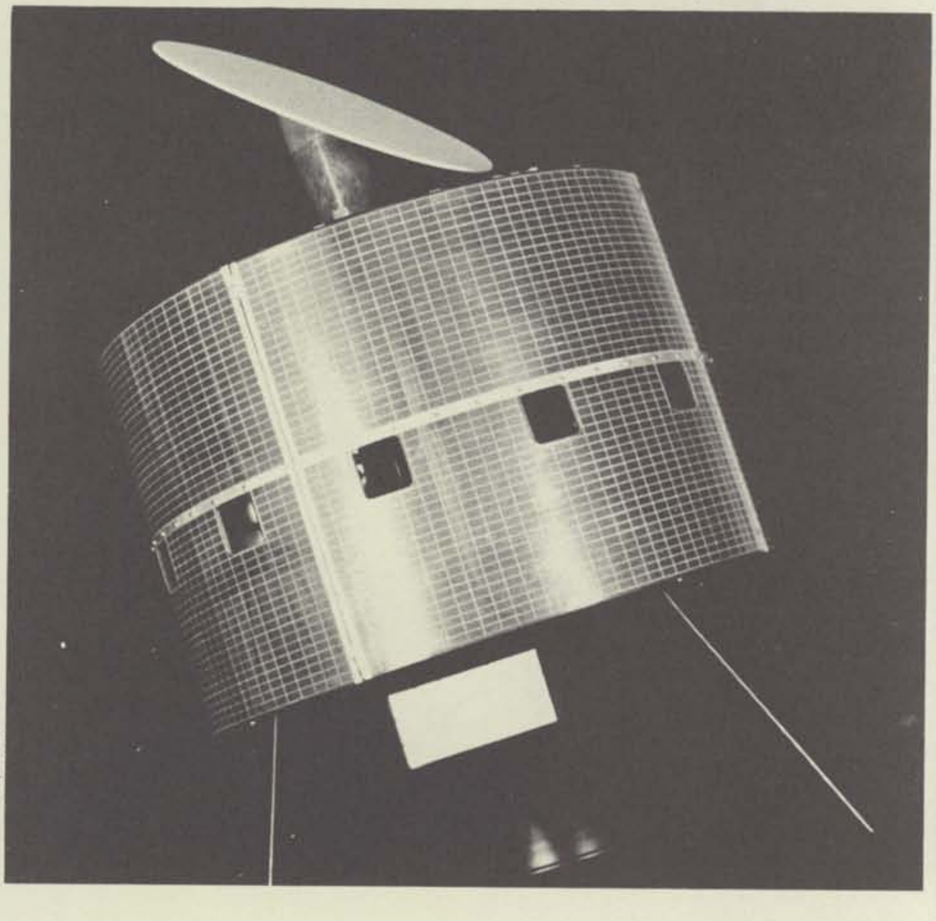


photo aerospatiale

Two major technical studies are presently being undertaken at the rquest of EUTELSAT. The first study is intended to raise the eclipse capabilities of the satellite from five communications channels to nine. The second is to analyse the possibility of using ECS for specialised business services.

Marecs

The Marecs Critical Design Review, held at the beginning of October 1979, resulted in the approval of the overall satellite design and allowed Marecs-A spacecraft integration to proceed subject to the satisfactory resolution of several problem areas. Integration was planned to commence in December 1979, after delivery of the service-module structure. Tests on the development-model antenna and payload have continued with reasonably good results. The Ariane L04 launch is now scheduled for 15 December 1980, and the Marecs-A satellite programme is compatible with this date.

With regard to Marecs-C, manufacture has started for those satellite units that are time-critical. Design work on the two alternative Pacific Ocean ground-station proposals (Japan and Noumea) has progressed and final technical assessment should be possible in early 1980.

L-Sat

On 29 November, the Industrial Policy Committee approved the recommendations of the Agency concerning the selection of British Aerospace as L-Sat Prime Contractor, award of the Phase-B1 prime contract, a series of four payload study contracts (12 GHz TV broadcast, 12.5 GHz specialised services, 20/30 GHz propagation beacons and 20/30 GHz transponder payload) and one mission study contract, amounting to a total of 1.4 MAU. The first of the contracts was to commence in mid-December 1979, with Phase-B1 ending in April 1980. Phase-B2 will follow immediately, culminating in a Phase C/D offer during the autumn, with the intention of a Phase C/D start by the end of the year, leading to a launch in mid-1984.

The L-Sat programme now has seven participants: Belgium, Denmark, Italy, Netherlands, Spain, Switzerland and the United Kingdom. Canada has also recently requested to join the programme.

Sirio

Final preparations and deliveries are in progress for the integration of the Sirio-2 spacecraft mechanical model. This model will undergo vibration and RF pattern tests during February 1980; it will then be refurbished to become the integration model by introducing electrically-representative subsystems.

The operational concept for the Sirio-2 exploitation phase (MDD and Lasso experimentation plus a support programme) was presented to the Agency's Meteorological Programme Board on 7 December for decisions on principles and funding.

Remote-Sensing (ERS) Programme

Remote-sensing system and payload studies are progressing according to schedule.

The results of the study on Canadian-specific mission requirements indicate that, in general, these will be met by the envisaged European remote-sensing satellite system.

Within the framework of the Remote-Sensing Preparatory Programme (RSPP), 14 contracts for critical technology items have now been awarded to industry. Canada is expected to join the Programme early in 1980.

Meetings of the Metric-Camera Working Group and of the Microwave Experiment Working Group took place in mid-November; the timelining of the experiments was reviewed on the basis of the new launch date of April 1982.

Spacelab

Development status
Preparations for the flight-unit subsystem tests have been completed and the assembly tests have been initiated. The engineering-model activities are presently concentrated on the testing of the operational software.

The major technical area of concern remains the Orbiter/Spacelab interface, where increased Orbiter dynamic loads during lift-off may require hardware changes, both in the Orbiter and Spacelab.

ESA and NASA have tried jointly to assess the cost risk of potential further changes up to the delivery of the Spacelab hardware, and then up to the first two Spacelab flights. In view of the tight budget situation, ESA is endeavouring to limit the European cost risk at least for the post-delivery period.

Instrument Pointing System
All Instrument Pointing System electronic and mechanical units are well advanced, except for the drive unit which failed its qualification tests. A major redesign has been initiated, causing the estimated delivery date for the IPS to be put back several months. The Critical Design Review for the IPS is now planned for mid-1980.

Follow-On Production (FOP)
Preparations for the Spacelab Follow-On Production contracts were successfully continued and are about to be concluded. ESA will act as NASA's procurement agent for European industry on a no-profit/no-loss basis. The hardware content will correspond approximately to one Spacelab flight unit to be delivered in the period 1982-1984. The deliverable hardware is valued at approximately 110 MAU (1978 prices). ESA's management costs will be charged separately to NASA.

Letters of contract were signed in July 1979 by NASA, ESA and ERNO for the procurement of long-lead items and effort to the value of approximately 1 MAU. The final Follow-On Production contracts were due to be signed in January.

The follow-on production for the Instrument Pointing System will have to be deferred until mid-1980, because the technical design definition is not yet sufficiently detailed.

Télédétection (ERS)

Les études sur le système et les charges utiles de télédétection progressent conformément au calendrier établi.

Les résultats de l'étude sur les impératifs de mission proprement canadiens indiquent que, d'une manière générale, ces impératifs seront satisfaits par le système européen envisagé de télédétection par satellite.

Dans le cadre du programme préparatoire de télédétection (RSPP), 14 contrats ont maintenant été attribués à l'industrie; ils portent sur des éléments technologiques critiques. On pense que le Canada se joindra au programme au début de 1980.

Des réunions du Groupe de travail sur la chambre photogrammétrique et du Groupe de travail sur l'expérience 'hyperfréquences' ont eu lieu à la mi-novembre; on y a passé en revue le graphique des expériences résultant de la nouvelle date de lancement fixée en avril 1982.

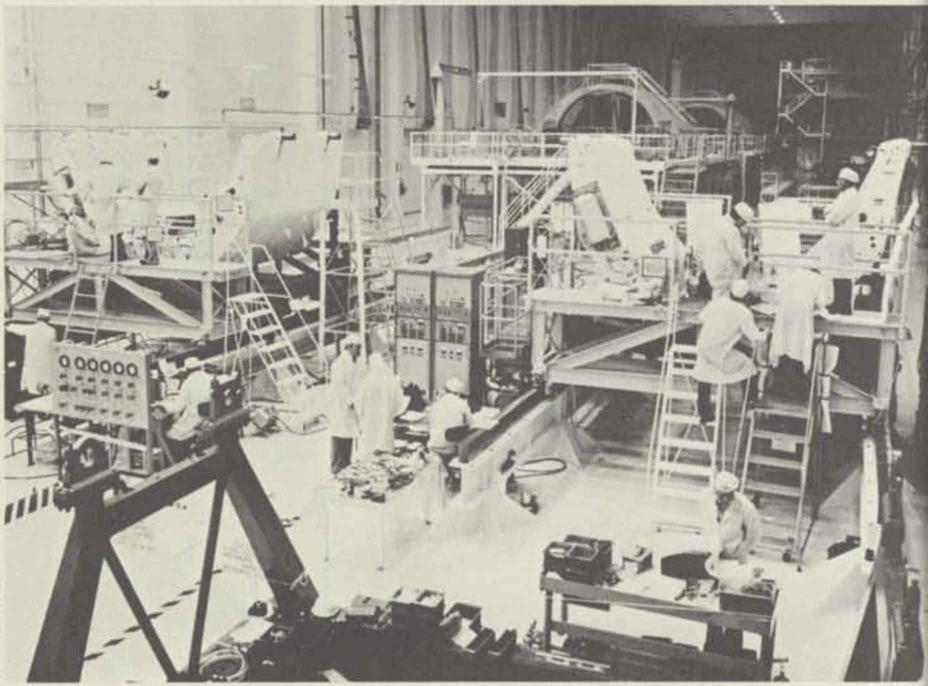


photo nasa

Vérification, par les techniciens du Centre spatial Kennedy, de deux porte-instruments du Spacelab livrés par l'ESA pour les vols OFT-2 et OFT-4 de la Navette spatiale.

Technicians at Kennedy Space Centre checking out two Spacelab Pallets delivered by ESA for Space Shuttle flights OFT-2 and OFT-4.

Spacelab

Programme de développement

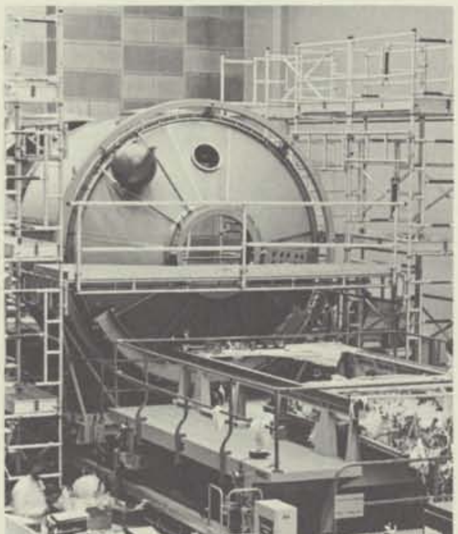
Les préparatifs en vue des essais des sous-systèmes du modèle de vol sont achevés et l'on a commencé les véritables essais d'assemblage. Les activités portant sur le modèle d'identification sont centrées sur l'essai du logiciel opérationnel.

Le principal domaine technique de préoccupation demeure celui de l'interface Orbiteur/Spacelab, les charges dynamiques accrues qui sont appliquées à l'Orbiteur pendant le décollage pouvant nécessiter des modifications de matériel, tant pour l'Orbiteur que pour le Spacelab.

L'ESA et la NASA se sont efforcées conjointement d'évaluer le risque financier entraîné par les modifications ultérieures potentielles jusqu'à la livraison du matériel puis jusqu'aux deux premiers vols. En raison de sa situation budgétaire délicate, l'ESA s'efforce de limiter le risque financier pour l'Europe, tout au moins pendant la période postérieure à la livraison.

Système de pointage d'instruments (IPS)

Tous les organes électroniques et



Le Laboratoire spatial en intégration à ERNO, Brême.

Spacelab integration at ERNO, Bremen

mécaniques du système de pointage d'instruments sont parvenus à un stade avancé, sauf en ce qui concerne le dispositif d'entraînement pour lequel les essais de qualification ont échoué. Une refonte importante de la conception est nécessaire; elle a été mise en route. Ceci reporte de plusieurs mois la date de livraison estimée de l'IPS. L'examen de conception critique de l'IPS est maintenant prévu pour la mi-1980.

Production ultérieure (FOP)

Les préparatifs concernant les contrats de Production ultérieure du Spacelab se poursuivent avec succès et sont sur le point de prendre fin. L'ESA jouera, à l'égard de l'industrie européenne, le rôle d'agent d'approvisionnement de la NASA, en appliquant le principe 'ni perte ni profit' pour l'Agence. La partie 'matériel' correspondra à l'équivalent d'une unité de vol du Spacelab à livrer dans la période 1982-1984. La valeur du matériel à livrer est d'environ 110 MUC (prix de 1978). Les coûts de gestion de l'ESA seront facturés à la NASA séparément.

Des contrats-lettres ont été signés en juillet par la NASA, l'ESA et ERNO pour des travaux et des commandes à long délai de livraison d'un montant d'environ 1 MUC. Les contrats définitifs de la FOP devraient être signés en janvier 1980.

La Production ultérieure concernant le système de pointage d'instruments devra être reportée jusqu'au milieu de 1980, la définition technique de la conception n'étant pas encore parvenue à un degré de détail suffisant.

Les relations privilégiées de l'Agence avec certains Etats non membres

M. Bourély, Conseiller Juridique,
Chef du Département des Affaires juridiques et de la Propriété intellectuelle, ESA, Paris

Avant de pénétrer dans l'immeuble où est installé le siège de l'Agence Spatiale Européenne, le visiteur ne peut manquer de remarquer les drapeaux qui surmontent l'édifice et, s'il a la curiosité de les compter, il en trouvera onze. Si notre visiteur entre ensuite dans la grande salle où se tiennent les réunions du Conseil, il verra, posées sur la table, plusieurs plaques, au nombre de quatorze, indiquant l'emplacement des délégations. Et si, perplexe, il interroge l'un des membres de l'Exécutif, celui-ci lui indiquera que la Convention portant création de l'Agence n'étant pas encore en vigueur, le nombre des Etats membres n'est en réalité que de dix!

Cette situation peut apparaître déroutante, mais elle trouve son explication dans les dispositions de la Convention de l'Agence qui prévoit non seulement que l'Agence est formée d'Etats membres, mais aussi qu'elle peut entretenir des relations particulières avec certains Etats non membres. Il est, certes, tout à fait habituel qu'une organisation internationale coopère avec des Etats non membres ou avec d'autres organisations internationales. Tel est, du reste, le cas de l'Agence qui est liée par plusieurs accords de coopération avec des partenaires extérieurs soit sur le plan général par des échanges d'informations ou de personnels, soit en vue de l'exécution de programmes particuliers.

Tout autre est le cas de certains Etats non membres qui participent au fonctionnement même de l'Agence et entretiennent avec celle-ci des relations privilégiées et dont la situation se rapproche de celle des Etats membres. C'est la Convention de l'Agence qui ouvre, ou plutôt qui élargit cette possibilité, et elle permet à chacun des Etats intéressés de jouir d'un statut adapté à son cas particulier.

Etats membres – Observateurs & Membres associés

Pour bien comprendre les règles juridiques qui gouvernent la question de la participation des Etats aux activités de l'Agence, il faut se souvenir que, depuis la signature, le 30 mai 1975, de la Convention portant création d'une Agence Spatiale Européenne, cette dernière n'a qu'une existence 'de fait' en attendant le moment où les conditions prévues pour son entrée en vigueur par son article XXI seront réunies, c'est-à-dire lorsque tous les pays qui étaient à la fois membres du CERS/ESRO ou du CECLES/ELDO auront signé et déposé leur instrument de ratification. Les pays en cause sont: la République fédérale d'Allemagne, le Royaume de Belgique, le Royaume de Danemark, l'Espagne, la République française, la République italienne, le Royaume des Pays-Bas, le Royaume-Uni de Grande-Bretagne et d'Irlande du Nord, le Royaume de Suède et la Confédération suisse. Comme il était prévisible que le processus de ratification de la Convention de l'ASE/ESA demanderait un assez long délai, les Plénipotentiaires qui l'ont signée le 30 mai 1975 avaient convenu que cette nouvelle Convention serait 'prise en considération dans toute la mesure du possible' afin que l'Agence, qui doit remplacer à la fois le CERS/ESRO et le CECLES/ELDO puisse dès le lendemain fonctionner 'de facto'. C'est sur cette base que l'Organisation Européenne de Recherches Spatiales a pris le nom d'Agence Spatiale Européenne et que la Convention portant création d'une Agence Spatiale Européenne a été appliquée aussi largement que possible. Toutefois, d'un strict point de vue juridique, la Convention du CERS/ESRO constitue encore le fondement juridique des activités de l'Agence, au moins dans certains domaines.

Tel est précisément le cas des dispositions relatives à la participation des Etats aux activités de l'Agence: la Convention du CERS/ESRO restant applicable jusqu'au jour de l'entrée en vigueur de la nouvelle

Vue de la Salle du Conseil de l'ESA en session.

Convention, ce sont seulement les dix Etats énumérés ci-dessus qui ont juridiquement, en ce moment, la qualité *d'Etats membres*, mais ils ne l'ont qu'au titre de l'Organisation Européenne de Recherches Spatiales.

Il faut ajouter que la Convention de l'Agence est restée ouverte, jusqu'au 31 décembre 1975, à la signature des Etats qui participaient à ce que l'on appelait la Conférence Spatiale Européenne (CSE). A ce titre, l'Irlande qui n'appartenait à aucune des deux Organisations antérieures a signé le 31 décembre 1975 la Convention de l'ASE/ESA, mais pour la raison indiquée ci-dessus elle n'a pas encore la qualité d''Etat membre' et ne l'acquerra qu' après l'entrée en vigueur de ladite Convention.

Ceci étant précisé, on rappellera aussi que c'est le Règlement intérieur du Conseil du CERS/ESRO (et non la Convention) qui avait créé la catégorie des '*observateurs*' en disposant dans son article 23 que 'le Conseil peut, par une décision prise à l'unanimité, accorder le statut d'observateur aux gouvernements d'Etats non membres et à d'autres organisations internationales'. Ce statut comprend 'le droit d'être représenté aux sessions du Conseil' mais il n'inclut, en aucun cas, le droit de parole ni le droit de vote.

Il faut ajouter que, pendant les discussions sur la révision de la Convention du CERS/ESRO, qui ont précédé celles sur la Convention de l'ASE/ESA, une nouvelle conception avait été proposée. Elle consistait à créer, à côté des Etats membres, une catégorie de *membres associés* qui, estimait-on, devait remplacer celle des observateurs. En d'autres termes, il s'agissait d'ouvrir la possibilité que certains Etats puissent suivre partiellement et temporairement les activités de l'Agence sous réserve d'une participation financière légère et sans être tenus aux mêmes obligations que les Etats membres proprement dits; en contrepartie, la présence, purement passive, des observateurs de type traditionnel ne serait plus acceptée. C'est effectivement ce que prévoit désormais la Convention de l'ASE/ESA dans les termes suivants:

- les membres de l'Agence, ou '*Etats membres*', sont ceux qui signent et ratifient la Convention ou qui y adhèrent ultérieurement. Tous les Etats membres participent aux activités obligatoires et contribuent aux frais communs fixes de l'Agence (art. I.2 et 3).
- les '*membres associés*' sont les Etats non membres qui s'engagent a contribuer au minimum aux études de projets futurs (art. XIV.3) qui font partie des activités de base (art. V.1.a).

Cependant, le nouveau Règlement intérieur que le Conseil a adopté dès que l'Agence a commencé à fonctionner 'de facto' contient encore un article 23 relatif aux '*observateurs*' et qui reprend entièrement les termes du texte précédent. La raison en est que la notion de 'membre associé' ne pourra devenir effective qu'après l'entrée en vigueur de la Convention ESA, et l'on peut même se demander si le Conseil voudra alors conserver la catégorie des observateurs.

Quoi qu'il en soit, et si le statut d'observateur n'est défini que d'une façon négative – c'est-à-dire par l'absence des droits de parole et de vote – le statut de membre associé n'est pas davantage défini dans la Convention de l'ASE/ESA qui se contente de prévoir que 'les modalités détaillées de cette association sont définies dans chaque cas par le Conseil, à la majorité des deux tiers de tous les Etats membres'.

Etats jouissant d'un statut particulier

C'est dans ce contexte juridique que doit être décrite la situation des quatre Etats qui sont actuellement représentés au Conseil de l'Agence sans avoir toutefois la qualité d'Etats membres: la Norvège, l'Autriche, l'Irlande, et le Canada. Chacun de ces pays se trouve dans une situation particulière, du point de vue historique et juridique, bien que leur régime actuel présente des points communs.

1. Trois des quatre pays mentionnés ci-dessus ont commencé par avoir seulement le statut d'observateur.

Tel est le cas de l'Autriche et de la Norvège qui avaient signé, le 1er décembre 1960, l'Accord de Meyrin instituant une Commission Préparatoire Européenne de Recherches Spatiales (COPERS) et avaient participé à la Conférence des Plénipotentiaires pour l'institution d'une Organisation

Signature de l'accord de coopération entre l'ESA et le Canada par M. R. Gibson, Directeur général de l'Agence et Mme J. Sauvé, Ministre Canadien des Télécommunications.

Européenne de Recherches Spatiales. Bien que ces deux pays n'aient pas signé la Convention adoptée par cette Conférence, le 14 juin 1962, le Conseil du CERS/ESRO a accepté de leur accorder le statut d'observateurs.

En ce qui concerne le Canada, qui était observateur à la CSE, le Conseil de l'Agence a décidé, en 1975, de lui accorder à son tour le statut d'observateur.

2. *Par ailleurs, les quatre pays en cause participent déjà, d'une façon ou d'une autre, aux activités de l'Agence.*
Le Canada a coopéré au programme Aérosat. L'Autriche participe aux programmes Spacelab, ASTP, études H/Sat et Sirio 2. L'Irlande participe à Earthnet, à la promotion Ariane, et à la phase préparatoire du programme de télédétection. Enfin, la Norvège participe au programme Marots.

Il est vrai que les décisions relatives à ces programmes sont prises dans des Comités spécialisés (Conseils directeurs de programmes) établis par des Arrangements auxquels ces pays sont parties et que les accords passés par les Etats non membres qui participent à l'un de ces programmes facultatifs prévoient que ces Etats acquièrent les mêmes droits que les Etats membres participants. Ceci leur permet donc d'être entendus par le Conseil et d'y voter sur les questions relatives au programme considéré – ce qu'ils ne pourraient faire en leur seule qualité d'observateurs.

3. *Bien que le statut d'observateur, complété par celui d'Etat participant à certains programmes facultatifs, établisse déjà des relations privilégiées avec l'Agence, il est apparu nécessaire de prendre des dispositions plus spécifiques dans le cas des trois pays suivants:*
Pour *l'Irlande* qui a signé la Convention de l'Agence sans pour autant devenir immédiatement observateur au Conseil, un accord du 29 novembre 1976, lui accorde un statut particulier et transitoire, afin de répondre à son désir de commencer à participer aux activités de l'Agence sans attendre l'entrée en vigueur de la Convention de l'ASE/ESA. Cet accord définit les relations entre le gouvernement de l'Irlande et l'Agence, ainsi que les conditions de l'association du premier aux activités de la seconde. Cette association ne doit pas être confondue avec le statut de 'membre associé' qui pour les raisons indiquées plus haut ne serait pas applicable dans la période actuelle et serait, au surplus, inadéquat, puisqu'il s'agit, au contraire, de donner à l'Irlande une situation anticipant celle d'Etat membre. La solution retenue a été de faire participer l'Irlande à certaines activités de base de l'Agence (enseignement, documentation, étude de projets futurs et travaux de recherche technologique) moyennant une contribution basée sur son revenu national moyen mais plafonnée à 100 000 livres irlandaises par an.

Pour *l'Autriche* qui n'a pas signé la Convention de l'Agence, mais qui a demandé le statut de membre associé, l'accord signé le 17 octobre 1979 donne un aperçu du contenu de ce statut particulier, encore que, selon la Convention de l'Agence, celui-ci doive être défini cas par cas. Le préambule de l'accord mentionne qu'en l'approuvant pour sa part, le Conseil de l'Agence a exprimé le voeu qu'avant son expiration, l'Autriche envisage d'adhérer à la Convention de l'Agence. L'Autriche participe aux études générales concernant des projets futurs, qui font partie des activités de base de l'Agence; elle peut également participer selon des arrangements particuliers à d'autres éléments des activités obligatoires, facultatives ou opérationnelles de l'Agence. La contribution de l'Autriche aux études générales s'effectue à un taux établi sur la base de son revenu national moyen; elle verse en outre une contribution de 1% aux frais communs fixes nets inscrits dans le budget de l'Agence – chiffre qui peut être révisé en fonction du nombre des activités et programmes auxquels elle participe.

Pour *le Canada*, enfin, un accord général de coopération avec l'Agence a été signé le 9 décembre 1978 et il laisse la porte ouverte à l'établissement ultérieur de relations plus étroites. Aux termes de cet accord, le Canada participe aux études générales concernant les projets futurs, études qui font partie des activités de base de l'Agence. La participation du Canada pourra s'étendre également à d'autres éléments du programme spatial européen correspondant à des activités obligatoires, facultatives ou opérationnelles de l'ESA. La contribution du Canada est calculée en fonction de la moyenne de son revenu national, mais le Canada accepte en outre de participer, pour un montant forfaitaire de 1% aux frais communs fixes nets du budget de l'Agence. Enfin, l'Accord prévoit que 'le Canada peut également participer à d'autres éléments des activités obligatoires, facultatives ou opérationnelles de l'Agence', auquel cas le chiffre de 1% sera augmenté.

Les trois accords dont il vient d'être fait mention diffèrent donc à la fois en ce qui concerne l'étendue de la participation aux activités de l'Agence et la contribution demandée. En revanche, les conditions de la représentation de ces Etats dans les organes délibérants de l'Agence – c'est-à-dire le Conseil et ses organes subordonnés – sont pratiquement identiques.

4. Chacun des trois Etats non membres peut être représenté au Conseil de l'Agence par deux délégués qui disposent du droit de vote sur les questions liées aux activités de l'Agence auxquelles leur pays participe et il peut être entendu au sein des organes subsidiaires du Conseil, lorsqu'ils traitent de ces questions.
En outre, chaque Etat a le droit d'être entendu au Conseil de l'Agence au sujet des autres questions et d'être représenté comme observateur aux réunions des Conseils directeurs de programme de l'Agence – à moins qu'il n'y soit représenté de plein droit, ce qui est le cas au titre des programmes facultatifs auxquels il participe.

Enfin, des dispositions sont prises pour assimiler les Etats non membres en cause aux Etats membres dans certains domaines et dans la limite des activités auxquelles ils participent (attribution de contrats, etc.).

Bien entendu ces dispositions d'ordre général n'affectent en rien les dispositions particulières relatives à la participation des Etats non membres dont il s'agit aux programmes facultatifs.

Conclusion
En résumé, le régime institué sous la Convention du CERS/ESRO permettait l'établissement de relations privilégiées entre un Etat non membre de l'Organisation et celle-ci, soit par l'octroi du statut d'observateur, soit par sa participation à un programme facultatif, les deux qualités pouvant d'ailleurs se cumuler. La Convention de l'ASE/ESA a créé une nouvelle catégorie, celle des Etats associés sans proscrire expressément pour l'avenir celle des observateurs.

Malgré les similitudes qui ont été relevées plus haut, il est en tout cas certain que le statut actuel de chacun des quatre Etats non membres qui entretiennent des relations privilégiées avec l'Agence est fondamentalement différent, car il doit être apprécié dans la perspective du changement de cadre juridique qui résultera de l'entrée en vigueur de la Convention de l'ASE/ESA.

L'Irlande en est au stade d'une coopération qui préfigure son passage au statut d''Etat membre' dès que la Convention de l'Agence sera en vigueur, tandis qu'à ce moment l'Autriche prendra la qualité de 'membre associé' en vertu de l'Accord qui vient d'être signé.

Pour le Canada, l'Accord de coopération en vigueur depuis un an pourrait, à terme, évoluer vers un passage au statut de 'membre associé'.

Quant à la Norvège, le Conseil devra dire si, après l'expiration de l'Arrangement Marots, ce pays pourra conserver son statut d'observateur à moins que son gouvernement ne prenne l'initiative de demander à devenir soit 'Etat membre' soit 'membre associé'.

La situation qui vient d'être décrite peut, sans doute, paraître complexe, mais ceci est la rançon de la diversité des possibilités et des besoins des Etats désireux d'établir des relations privilégiées avec l'Agence Spatiale Européenne.

The European Approach to the Financing of Space Ventures*

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Contrary to the prevailing situation in the United States, private funding has so far played a minimal role in the financing of the European space programme. Europe's bankers have been called upon rarely by ESA, and then generally to arrange short-term loans to cover temporary shortfalls occurring within the Agency's total funding envelope of its Member-State contributions. With the transition now of many ESA-developed technologies from a development to an operational phase, there may soon be a role for longer-term, private-sector financing for European space projects.

Europe is investing significantly less in space activities than the United States, and one may well ask why. There are, I believe, several primary reasons.

The space race between Russia and the United States caused the Kennedy administration, for political reasons, to boost space activities. Large scientific and industrial capacities were built up and these occasioned the industry, after the moon venture, to ask for new tasks in order to keep both people and production facilities employed. Consequently the US space budget could not be reduced very much.

Approximately 10 000 engineers are engaged in European space activities, whereas in the United States some hundreds of thousands earn their wages from space business.

Furthermore, the United States' space industry has a large private sector, but in Europe this is not the case to the same degree. All European space orders are placed by Government agencies.

The eleven countries participating in the European Space Agency speak no less than eight different languages. They have diverging economic interests, and have had inflation rates ranging from 2% to 26% per year in the recent past. The unanimity needed for space programmes can therefore often be achieved only with difficulty.

Aside from the activities of NASA, the United States has developed a successful commercial space production and applications industry. Europe is still far from doing so.

Up to now, on the old continent (Eastern countries not included), all space ventures have been the concern of Governments or Government-controlled companies.

Table 1

	USA	Europe
Population	220 million	313 million
Gross domestic product	2133 billion dollars	2357 billion dollars
Average domestic product per capita	9695 dollars	7530 dollars
Investment in nonmilitary space activities from public funds:		
total	4540 million dollars	1100 million dollars
per head	20.6 dollars	3.5 dollars[1]

[1] six times less than in USA

* Based on a presentation to the 1979 Goddard Memorial Symposium in Washington.

All of these factors have served to tailor the European attitude to space activities, and the above enumeration of influences is far from complete.

About two thirds of Europe's annual space investment is handled by ESA, the 1979 budget of which was 547 MAU (millions of Accounting Units), equivalent to 675 million dollars, against NASA's 4540 million dollars (Table 1). ESA's funds are raised by contributions from Member States, which means, as a matter of principle, that all its ventures are usually financed by European Governments, and no outside financing should be necessary, either via national channels or through ESA.

Financing so far

Private financing sources in Europe have been only marginally involved in space activities until now, and two main areas of participation can be distinguished:

(a) Project financing for European industrial companies when, exceptionally, public funds have been insufficient or not available in time. To give an example, Bankhaus Reuschel and a second private German bank, both house banks of the European Space Agency, had occasion in 1978 to grant the Spacelab prime contractor ERNO a short-term bridging loan amounting to approximately 38 million dollars, for a period of six months. This loan was informally guaranteed by ESA, and capital and interest were reimbursed by the Agency in January 1979.

(b) A second area relates to temporary shortages of funds in the budgets of the European Space Agency for covering project-development costs. As an example, the development programme for Europe's Ariane launcher, with a total funding of approximately 950 million dollars, required a bridging loan amounting to some 43 million dollars in different currencies in 1978. A consortium of ESA's house banks, including Bankhaus Reuschel, shared in the financing of this particular loan. Because ESA, as an international organisation, has both a triple-A credit rating and free access not only to national credit sources but also to the Euromarket (without being affected by exchange restrictions), the Ariane bridging finance could be arranged at preferential rates. Repayment was effected with funds from the 1979 contributions of the Agency's Member States.

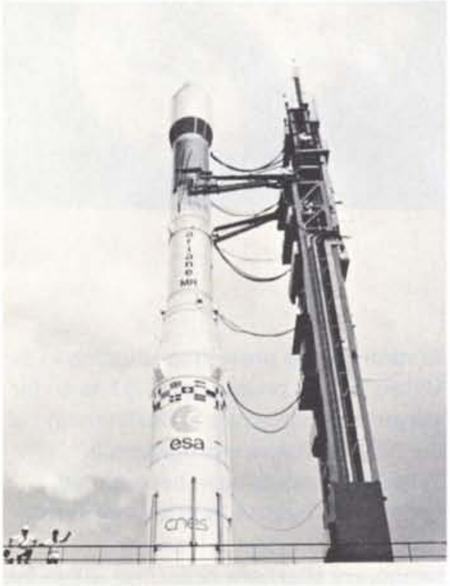
Similar short-term transactions took place in 1979 and will arise again in 1980, but it must be stressed that these loan arrangements are merely a short-term bridging facility, which is underwritten by direct or indirect guarantees by ESA's Member States.

Financing outlook

Another kind of medium to long-term financing requirement is now in sight, namely project-specific financing. When one considers that of 956 satellites still in orbit at the beginning of 1978, 480 were of Soviet origin, 388 were launched by the United States, and only five originated from ESA, and only one of these five was an applications satellite, one has to admit that this small space presence by Europe is not in keeping with its global role. On the other hand, Europe, from an insignificant start in 1964 (10 million dollar budget), has achieved recognised success in the scientific-satellite field and has achieved promising results with its applications programmes. Therefore, I believe it now to be both possible and necessary – because nobody can afford always to spend money without a financial return – to commercialise the knowhow gained.

Studies by Frost N. Sullivan in the United States and by Eurospace in Paris, forecast a world market of 10 to 15 billion dollars for communications satellite systems for the eighties. I believe that this potential market represents a good opportunity for Europe too.

It is not yet clear whether the European

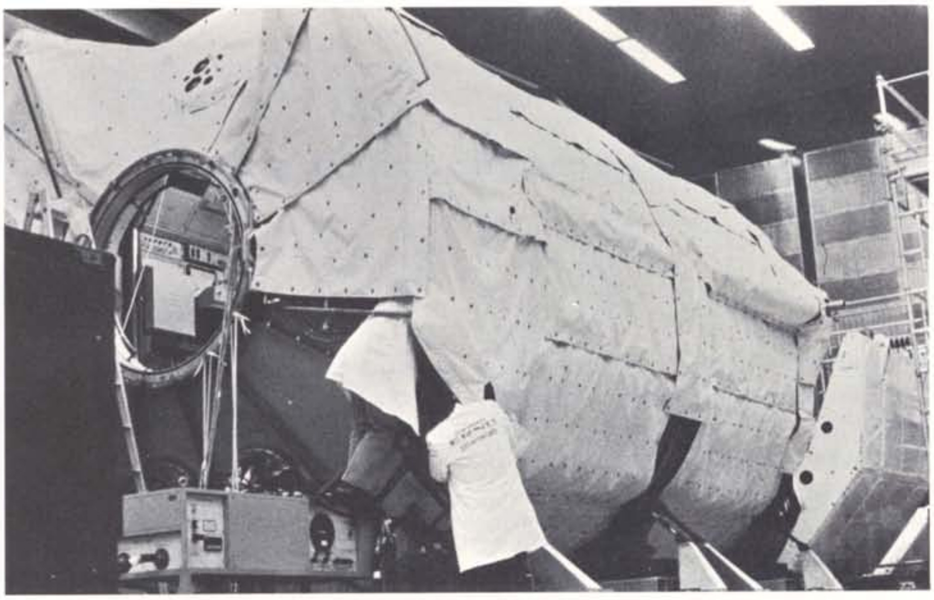


Space Agency will be authorised by Europe's Governments to operate and exploit commercially the satellites, the launchers and the Spacelab it has developed. Even now the Agency's budget does not cover expenditure for production activities to be undertaken by ESA on behalf of third parties. In these cases financing from private sources will be necessary.

Three possible ventures along these lines are already being discussed with the Agency:

(a) The financing of ESA's offer to Inmarsat to deliver three Marecs maritime communications satellites at a total cost of 82 million dollars. Bankhaus Reuschel, together with a consortium that it has formed, has been examining a loan to be granted for a period of seven years, probably contracted in Swiss francs. It may be tailored as a roll-over credit or with fixed interest, reimbursement being ensured by Inmarsat in the same currency, which permits low interest rates without any exchange risk.

(b) The financing of the second Spacelab for NASA at a cost of around 180 million dollars. The full production



costs will be paid by NASA, but it is foreseen that the annual grants available in the relevant US fiscal years will not necessarily be in step with the industrial expenditure in Europe. Bridging finance of up to 30 million dollars a year will be necessary. Again, it will be an ESA banking consortium that will be involved in raising these funds, for which the Agency will be the debtor.

(c) The financing of Ariane follow-up production. In addition to the first five launchers financed from ESA's own budgets, production of a second batch of five vehicles is now planned. One of these has been bought by Intelsat, and installments are being paid at regular intervals. Financing for the second batch – roughly 160 million dollars based on selling contracts – could be envisaged by European banks, though several questions would have to be cleared first, such as the availability of export guarantees in the case of sales to countries for which domestic financial institutions like the German Ausfuhrkreditgesellschaft make such underwriting a must.

The European Airbus, now being sold to both European and overseas airlines, is one example of a European joint venture that has obtained such guarantees for financing. It is not a problem, then, to raise funds for production or export credits – given stability in the money market – even if the credit line, as will be the case with Airbus in a few years' time, runs to five billion dollars or more.

If, however, launchers are to be produced prior to a sales contract, the viability of the financing depends on the standing of the borrower, an approach similar to that adopted by US bankers. The United States public eagerly paid 200 million dollars for 10 million shares in Comsat in 1964 – a remarkable step in the light of the then unproven technology and the high degree of risk. Nevertheless, Comsat General has been able, a decade later, to negotiate a credit line of 50 million dollars with a consortium of US banks only because of contractual arrangements that insure a revenue flow to the corporation from the Comstar and Marisat (US Navy) systems, though it had been allocated 200 million dollars in capital funds by the Comsat parent company.

Conclusion

To sum up, as all space activities in Europe to date have been undertaken in the public sectors only, there has normally been no need for private financing apart from bridging loans, which have been short-term. Buyers' credits are feasible on the usual terms, and project financing for spacecraft or payloads can be arranged, provided:

- the political risk, where applicable, is tolerable or can be covered by national export-guarantee systems
- the revenue, in the case of an applications system, is insured by the loan contractors, and
- the system is covered against the risks that put into question the return (e.g. failure in orbit).

Currency risks can normally not be covered by insurance contracts, and it is therefore necessary to refinance loans in the same currency.

When it comes to the question of raising risk capital, public relations and private initiative play a major role. Every year the German people invest one billion dollars in such ventures as film financing and oil exploration. OTRAG (Orbital Transport und Raketen AG), to take another example, has secured 120 million deutschemarks (65 million dollars) in risk capital by private initiative and from private sources within the last five years, though no revenue is yet in sight.

Such examples serve to bolster confidence that Europe could also satisfy the financial needs of certain of its space ventures in a similar manner.

Telecommunications Satellites for Developing Countries – Extension of Satellite Use to Rural Areas

A. Pinglier, Directorate of Applications Programmes, ESA, Paris

In the last decade many developing countries have become members of INTELSAT and have or are about to have a ground station to access the international satellite telecommunications network. As a consequence, it is often easier to call the outside world from the capital city than to contact many parts of the country itself. This involvement with INTELSAT and telecommunications satellites has led many developing countries to envisage using satellites to overcome their domestic intercity link problems also, and about a dozen countries have already installed ground stations and leased INTELSAT transponder capacity. Some others, like Indonesia, have already implemented their own space systems. Many more are presently contemplating installing a domestic satellite system.

With generally less than one telephone per 100 people, and sometimes even less than one for 1000 people, the telecommunications situation in many developing countries is far from satisfactory. Telephone services are often restricted to urban areas with virtually no service available in rural areas. Trunk routes linking cities, when available, are often saturated and sometimes of very poor quality. Connections between neighbouring countries are deficient in many cases. Television services exist in the great majority of developing countries, though not in all of them, but often the coverage does not extend much beyond a few urban areas. Radio programmes can be received practically everywhere, but often reception is technically very poor. Given the present situation, there is scope for improvement in all fields of telecommunication.

Requirements for improved services

Telephones

For urban areas there should be an increase in the number of telephones and an improvement in the quality of service (reduction of the oversaturation of telephone circuits and hence of waiting time, and improvement in link quality). This implies a substantial increase in numbers of lines and telephone exchanges. The general trunk-line network linking various urban areas should be improved both in quality and quantity (more circuits available and opening of new trunk routes. Similarly, telephone links should be established between various parts of neighbouring countries. Rural areas in many countries should be opened to telephone services and in those already having a limited telephone service the density of the coverage should be greatly increased.

Television

The television coverage area, generally restricted to urban areas, should be extended to the country as a whole, and easy exchange of television programmes between the various developing countries should be facilitated.

Radio

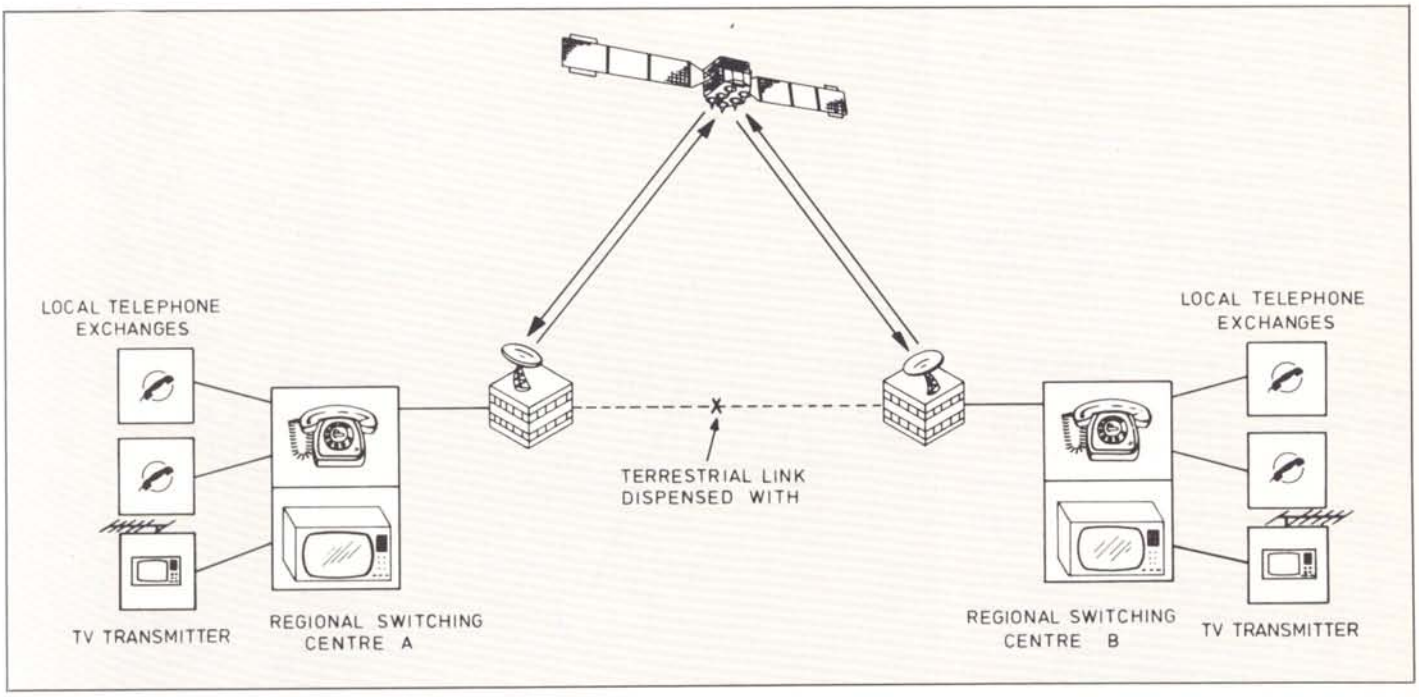
The quality of sound broadcasting should be greatly improved in many areas.

Competitiveness of satellites

From a geostationary satellite it is possible to 'see' about a third of the globe, and a whole continent can be covered by a single 'global' beam or several smaller beams. All developing countries, irrespective of their size, can be covered by a single beam, allowing any point in the country to be connected to any other and so leading to a 'global connectivity'. Regional coverage extending over several neighbouring countries can also be achieved in many areas with a single beam, thereby providing a 'regional connectivity'.

Satellites can thus solve trunk-route communications problems between urban areas for telephony traffic, television and radio distribution. They can provide a telephone circuit and television or radio reception to any point in any rural area equipped with the necessary ground equipment, irrespective of the prevailing geographical conditions

Figure 1 – High- and medium-capacity trunk lines for television and telephone networks



(deserts, forests, mountains, etc.). At the same time, satellites offer a unique degree of flexibility, by allowing all or part of the available satellite capacity to be shared between the various destinations, according to demand.

Satellite-based communications also lead to the highest possible reliability because the satellite constitutes the only link in the telecommunications chain. With its many redundancies, it is very reliable, and in operational systems there is usually a back-up satellite in orbit. Should a ground station be out of order, the service is discontinued only at that particular location, whereas a ground network with its many relay stations, which all have to be working simultaneously, has a much higher probability of outage. For this reason, satellite-system ground-station maintenance problems are not so critical and they are also easier to solve, because the equipment is installed in inhabited areas.

For all the above reasons, satellites would seem to provide one of the most efficient means of developing telecommunications networks for telephony, television and radio distribution, both for intercity trunk routes and for rural areas.

Intercity trunk routes

Nowadays, terrestrial trunk routes between cities relay mainly on microwave links and a number of such links have been or are being built in various developing countries. They are economically attractive for short and medium distance links (a few hundred kilometres) and/or for high-capacity requirements (several hundred circuits). On the other hand, they are not so attractive for 'thin' routes (a few dozen circuits), where radio links have often been used in the past.

As already pointed out, a network relying exclusively on ground links may lack flexibility, unless it is highly developed with a large number of alternative routes, which is very seldom the case in developing countries. It may also have a low reliability.

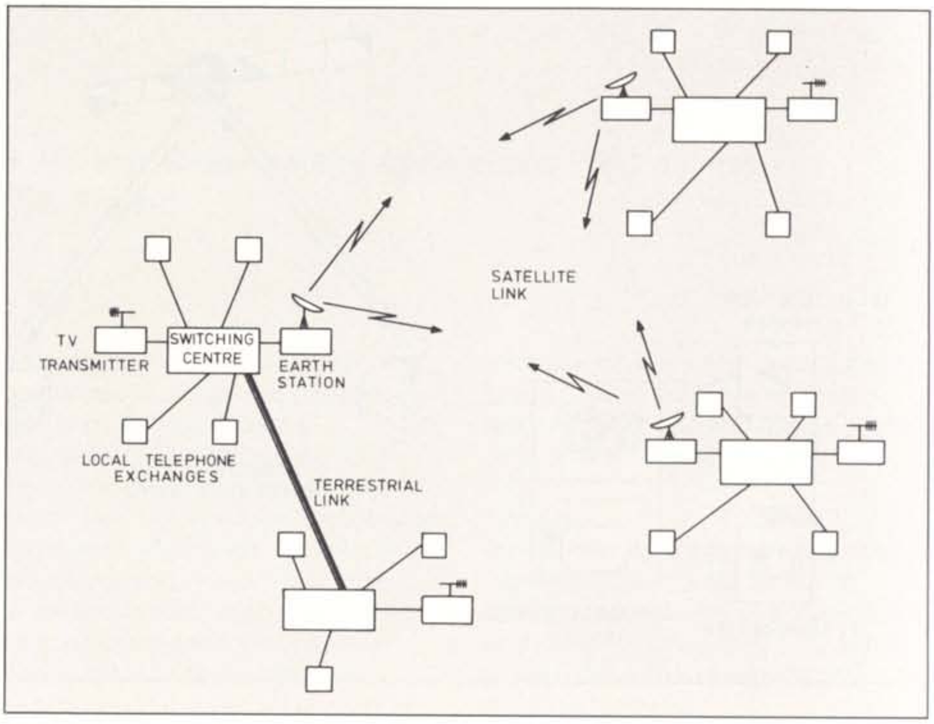
In fact, satellites and microwave links are not competitors, but rather are complementary and can be integrated to form a coherent global system. The optimum balance between the two must be established case by case, with traffic distribution patterns, distances and geographical constraints as the main parameters. Some of the planned terrestrial links over specially difficult terrain or for very thin routes will tend to be replaced by satellite links (Fig. 1), and the trunk network will be a mix of ground and satellite links (Fig. 2).

Some developing countries already rely to a large degree on satellites for their domestic trunk networks. In Africa, for instance, Nigeria, Sudan, Uganda and Zaire lease capacity from INTELSAT.

These domestic systems can be set up with ground-station antennas as little as 5 m across, their diameters usually varying between 5 and 12 m. An INTELSAT standard transponder (36 MHz bandwidth) associated with a global coverage antenna and delivering a 22 dBW EIRP* used with a single channel

* EIRP = Effective Isotropic Radiated Power

Figure 2 – Trunk network with a mix of ground and satellite links



per carrier technique and voice activation, may have a capacity of up to 300 channels in the case of 5 m-antenna ground stations, increasing to about 800 channels for 10 m stations. If higher satellite powers were to be used, this capacity would be increased. With 33 dBW EIRP and 5 m ground stations, for example, it could be in the order of 1400 channels.

Ground-station costs usually range from $ 300 000 to $ 1.5 M, depending mainly on antenna size, channel capacity and degree of redundancy.

Telephony, television and radio for rural areas

Theoretically these services could be provided by classical terrestrial means, but in fact for many countries the practical difficulties (technical, but even more financial) are such that only a very limited ground system has so far been implemented, leaving vast portions of territories virtually without any telephone facilities and with no television coverage.

Some countries cover a vast area with, in many cases, population densities as low as 1 to 3 inhabitants/km^2. The distance difficulties are often made worse by adverse geographical conditions (desert, forests, mountains and also climate). To this must be added the limited financial resources that these countries can dedicate to telecommunications. In many instances the sum available for the whole national telecommunications activity, both urban and rural, is as little as $ 0.5 M per year, and it seldom exceeds $ 10 M to $ 15 M.

Comparing the cost of an efficient ground network covering the whole country and the available financial resources leads one to conclude that many of these developing countries will never have a satisfactory telecommunications network unless a much cheaper and more efficient system is found, and satellite-based systems may well be the answer.

Satellites for rural telephony

Many developing countries put a higher priority on rural telephony than on local radio and television availability. Such a service via satellite could be attractive if small, cheap, low-capacity receive/transmit ground stations could be designed. They should also be easy to install and maintain. Ideally, each village should have its own ground station to which a dozen or more telephones would be connected. Initially, each station would probably have to serve several adjacent villages.

The viability of such an approach is very much linked to the cost of the station, which a first analysis shows should not exceed some $ 30 000 (without the associated mini ground network). By relying on 'narrow beam' satellites with high radiated power, it is possible to envisage small stations that are simple, rugged and sufficiently cheap. There is a potential market for some tens of thousands of small ground stations worldwide; for sub-Saharan Africa alone, the current estimate is 8000 to 20 000.

The ground station may be connected to just a few telephones or it may be associated with a small ground network, which could be a classical land-line network (coaxial cable, open wire . . .) or based on radio-telephony. A case-by-case study would be needed for each country to determine the correct balance between the number of ground stations to be installed and the nature and importance of the ground network to be associated with each station. A typical rural satellite network is shown in Figure 3.

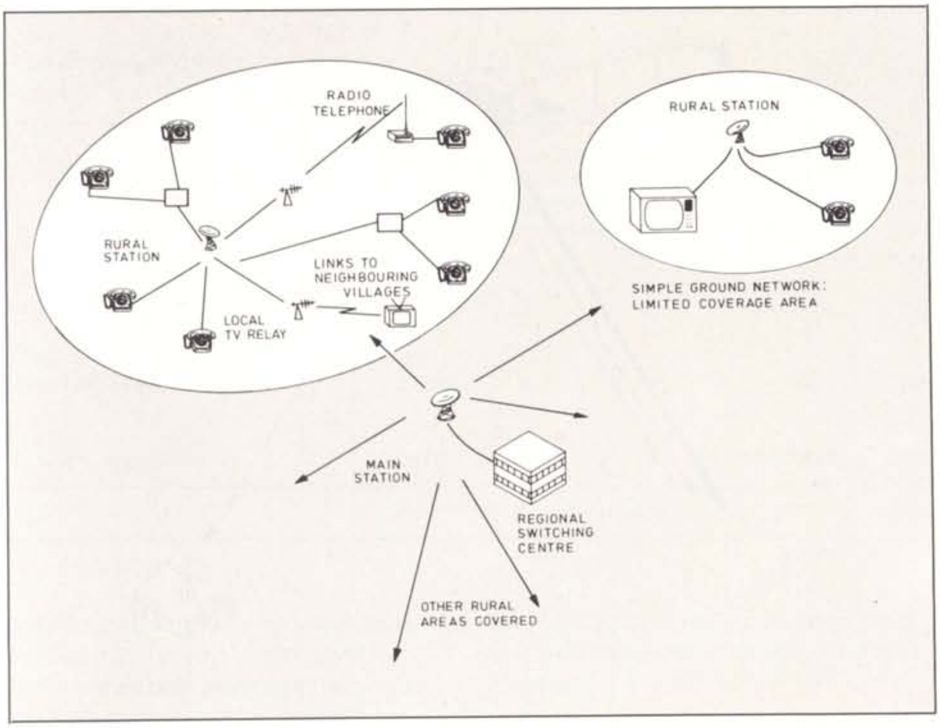
Satellites for television and radio broadcasting

Two approaches may be envisaged here, namely direct broadcasting and redistribution.

For direct broadcasting the satellite radiates a high-power signal and the country-wide channel can be received directly by the viewer or listener with fairly simple and comparatively cheap equipment.

A plan for direct television-broadcast

Figure 3 – Typical rural satellite-based telephony network



satellite systems was adopted by the member countries of the International Telecommunications Union (ITU) in 1977. It lays down the main characteristics (coverage, power, number of channels, frequencies, etc.) for a 12 GHz broadcasting system for countries in Regions I (Europe and Africa) and III (Asia). The plan assumes direct reception by users equipped with stations with a 6 dB/K figure of merit, which corresponds to use of a 0.8 – 0.9 m parabolic antenna. Such a system seems best suited to the needs of developed countries and Europe in particular.

The power requirements per channel on board the satellite are high, corresponding to a radiated power of the order of 100 to 400 W RF, depending on the size of the country to be covered. The power demand can be reduced by using a larger ground receive station (12 to 14 dB/K), with an antenna 1.5 to 2 m in diameter. This type of system is referred to as a semi-direct television-broadcast systems.

Semi-direct broadcasting with similar sized antenna can also be implemented in the 2.6 GHz frequency band, which is often considered better suited for developing countries, despite its power flux density limitation and limited available bandwidth. The advantages are to be found in reduced rain attenuation and cheaper hardware production costs.

If only for economic reasons, the number of television receivers in rural areas will be limited to a few per village at most, leading to a total of not more than 10 000 sets in the rural areas of many developing countries. If a satellite system is to be used, therefore, the overall economics call for a semi-direct type of television transmission, which reduces the demand on satellite resources and leads to a reduction in space-segment cost that far outweighs the cost increase for the limited ground segment.

It is now generally agreed that, at least for quite some years to come, semi-direct television broadcasting is more suitable for developing countries than direct television-broadcast satellite systems.

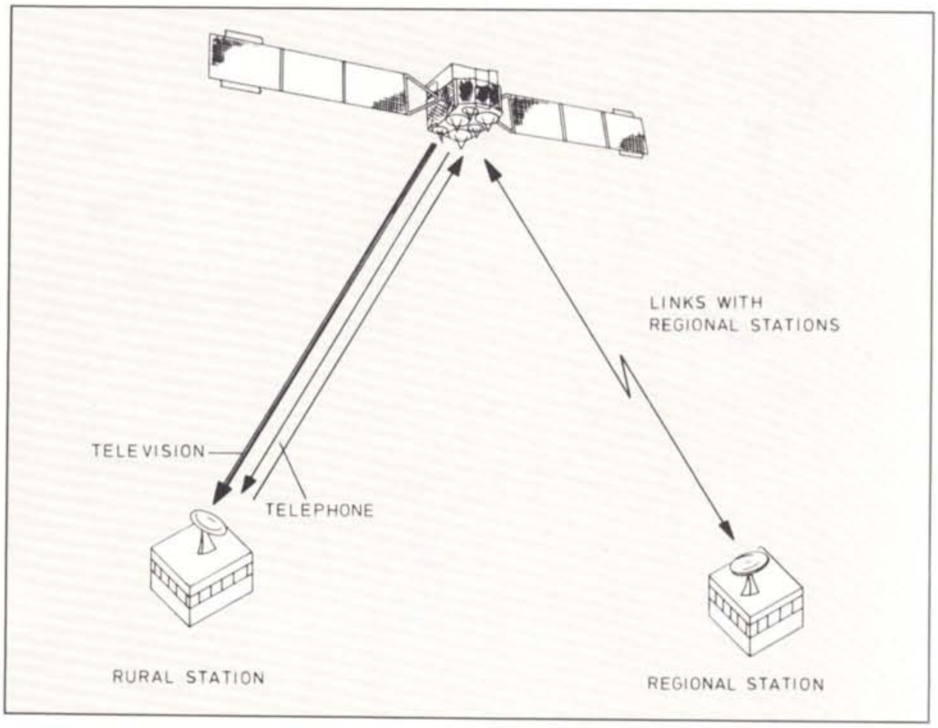
Terrestrial sound broadcasting uses lower frequencies (long, medium, short waves) than television and theoretically even larger countries should need only two or three transmitters for complete coverage. In practice, the quality of reception is often very poor due to propagation anomalies and there is, in many cases, a definitive requirement for improved sound-radio broadcasting.

Satellite sound broadcasts may be the answer and for low-latitude countries, as in Africa, large continental areas could be covered by transmissions from geostationary satellites radiating a few hundred watts per channel. The 1979 World Administrative Radio Conference (WARC) has adopted a resolution permitting experimental use of the 1429–1525 MHz frequency band for such a service. Many developing countries are potential customers for such a system, but political problems linked with the extension of the 'usable' coverage zone may prove a barrier.

As an alternative to the arrangements just described, there exists another mode of operation in which the programme originating in the central studio is received locally by fairly large and complex installations and from there *redistributed* to all end users in the neighbourhood via conventional television or radio retransmitters or cables.

The practical differences between a semi-direct television-broadcast satellite system – especially if the receiver equipment is connected to a limited cable-distribution network – and a satellite-based redistribution system with small receive stations are becoming less and less apparent, and lie largely in the regulatory and legal fields. With the present state of the art in satellite technology, the redistribution ground-receive stations are simple and comparatively cheap (in the order of $10 000 for a 5 m receive-only station in the 4 GHz band, to which must be added the cost of the redistribution network, i.e. TV retransmitter or cable network).

Figure 4 – Concept for an integrated television and telephony service relying on redistribution



From a coverage point of view, at first sight direct or even semi-direct broadcast seems preferable to redistribution, since theoretically a programme can be received anywhere provided the user has the necessary equipment. Redistribution, on the other hand, is limited to the coverage area of the redistribution network. In fact, the number of semi-direct receive systems will also be limited for financial reasons for quite some time to come to sufficiently populated rural areas, leaving the very thinly populated zones without television reception. In practice, therefore, the two approaches are likely to lead to the same partial coverage in rural areas.

Integration of telephone and television services

Redistribution has one distinct advantage over the semi-direct approach in that the receive ground station can be shared with the local rural satellite telephony station, allowing the television receive function to be realised at marginal cost.

This integrated approach can lead to a rural ground station with a wideband receive capability for television and a few incoming telephone channels, and a narrowband low-power transmit capability for telephone return channels (Fig. 4). As for telephony, a mini television ground network can be connected to the ground station with just two or three television sets, or a more extensive cable-distribution system or television retransmitter (Fig. 3).

This approach could be used conventionally for telephony or entertainment television or, in a more novel way particularly suited for rural areas, for very effective tele-teaching, with a possibility of dialogue between the local teacher and both the pupils and the regional tele-teaching centre. Many other uses implying a dialogue would also be possible, such as remote medical care.

This integrated type of network needs only one station for all telecommunications services, leading to considerable savings and offering maximum flexibility. In particular, it would seem to be more suitable for teaching purposes than the direct or semi-direct broadcasting satellites envisaged so far.

Capacity requirements

For the *telephony requirements* of the developing countries, no detailed analysis is yet available and a country-by-country study is needed to determine what satellite services are required and the optimum sharing with terrestrial systems. Nevertheless, it is possible to arrive at a rough estimate by examining what the requirements of a 'typical' sub-Saharan African country might be in a few years' time, after a reasonable improvement in the telecommunications situation.

We can assume a total population of 6 million, 4 million of whom live in urban or semi-urban areas (including rural areas near urban centres), with 500 000 in and around the capital city. The other 2 million can be assumed to live in fairly remote rural areas.

The average telephone density aimed at is in the order of 1.2 telephones per 100 inhabitants, but fairly unevenly distributed (20 000 in the capital area, 40 000 in the other urban zones and 10 000 in the rural areas). At present, the total density in many developing countries is much lower than this and is far more unevenly distributed, i.e. our model represents a substantial improvement.

We assume that only a third (a very conservative assumption for many developing countries) of the intercity communications and all communications to remote rural areas go via satellite. Ten to twenty telephones would usually be connected to each rural ground station, i.e. a station for 2000 to 4000 people and a total of 500 to 1000 stations for the country, and each telephone would be fairly heavily used (several hours per day). A total capacity in the order of 1500 half circuits is then necessary for good performance of the overall system, about a half being used for rural traffic.

Assuming a capacity of around 1000

Table 1 – Financial implications of installing a satellite-based telephony network in a 'typical' developing country

	Population (millions)	Number of telephones	Telephone density per 100 inhabitants	Capital cost over 20 years $M	Capital cost per telephone $	Total annual cost $M	Annual amortisa-tion $M	Annual cost per telephone $	Annual cost per capita $
Phase-I Major centres	2	40 000	2	60	1500	7.8	4.2	200	4
Phase-II Secondary centres	2	20 000	1	45	2250	4.75	3	240	2.4
Phase-III Remote rural areas	2	10 000	0.5	40	4000	4.1	2.9	410	2
	6	70 000	1.2	145	2100	16.65	10.1	240	2.8

telephone channels (or half circuits) per satellite transponder, the telephony requirement, both trunk and rural, in our example is for something between one and two satellite repeaters.

The total population of sub-Saharan Africa is around 250 million people, and since not all African countries will 'go satellite' within the next decade, the total requirement for that part of the continent by the year 1990 is likely to be between 20 000 and 40 000 half circuits, corresponding roughly to 20 to 40 transponders.

The number of 'large' stations needed for trunk routes could be in the order of 100 to 150, and the number of rural ground stations between 8000 and 20 000.

As far as the *television requirements* are concerned, in the course of the next decade each country will attempt to reach the greatest possible portion of its population with a channel to be used during daytime for educational programmes and in the evening for entertainment. Large countries will rely on satellites, and ultimately each will require at least one television channel (i.e. one or possibly half of a repeater). Initially not all countries will be in a position to produce or finance programmes for the whole day and one channel could be shared by two countries, leading to an immediate need in sub-Saharan Africa for between 7 and 15 repeaters.

Implementation of a satellite system

Only a few very large and more densely populated developing countries have a satellite capacity requirement that could justify a purely national system. Our 'typical African country' needs only two or three repeaters. Basically, two routes can be followed in providing such a capacity:

(i) The various interested countries can join forces to implement a space system, each financing part of the cost as a co-owner and using just part of the system's capacity for its own needs.

(ii) The alternative is an 'entrepreneurial satellite', with an outsider financing and implementing a satellite system able to fulfil what he thinks are the needs of countries to which he wishes to lease capacity. This is certainly the quickest way to implement a space system, but the characteristics of the leased capacity may not always exactly match the customer's needs. The present INTELSAT leased transponders, for example, are designed for international traffic and not domestic use.

Financial requirements

The fundamental question to be answered here is: can a developing country afford such systems? Again, a country-by-country analysis is needed to arrive at the answer but we will nevertheless attempt to give an order of magnitude appraisal for our 'typical sub-Saharan African country' of the financial implications of a telephony network relying largely on telecommunications satellites.

The implementation of the network can be divided into three phases:

- Phase-I covering the network in the capital city and two or three other major centres, and the trunk routes linking them, for which classical microwave links have been assumed.
- Phase-II covering a dozen or so secondary urban centres, with the trunk routes to these centres established via satellite.
- Phase-III covering rural telephony to remote areas, based on satellite transmission.

In Table 1, which gives an analysis of the financial requirements for these three phases, it can be seen that the use of

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Quest

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All organisations working with advanced technology need efficient access to a bewildering variety of scientific, technological, and other types of information. While some of this information is generated internally, much has to be gleaned from external sources on a worldwide basis. In the field of aerospace alone it is estimated that at least one million reports, journal articles, and conference papers, etc. published annually are of potential interest. Fortunately much of this data is now handled by computers. The Agency's own online information retrieval service, first introduced more than a decade ago, has recently taken a substantial stride forward with the introduction of new applications software called 'Quest', two prime features of which are improved response times and the ability to support many more users simultaneously.

An online information retrieval system is based on a centrally maintained, and usually large database which may be interrogated remotely from many different locations. The central location offers the most cost-effective operation since computer equipment, and in particular the large number of disk drives needed to store the data files, need not be replicated at the different sites. Moreover, the work of constantly updating the files needs to be carried out only once, which also eliminates the possibility of files at different locations becoming out of phase with one another.

The user of such an online system, sitting at a remote data terminal which may be hundreds or thousands of kilometres from the computer centre and connected to the latter via the telephone network, is just one of a large family of users, all of whom are connected simultaneously with the central computer.

Recon

In 1969, when ESRO, ESA's forerunner, was evaluating the feasibility of introducing an online information system, NASA had already taken the decision to introduce a system developed by Lockheed. NASA called its new service NASA-Recon (for REmote CONsole). An agreement was subsequently reached between ESRO, NASA and Lockheed, through which the system that was later to become known as ESRO-Recon was brought online in Europe.

The early system offered only a single computer database, the NASA file of aerospace information, and was accessible only at ESRO Headquarters in Paris, ESTEC in the Netherlands, and ESOC in Germany. Soon afterwards, access became possible via national organisations in many ESRO Member States, while the NASA file was augmented with other major databases in the fields of electronic engineering, computing, physics, materials science, etc.

The early remote terminals needed to interrogate ESRO-Recon were rather complex devices which had to be permanently connected to the computer via a leased telephone line. By 1975 the Remote Terminal Concentrator (RTC) was being field tested. This concentrator enabled a user to connect a simple data terminal with the central computer by dialling via the local telephone network to the nearest concentrator and then placing the telephone handset into the terminal's acoustic coupler.

By 1978 almost one thousand organisations throughout the Agency's Member States and other countries were regularly using this service, from which almost 12 million items were accessible online. Some one hundred hours of connect time were being logged every working day.

Quest

ESRO-Recon was based, as has been said, on a system design conceived by Lockheed in the late sixties. Ten years later the Recon system was being asked to support more users and more data than its designers had ever contemplated. The Agency's Information Retrieval Service had been continuously

Figure 1 — The IRS computer room

Figure 2 — The IRS-developed multi-alphabet Eurab terminal

developing the original computer software in order to accommodate more files, new kinds of data, simpler and more powerful user features, and so on. It was clear by the early seventies, however, that the original design concepts of the system had been far exceeded, and that the law of diminishing returns was beginning to apply.

For the last four years, therefore, IRS has been developing an entirely new software system intended ultimately to replace Recon. This development has taken some time because it has had to be carried out in parallel with the development of the existing operational system, which could not be allowed to stagnate, and with the continuing constant workload associated with updating all the existing files each month with newly arriving data.

Various elements of the new online retrieval system, to be known as Quest, have been under test since early 1979, and implementation of the complete new system was finally completed last October.

A number of important objectives have played a fundamental role when establishing the design concepts for the new system. Quest has been structured to support a larger number of users simultaneously, while at the same time improving the queuing time and eliminating the peak-load effects which slowed response for all users of the old system. The new system also has provision for multiple command sets or languages. (The command sets are the instructions that must be typed on the remote terminal by the user; e.g. 'BEGIN2' instructs the computer to switch into file number 2 and prepare for a search, 'DISPLAY' instructs the computer to display an item on the user's remote terminal, and so on).

IRS will continue to support fully and further develop the familiar command language of the previous system, since this is already known and employed by more than 1300 regular users. The first new command language to be introduced will be that defined for the European Commission's Euronet network, to which many new European online services are expected to connect. The concept here is one of a Common Command Language, known as CCL, that, once learned, can be used on any of the various systems. A third command language is also being developed to support a bilingual Arabic/French database under contract to an organisation in Morocco.

A multi-alphabet terminal called the 'Eurab terminal' has been developed in parallel with Quest by IRS. This terminal is capable of displaying two texts in different alphabets side by side on the same screen (the first alphabet pair was Latin/Arabic). It employs standard ASCII coding, and other alphabets can be readily accommodated, e.g. Greek. Quest will permit the full potential of the new terminal to be realised. Input of data for the Arabic Lexicon (Lexar) has already begun from the IERA Institute in Rabat. Lexar files will contain both English and French equivalents of Arabic words and phrases.

Quest has also been developed to support the online entry of local data. With this service the remote data terminal may be used not only for information retrieval, but also for the input of data for private files. Such data can be recalled via the remote data terminal, edited or replaced, while still being safeguarded by security procedures.

Figure 3 – A search of IRS's files in progress

78A46496 NASA Issue 20 Category 12
Material sciences in space. II - Future interest and expectations --- from Spacelab experiments

78A44620 NASA Issue 19 Category 12
Material research with Spacelab

78A41937 NASA Issue 19 Category 12
Materials research and processing - New prospects for the space programme of the Federal Republic of Germany

78A41936 NASA Issue 18 Category 12
Preparatory experiments for Spacelab mission --- direct and indirect gravitational effects in space processing

78A41934 NASA Issue 18 Category 12
ESA material science experiments and experimental facilities for the first Spacelab payload

Printout 1

78A41937 NASA Issue 18 Category 12
Materials research and processing - New prospects for the space programme of the Federal Republic of Germany
Greger, G.; Blechert, G.
780700 (British Interplanetary Society, Meeting on Spacelab: Materials Research and Processing, London, England, Sept. 14, 15, 1977.) British Interplanetary Society, Journal (Spacelab Experiments), vol. 31, July 1978, p. 264-266. 3 p.

Research on materials processing in a zero-g environment, e.g., in the Shuttle/Spacelab system, is considered with attention to five major areas of concentration: improvements in the physical qualities of metals and composite materials, studies of transport phenomena and boundary surface dynamics, the growth of crystals for electronic applications, e.g., Si, InSb, GaAs, CdTe, etc., physico-chemical interactions in processes which may be used on an industrial scale, and the processing of pharmacological products. D.M.W.

Printout 2

A typical search

A typical Quest online search might be conducted in response to such a question as 'what information is available about the proposed materials processing experiments on Spacelab?'. Having dialled a concentrator to connect the data terminal with the IRS computer, the searcher can begin searching the NASA aerospace file by typing in the simple command:
FIND SPACELAB and MATERIAL? ? and PROCESSING
(the question marks find both singular and plural forms of the word). The computer will respond by stating that 42 items are on file; to do so it has checked about one million items in a matter of 12 seconds! The searcher can then instruct the computer to display the titles of the most recent items for rapid scanning. An example of the result is shown above left (Printout 1).

If, for example, the third item is chosen for closer examination, the computer will display more complete details including an abstract (Printout 2).

The complete details of this and any number of other documents that appear interesting can be printed out offline for transmission to the searcher.

Not all online searches are as simple as this one of course, and the average search time is likely to be between ten and fifteen minutes and the cost approximately one unit of account per minute. These online systems become significantly more cost-effective as more data is incorporated because the incremental cost is then small compared with the overall investment.

Conclusion
New features will inevitably be introduced which will make online systems even easier to use in the future. Currently a major problem lies in the difference between the various databases; standardisation has not yet even begun to be introduced and work is badly needed to simplify the task of searching several files preferably simultaneously. The introduction of Quest, to be regarded as a very significant system development and one which brings to an end dependence on the American-developed Recon software, marks a commitment to continuing development and increased efficiency in this particular field on the part of the Agency.

Article by A. Pinglier, continued from page 71

telecommunications satellites brings the capital cost per telephone for rural areas to just over twice that for urban areas. This remarkable achievement would be impossible if one had to rely on conventional terrestrial links.

These figures have then to be compared with the funding possibilities in the developing countries. According to the ITU, there is a relationship between per capita income and the percentage of GNP that a country can devote to annual investment in telecommunications. With an annual income per capita of $300, a country can devote 0.2% of its GNP to telecommunications investments, with $400 per capita 0.3%, and with $500 per capita 0.4%.

In our example, the available amounts on this basis are $3.6 M, $7.2 M and $12 M; comparing with Table 1,

- with a $300 per capita income, it will be very difficult to implement Phase-I using the country's own resources, and subsequent phases are impossible
- with $400 per capita; Phases-I and II can be implemented without outside aid. Phase-III (rural telephone) cannot be implemented
- with $500 per capita all three phases can be implemented.

Conclusion
Satellites can considerably improve the general telecommunications situation in many developing countries, giving vast rural areas access to telecommunications for the first time. The comparatively low funding requirements are already within the exchequers of many developing countries, and the others should be given the necessary aid to ensure that all developing countries can benefit from the decisive contributions that space links can make in the fields of teaching and, more generally, national development.

The Agency's Industrial Policy – Its Principles and Their Implementation Since 1975

G. Dondi, Industrial Policy Department, Directorate of Administration, ESA, Paris

When ESA was created in 1975, its Convention explicity stated that the Agency should promote cooperation among European states in space research and its applications 'by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States'.

Has an industrial policy been defined for ESA? Have appropriate measures been taken to ensure its implementation? Does the present situation require a redefinition of the Agency's industrial-policy principles or of the related measures for their implementation? These are three of the questions that this article attempts to answer.

Industrial-policy principles: their evolution at the time of ESA's creation.

An historical review of ESRO's efforts concerning industrial policy during the period 1963-1974 has already been presented in the ESA Bulletin*.

These efforts were instrumental in bringing to light some concepts and ideas that were later to become part of the Convention of the new European Space Agency, which came into being in 1975.

In an international organisation dealing actively with industry, it is essential to recognise, to be capable of influencing, and finally to control the problem of 'fair return'.

To this end, it is necessary to provide structures and procedures to deal with this problem both internally in the organisation and externally by utilising industry.

The principle of a 'fair return' should be only one of the aspects of the industrial policy of an international organisation dealing with advanced- technology problems; long-term actions need to be pursued also for, for example:

- technological development (selection of technical fields to be developed, and of specific actions to be undertaken), and protection of the technological efforts undertaken
- industrial structure definition and implementation
- improvement of space-industry competitiveness
- rationalisation of infrastructure and services with the help of industry.

Conflicts between these various aspects of an industrial policy need to be recognised, and solved pragmatically on a case-by-case basis.

A good deal of preparatory work took place in order to introduce these ideas into the institutional framework of the new Agency when it was created in mid-1975. Since then industrial policy has become part of the planning and execution of the Agency's programmes; it is therefore necessary to make reference to the planning and execution cycle in order to understand how an industrial policy is defined and implemented.

The role of the Agency's industrial policy in the definition and implementation of European space programmes

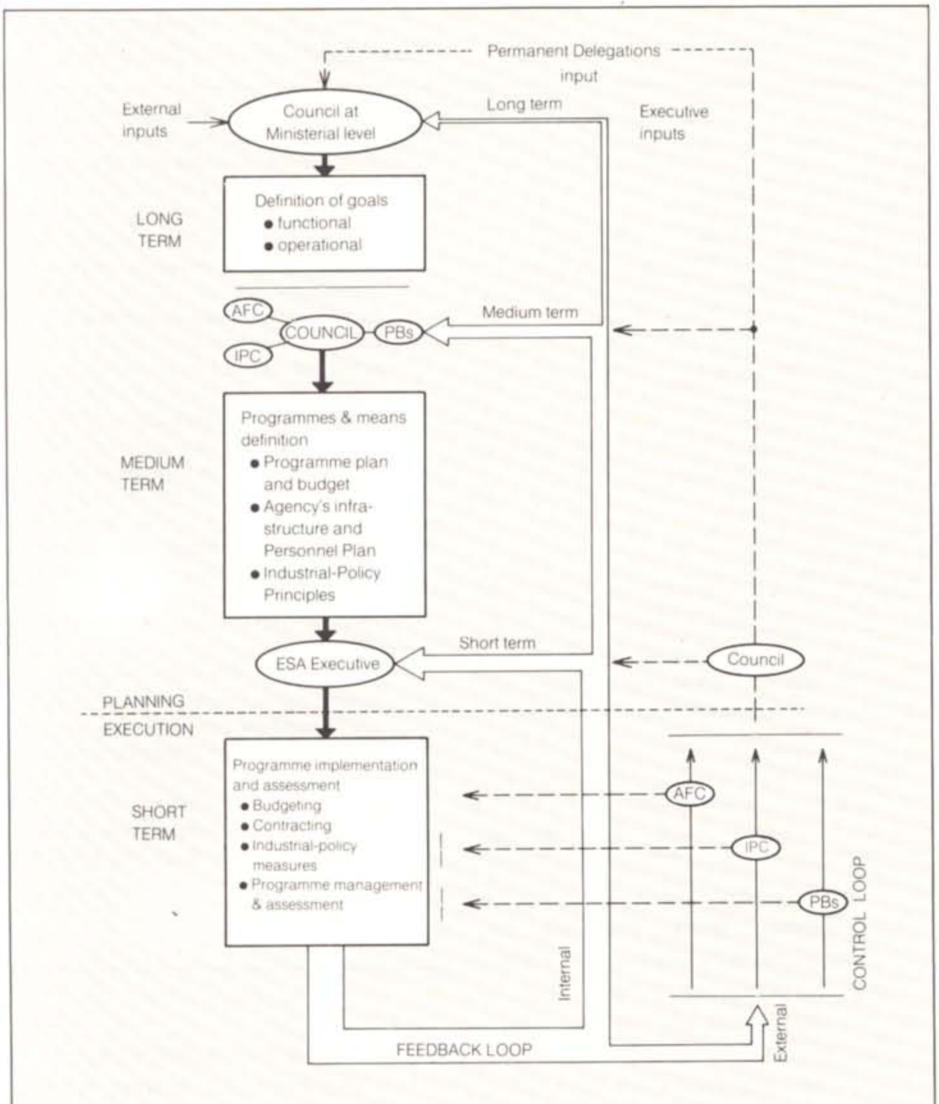
The planning and execution of European space activities

European space activities carried out within the framework of the Agency require a considerable amount of coordination and planning. To illustrate how industrial policy intervenes in these activities, what is inherently a complicated process has been 'idealised' in Figure 1. Three phases are clearly recognisable:

1. *Definition of goals:* carried out mainly at a political level (Council at ministerial level) and concerned with long-term objectives, such as the undertaking of space applications programmes in

* See ESA Bulletin No. 12, February 1978, pp. 24-29.

Figure 1 – Idealised 'flow chart' for the planning and implementation of ESA's space activities



addition to scientific programmes, development of a European space transportation capability, etc. By necessity, these kinds of decisions are taken at specific intervals and span at least a number of years.

2. *Programmes and means definition:* again carried out at a political level (Council), but concerned with medium-term objectives and constantly linked with implementation problems. The main problems dealt with in this phase, and the relevant decisions, usually concern the Agency's Programme Plan and Budget, its Infrastructure and Personnel Plan, and the industrial-policy principles governing the relations between the Agency and industry.

3. *Programme implementation:* carried out by the ESA Executive within the framework of the instructions received and of the resources put at its disposal. The programme is monitored internally by the ESA Executive itself and externally by Council-delegated bodies (occasionally by the Council itself for the more important matters or for the global problems, such as budgeting).

Agency goals and guidelines for their attainment

The ESA Convention contains a series of indications of what the Agency's tasks are and how they should be fulfilled; logically it seems appropriate to distinguish:

- indications of what the Agency should do in general terms (goals)
- indications of what the Agency should do as far as its relations with industry are concerned (industrial-policy principles)
- indications of how the activities of the Agency should be carried out (implementation guidelines).

The goals for the Agency can be divided into two types:

- functional goals, i.e. goals aimed at defining a capability in abstract terms, without explicit reference to the purpose for which this capability may be used
- operational goals, i.e. goals aimed at defining specific mission objectives (or end-products or services) without explicit reference to what technological capabilities may be necessary to achieve these objectives.

A list of the functional and operational goals for the Agency is given in Table 1, where specific reference is made to the text of the Convention pertaining to each of the goals.

The industrial-policy principles are summarised in Table 2. In general terms, one can say that these principles embrace the following concepts:

- the role of industry in the implementation of the Agency's programmes (principle 1)
- how industry should be used for this implementation (principles 2 and 3)
- the 'fair return' concept (principles 4, 5 and 6)
- the long-term aims ensuring the qualitative development and the quantitative growth of the European space industry (principles 7, 8, 9 and 10).

Table 1 – Goals of the Agency as incorporated in the ESA Convention

Functional goals	
Development of a European **space capability** in the field of:	
– space supporting technology	Article I.1a(i)
– spacecraft manufacturing and operation	
for scientific missions	Article V.1a(ii)
for applications missions	Article V.1b(i)
– launch systems and launch services	Article V.1b(ii)
– operational applications systems, including spacecraft, launch, ground installations and system operation	Article V.2
Development of a **competitive space industry** in Europe	Article VII.1b
Operational goals	
Provision of **services** in response to specific needs (clear or unclear; in latter case the Agency should be instrumental in clarifying them):	
– scientific missions	Article V.1a(ii)(iii)(iv)
– applications missions	Article V.1b, V.2; see also Article II, introductory sentence
Development of an **efficient infrastructure** to support space activities in Europe; in particular utilisation of existing national installations and services	Article VI

Table 2 – Principles of industrial policy as incorporated in the ESA Convention

1) For the execution of the Agency's programmes, maximum use should be made of industry (in opposition to building up ESA in-house capabilities)
Article VII.2

2) Available resources should be used in a cost-effective manner; in particular, utilisation of industry should be based on free competitive bidding
Article VII.1 (a) and (b)

3) An appropriate procurement policy should be defined and approved before a procurement action is undertaken
Annex V, Article III

4) Developments and procurements should, in principle, be carried out making use of Member States' industries
Article VII.1 (c) second part and Annex V, Article II.1

5) In particular, launchers developed by the Agency should in principle be used in support of European programmes
Article VIII

6) An equitable geographical distribution of contracts to Member States' industry should be ensured
Article VII.1 (c) first part

Finally, a few words about the implementation guidelines. Here the Convention stresses the principles of coordination and harmonisation:
- at the policy level, between the Agency and national or international organisations concerned with space activities (Article Ia)
- at the programme level between the Agency programme and national programmes (Article Ic)
- at the industrial-policy level (Article Id and Annex IV)
- at the facilities and services level (Article VI).

The implementation process
The implementation process includes the following phases:
- Definition of the Agency's programme and means
  This phase requires the completion and iteration of a number of complex steps, ensuring:
  - definition of a programme satisfying the Agency's goals
  - harmonisation of the programme with outside requirements and definition of the funding level
  - definition of options for programme implementation, and finally, after selection of the best option, definition of a series of plans (financial, infrastructure, personnel).
- Programme implementation and assessment
  This phase requires the carrying out of a number of activities which may be summarised as follows:
  (i) The conversion of plans and guidelines – which are, by their very nature, oriented towards the medium-term horizon and of a general character – into specific implementation plans and guidelines. In practice this requires:
  - the preparation of the yearly budget, and its execution (accounting of expenditures and execution of payments)
  - the negotiation, awarding and management of contracts to formalise the interaction of the Agency with industry
  - the transformation of industrial-policy principles into industrial-policy measures, to be carried out on a day-to-day basis during contract negotiation, award and management*.

To this end, appropriate statistics on awarded contracts should be maintained, a return coefficient for each country should be evaluated quarterly, and appropriate corrective actions should be undertaken if unbalanced situations develop.
Annex V, Articles IV and V

7) A balanced development of a competent European space industry should be aimed at, by utilising, structuring and rationalising existing industrial capabilities
Article VII.1 (b) second part

8) To this end, industrial potential and industrial structures should be under review by the Agency, in order to monitor and, if necessary, adapt the Agency's industrial policy
Annex V, Article I.2

9) Measures should be taken to improve the world-wide competitiveness of the European space industry Article VII.1 (b)

10) Possible conflicts originating in the simultaneous implementation of two or more of the above principles should be solved in a pragmatic manner
Article VII (d), second part

Table 3

Basic requirements	Conflicting requirements
1) Adopt the most efficient procurement policy	1) Ensure an equitable geographical distribution of contracts 2) Utilise European technology/components
2) Resort to free bidding	1) Restrict industrial capacity to what the market can support 2) Utilise national funding in support of technological research activities 3) Encourage the formation of consortia for geographical-distribution reasons
3) Ensure that a service is made available to ESA at low cost and efficiently	1) Ensure rotation of technical-service contractors

(ii) The actual execution of the various activities.
(iii) The analysis of the results obtained in performing the individual activities and the assessment of the overall situation by comparing the integrated results with the original plan.

Industrial-policy measures since 1975
Since ESA's creation, each of the rather general principles listed in Table 2 has been transformed into a series of measures to ensure practical implementation of the industrial policy. This transformation forms part of the day-to-day life of the Agency and is undertaken either on the initiative of the Executive or at the request of national Delegations, but always in response to the identification of practical problems to which the principles may be applied. Implementation measures are nearly always based on two elements:
- the availability of money to undertake specific actions
- the formalisation of this undertaking through a contract.

Only rarely does the implementation effort take the form of an organisational or study effort carried out internally by the Agency utilising its own resources.

The following paragraphs summarise the most important industrial-policy measures taken to date by the ESA Executive as practical replies to implicit requests for actions foreseen in the Agency's industrial-policy principles as listed in Table 1 (the measures described are grouped under the pertinent industrial-policy principles).

'Make maximum use of industry'
Two main lines have been followed by the ESA Executive in implementing this principle. The first, delegation to industry of all activities that are not sufficiently 'specialised' to warrant an in-house approach, covers such items as:
- maintenance and operation contracts for the ESA Spacecraft Operations Centre and ground stations
- maintenance and operation contracts for various ESA computer systems
- technical assistance for the maintenance and operation of environmental-test installations
- technical assistance for the maintenance and operation of checkout equipment
- technical assistance for software development and maintenance (Meteosat system, Multi-Satellite Support System (MSSS), checkout equipment, etc.)
- management of the European Space Tribology Laboratory (ESTL)
- utilisation of external general-purpose computers instead of extending ESA's own installations.

The second line of action (transfer to industry of activities and equipment allowing industry to ensure a more cost-effective service in view of a foreseeable higher utilisation of the transferred equipment) embraces such items as

* For example, the principle stating that 'in the execution of the Agency's programmes, maximum use should be made of industry' (as opposed to building up the Agency's in-house capabilities) must be converted into contract proposals for delegating the maintenance and operation of the Agency's ground facilities to contract staff.

checkout equipment for telecommunications programmes.

'Utilise efficient procurement methods'
Utilisation of efficient procurement methods has been pursued by the ESA Executive in various ways, including the setting up of internal procedures discouraging use of noncompetitive procurements, the adoption of a new procurement policy for large development contracts, and consultation with non-Member-State firms whenever there is reason to doubt that Member-State sources could take advantage of a monopoly (or quasi-monopoly) situation.

Limitations to the principles of free competitive bidding have had to be accepted in some instances, for reasons of:
- efficiency in follow-on contracts for some specialised procurements
- development of specific expertise in 'small countries'
- programme agreement with countries participating in the Advanced Systems Technology Programme (ASTP)
- corrective actions aimed at improvement of the return coefficients of certain countries.

'Define a new procurement policy'
The aims of the new procurement policy outlined in the Convention are that:
- Delegations should limit themselves to approving the policies for the most important procurement actions (instead of approving the awarding of the great majority of procurements); awarding of contracts should be delegated to the Agency once the procurement policy had been agreed.
- Delegations should nevertheless have the possibility to discuss the awarding of specific contracts if they so wish.

New contract rules, reflecting these ideas, have been defined by the ESA Executive and approved by Council, and they entered into force on 1 January 1980.

The new rules not only include the principles mentioned above, but also incorporate explicit instructions for when noncompetitive procurements (or restricted-competition procurements) must be envisaged.

'Buy European'
The two main lines followed by the ESA Executive in implementing this principle have been:
- working out of guidelines concerning definition of and dealing with firms that do not belong to ESA Member States, and
- definition of specific actions favouring procurement of systems/subsystems developed in the Member States.

In particular, the following three problems have been analysed:
- definition of a firm as belonging to a Member State
- definition of a policy concerning sending of invitations to tender to non Member-State firms
- definition of a policy concerning awarding of contracts to non-Member-State firms.

Specific actions taken in favouring procurement of Member-State system/subsystems include:
- procurement of European configurations for ESA computer systems (general purpose Multi-Satellite Support System, Meteosat System, etc.)
- specification of European components for ESA projects (on-board data-handling equipment, hydrazine thrusters, apogee boost motors, etc.)
- requesting that non-European subsystems are to be considered only as 'alternatives' in baseline offers for ESA satellite systems (Space Telescope and International Solar-Polar Mission)
- specification of procurement policies favouring use of electronic components of European origin in ESA satellite systems.

'Utilise European launchers'
Specific rules and procedures have been established by the Executive (and agreed by Council) for use of Ariane in support of European programmes (ESA and national programmes). Agreement has been reached on the cost of a launcher for ESA programmes, the cost of a launcher for a national programme of a Member State, and the cost of a launcher to a non-Member-State client.

Preliminary discussions have already taken place concerning the management of Ariane production activities after completion of the second Ariane production series (definition of the terms of reference of 'Arianespace').

'Ensure an equitable distribution of contracts'
The Executive's activities in support of this particular principle fall into four main categories:
1 Definition and application of a methodology for measuring the geographical distribution of contracts:
- definition of the return coefficient for one programme
- definition of the return coefficient when there are several programmes to which each country makes a different contribution.

2 Definition and application of policies to account specific categories of expenditure:
- definition of weighting factors for nondevelopment work
- definition of weighting factors for work performed within the framework of satellite development contracts
- accounting of work performed by a firm of country A in country B
- accounting of work performed by European industry for Ariane production.

3 Definition and application of procedures to take into account the influences of inflation and exchange-rate variations on

the data used for the return- coefficient computation.
4 Definition and application of measures to improve the return coefficient of a country:
- favouring the formation of industrial consortia
- definition of a new procurement policy for major satellite projects, in particular indication to potential contractors of the desired trends for the geographical distribution of the contract to be awarded
- sending of invitations to tender to firms of a 'deficit' country for programmes in which this country does not participate
- proposal of ad-hoc measures to favour 'deficit' countries at the time of contract award
- definition of the '0.92 rule' for reducing the contributions from 'deficit' countries to the Agency's ECS and Marecs projects
- definition of the 130% rule, to improve the return on technological research activities to Belgium, Spain and Switzerland.

'Ensure the balanced development of a competent European space industry'
The three main lines followed by the ESA Executive in implementing this principle have been:
1 Definition, development and protection of the most interesting technologies for supporting the ESA programmes:
- definition of a technological research programme in support of future programmes in general, and of supporting-technology programmes for specific applications (telecommunications, earth resources, etc.), with harmonisation of overlapping activities
- in particular, sponsoring development of specific space systems, elements or technologies (launchers, apogee boost motors, hydrazine thrusters, solar cells, on-board data-handling systems, cryostats, etc.)
- harmonisation of ESA programmes with national programmes; in particular, acceptance of partial national financing of ESA programmes (hydrazine thrusters, cryostats, etc.)
- development of advanced technologies restricted to a reduced number of competent firms, ensuring competition but avoiding a 'starved' market (definition of appropriate industrial policies in Technological Research Dossiers, covering individual technological areas)
- spreading of advanced technology to small countries, via the 130% return rule in favour of Belgium, Switzerland and Spain, and adoption and implementation of the ASTP programme (harmonisation of nationally funded technological research activities with ESA programmes under ESA management)
- imposition of the utilisation of subsystems/components in ESA projects which have been developed within the ESA technological research programme.

2 Indirect intervention favouring the formation of industrial structures adapted to the implementation of ESA programmes:
- formation of consortia for important satellite-development contracts
- formation of international commercial partnerships for important ESA procurements
- reduction of the number of prime contractors and increased competition at subcontractor level for satellite-development programmes.

3 Encouragement of initiative favouring cross-fertilisation with and within industry:
- encouragement to university groups to cooperate with industry in the specific domains of telecommunications (University of Louvain), antenna design (Technical University of Denmark), structures and data processing (University of Stuttgart) and scientific instrumentation (various universities)
- encouragement to rotation of technical-assistance contractors (software development, etc.)
- employment of independent consultants or study groups to prepare the ground for future development contracts.

'Review industrial capabilities and structures'
Steps taken in this respect include:
1 Execution of studies centred on European space industry:
- space market accessible to European industry
- evaluation of capabilities and workload of European industry
- evaluation of benefit accrued to industry as a consequence of space activities.

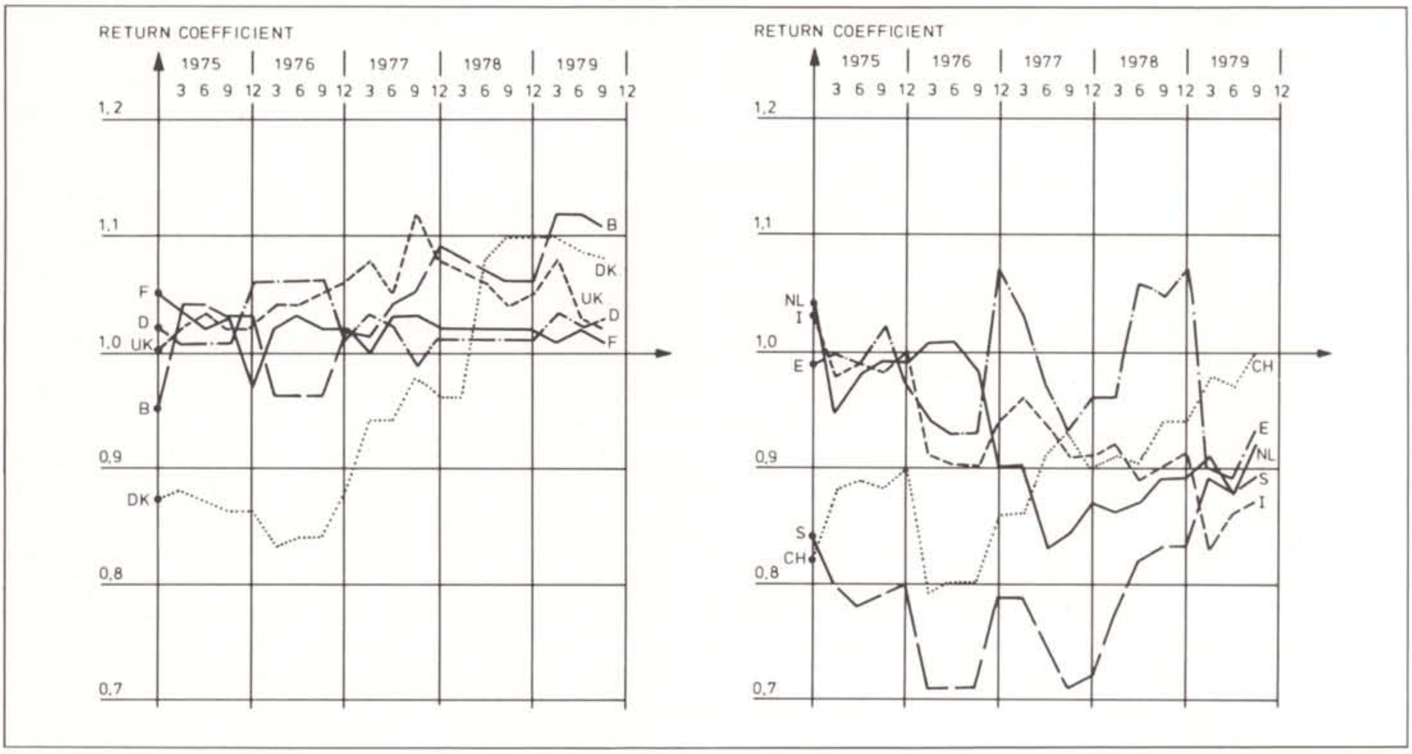
2 Studies on the most desirable evolution of space-industry structures.
3 Setting-up of 'industrial files' on the main ESA contractors.
4 Development of a dialogue with industry by appropriate adaptation of the Agency's internal structure.

'Improve world-wide competitiveness of European space industry'
The activities of the ESA Executive in support of this principle are:
1 Promotion of the use outside Member States of systems/technologies developed by ESA, including:
- the Ariane launcher
- European participation in the Intelsat-V project
- the Eurab terminal.

2 Promotion of space applications (or space-related services) whenever a potential need becomes apparent:
- presentation of ESA knowhow and the capabilities of European industry to third-world countries
- promotion missions to Indonesia, Latin America, China, Turkey, etc.
- demonstration of Meteosat primary and secondary data user terminals (PDUS, SDUS) and data-collection platforms (DCPs) in several countries.

3 Support of commercial space projects undertaken by European space industry:
- utilisation of Agency knowhow by

Figure 2 – Evolution of the industrial return coefficients for ESA's Member States since 1 January 1975



potential clients (e.g. India)

- offer of utilisation of Agency infrastructure for the development (checkout, testing) and operational phases of commercial projects (Brazilsat, possibly Arabsat)
- transfer of equipment (checkout for telecommunications projects) to industry to improve its flexibility on commercial projects.

4 Standardisation efforts to reduce the industrial cost of space hardware and services.

5 Protection of the European space market where advanced development is needed (hydrazine thrusters, solar cells, apogee boost motors).

'Solve conflicting industrial-policy requirements'

Conflicting industrial-policy requirements have been encountered by the ESA Executive from time to time and a number of examples are cited in Table 3. These conflicting requirements have been dealt with on a case-by-case basis as they have arisen, taking into account the contingent situation at the time the decision was needed.

Industrial-policy results since 1975

The results of ESA's industrial policy since 1975 have to be assessed in three different perspectives.

Firstly, the geographical distribution of contracts among ESA Member States has to be examined in the light of the evolution of return coefficients since 1975 (Fig. 2). In the last five years, the return coefficients of all Member States have fluctuated between 0.8 and 1.1, with only Sweden occasionally approaching the 0.7 level. Countries that were in a critical situation at the end of 1974 (Denmark, Switzerland and Sweden with return coefficients in the 0.8 area) have now recovered, while the situation in the Netherlands and Italy (coefficients $\geqslant 1$ in 1975) has deteriorated. In the case of Italy, the imbalance is difficult to correct considering the country's sizeable contribution to the budget, and special measures are now being considered. The overall situation of the other Member States may be considered satisfactory ($0.89 \leqslant RC \leqslant 1.09$).

Secondly, it is necessary to assess to what extent and how efficiently the industrial-policy principles expressed in the Convention have been put into practice. It can be noted that practically all guidelines have at least been transformed into a number of implementation measures; progress in implementation is more visible in some areas than in others, depending partly on the difficulty of the tasks themselves, partly on the 'consensus to proceed' reached by the various Delegations. The main items still in a 'preparatory' phase, are the implementation of a new procurement policy, now under way with the application of the new contract rules which have become operative since 1 January, the definition and utilisation of indirect measures to obtain industrial structures adapted to the practical implementation of ESA programmes, and the definition and implementation of adequate measures leading to standardisation of equipment/services, in order to improve European space industry's competitiveness.

Finally, the very task of elaborating and implementing an industrial policy has made the ESA Executive particularly aware of the industrial problems of the future, which have to be foreseen and analysed in deciding the Agency's future programmes.

A tentative list of these 'problems of the future' might include:

- adaptability of current industrial structures to the execution of different space programmes (ESA, national, commercial, etc.)
- national and international constraints on industrial structures for space projects
- industrial competition/cooperation with US space industry in joint ESA/NASA ventures
- industrial specialisation for technological research activities, including the role of the ASTP programme and its impact on industrial specialisation at the European level
- guarantee of industrial return to a Member State participating in a production programme following a development programme
- modification of the rules for the computation of the return coefficient to take into account:
  a) a limited time horizon (e.g. the contracts awarded during the last five years)
  b) the expenditures financed outside ESA but originating from ESA initiatives
- industrial problems linked with the standardisation of equipment, including
  a) incentive schemes for involving industry in the development phase
  b) the role of small countries in a standardisation programme
  promotion of standard equipment.

FORTHCOMING SYMPOSIUM

PROCEEDINGS TO BE PUBLISHED
IN SEPTEMBER 1980
BY ESA PUBLICATIONS BRANCH
AS ESA SP-151

Parliamentary Assembly
Council of Europe

european space agency

Université Louis Pasteur

International Colloquium

ECONOMIC EFFECTS OF SPACE AND OTHER ADVANCED TECHNOLOGIES

Palais de l'Europe,
Strasbourg, France
28-30 April 1980

For information: Dr. G. Niederau, European Space Agency,
8-10, Rue Mario Nikis, 75738 PARIS Cedex 15 France, tel. 5675578

In brief

New ESA Director General Appointed

At its meeting on 19 December 1979, the ESA Council appointed Mr. Erik Quistgaard to the post of Director General of ESA in succession to Mr. Roy Gibson. Mr. Quistgaard, who is 58, is married and has two sons, both of whom are engineers. He is of Danish nationality and graduated in Mechanical Engineering at the Technical University of Copenhagen. Much of his life has been spent in industry, including three years with the Chrysler Corporation in the United States. He has been a Director and General Manager of Volvo in Sweden. After leaving Volvo, he became Managing Director of Odense-Lindö Stalskibsvaerft A/S, the ship-building firm in Odense, Denmark. Mr. Quistgaard takes up his duties with ESA on 15 May 1980.

Mr. Erik Quistgaard, who takes over as ESA's Director General on 15 May

Prime Contractor Selected for Large Satellite Programme

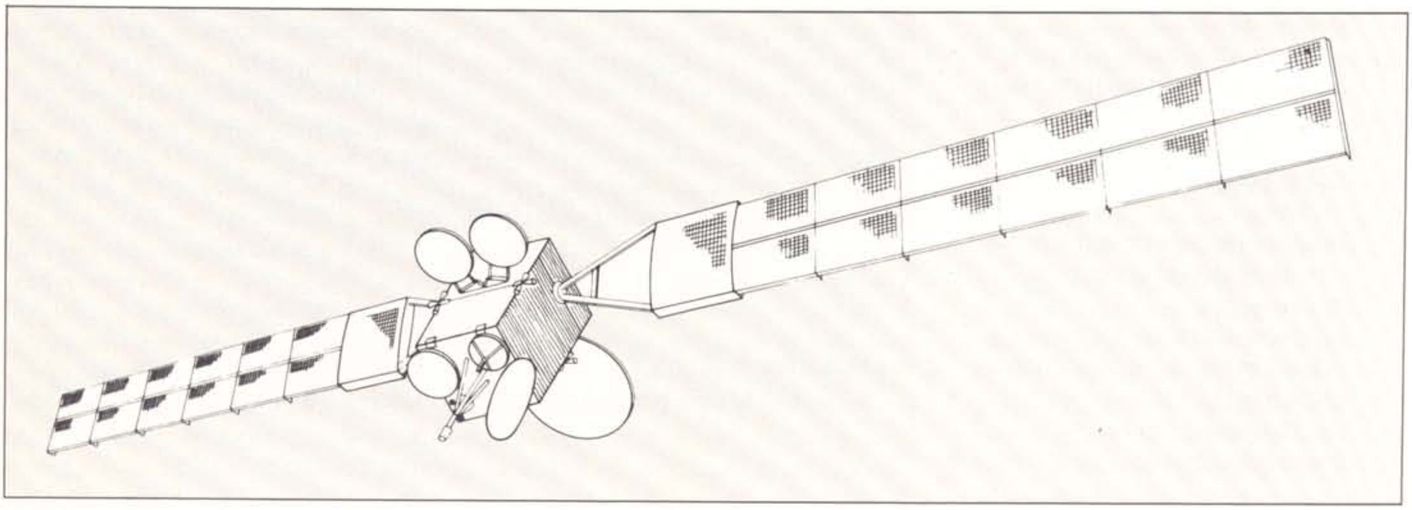
At its meeting on 29 November, the Agency's Industrial Policy Committee accepted the Executive's recommendation to nominate British Aerospace as Prime Contractor for the Large Satellite Programme and approved the award of a contract for the first part of the project definition (Phase B1).

In addition the IPC authorised the negotiation and award of contracts for payload studies associated with the demonstration payload for the first flight to:

- Selenia (Italy) for the TV-broadcast and 20/30 GHz transponder payloads
- Marconi Space and Defence Systems (UK) for the specialised-services payload
- BTM (Belgium) for the 20/30 GHz beacon payload, and
- Telespazio (Italy)/Philips (Netherlands)/Marconi (UK) for mission studies related to the 20/30 GHz transponder payload.

The total value of these approved contracts is 1.4 Million Accounting Units (1 MAU ~ $1.23).

The ESA Joint Board on Communication Satellites has also approved, in December, a financial envelope of 13.4 MAU for the second phase of the



project definition (Phase B2). This is to cover both industrial and ESA internal costs, provision having been made for breadboarding of critical hardware and the ordering of long-lead parts in advance of the main development phase.

The two essential objectives of the L-Sat Programme are:
- the development of a multipurpose large platform meeting the user requirements for future telecommunications applications
- the development and in-flight evaluation of a demonstration service payload that will help users to assess the potential of new satellite services, stimulate satellite usage and promote new markets.

Phase B1 is expected to be completed by the end of May 1980 and to be followed by Phase B2, which is planned to lead to a contract decision for the start of main development by the end of 1980 and a launch early in 1984.

The Agency Member States presently participating in the Large Satellite Programme are Belgium, Denmark, the Netherlands, Spain, Switzerland and the United Kingdom.

'Man and Space' – Art Competition

The 'Young Europeans and Spacelab' programme, which has been developed by the European Space Agency (ESA), is intended to popularise space activities and, in particular the Spacelab programme and its evolution, to promote scientific and technical hobbies among young people, and to encourage European cooperation in space ventures. In this context, several events are planned, some of which will offer young Europeans the possibility of carrying out experiments on Spacelab.

In the framework of this programme and with the aim of illustrating its objectives, an art competition will be organised by the European Space Agency with the theme: 'Man and Space'.

All young Europeans from Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom, who are between the ages of 12 and 21 years in 1980 are invited to illustrate the theme, choosing their own art medium (drawing, painting, sculpting, modelling, poetry, short story, play, audio-visual, musical, etc.).

The competition will be organised at two levels: national and European. The national authorities sponsoring the competition will be responsible for its local organisation, will define the procedures for participation, will establish selection criteria, carry out the selection and award the prizes foreseen at national level. ESA will organise an exhibition of the works selected at national level and will present the prizes foreseen at European level. The exhibition will be held at – and with the co-sponsorship of – the 'Conservatoire National des Arts et Mêtiers' in Paris.

The closing date for submission of works to the national selection boards is June 1980, and the exhibition in Paris will be held during November/December 1980.

The authors or team leaders of five works per country will be invited by ESA for a four-day visit to Paris, on the occasion of the opening of the exhibition, for which up to five additional works per country will be accepted. During the exhibition the public will be invited to select the twelve best works (i.e. one per country). The authors or team leaders of these works will be the guests of ESA on a visit to the Kennedy Space Center where they will be able to visit the Shuttle/Spacelab facilities.

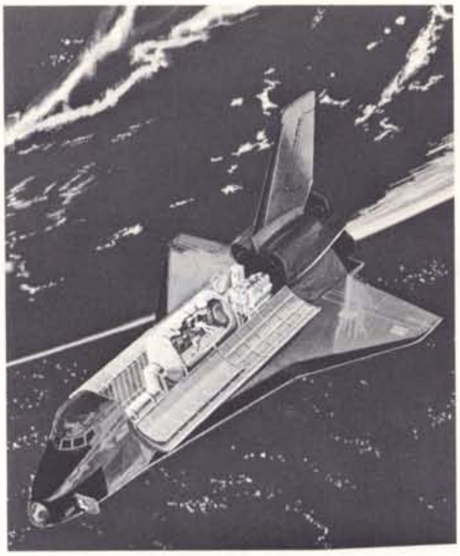
Further information can be obtained from the following national points of contact:

Austria
Dr. Erwin Mondre
ASSA
Garnisongasse 7
A 1090 Wien

Belgium
M.M. Jacob
Programmation de la Politique Scientifique - Rue de la Science 8
B 1040 Bruxelles

Denmark
Ungdommens Naturvidenskabelige Forening - H.C. Ørsted Instituttet
Universitetsparken 5
2100 København Ø

France
A.N.S.T.J. - Spacelab
Palais de la Découverte
Avenue Franklin D. Roosevelt
75008 Paris



Germany
Deutsche Gesellschaft für Luft- und Raumfahrt (DGLR) - Jugend und Weltraum - Postfach 131 750
5600 Wuppertal

Netherlands
Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (NIVR) f.a.o. D. de Hoop - Postbox 35
2600 AA Delft

Ireland
National Board for Science and Technology 'Youth/Spacelab'
Shelbourne House - 21 Shelbourne Road
Dublin 4

Italy
Associazione Italiana di Aeronautica e Astronautica (AIDAA)
Via Po Nº 50
00198 Roma

Spain
Dirrección General de la Juventud
Ministerio de la Cultura, Planta 6º
Avenida del Generalisimo, 39
Madrid 16

Sweden
Lennart Steen
Tekniska Musée
Museivagen 7
11527 Stockholm

Switzerland
La Science appelle les Jeunes
Observatoire de Genève
CH 1290 Sauverny

United Kingdom
Mr. A.M. Hughes
British Association for Young Scientists
Fortress House - 23 Savile Row
London W1X 1AB

Publications

The documents listed have been issued since the last publications announcement in the Bulletin. Requests for copies should be made in accordance with the Table inside the back cover and using the Order Form on page 93.

ESA Journal

The following papers were published in Vol 3 No 4:

RADIO-PROPAGATION RESEARCH BY THE EUROPEAN SPACE AGENCY
G BRUSSAARD

THE GEOS-1 DYNAMIC EXPERIMENT
PH BOLAND & F JANSSENS

A NOVEL REALISATION FOR MICROWAVE BANDPASS FILTERS
R J CAMERON

PERFORMANCE OF A HEAT-PIPE-COOLED X-BAND GaAs FET AMPLIFIER IN A SPACE ENVIRONMENT
M H GIBSON, C J SAVAGE & S J G STRIJK

PERIODIC-STRUCTURE AMPLITUDE AND PHASE MODULATORS: DESIGN IDEAS
G P BAVA & C NALDI

A LINE-SCAN METHOD FOR METEORLOGICAL-SATELLITE IMAGE GRIDDING
C G TSOLAKIDIS

THE (31,21) BCH CODE FOR METEOSAT DATA-COLLECTION-PLATFORM ADDRESS TRANSMISSION AND RECOGNITION
T WOLFF

Special Publications

ESA SP-1017 CATALOGUE OF ESRO/ESA PUBLICATIONS 1964-1976 (OCTOBER 1979)
BATTRICK B (COMPILER)
PRICE CODE: NO CHARGE

Brochures

ESA BR-01 BIOLOGY AND MEDICINE IN SPACE (AUGUST 1979)
BJURSTEDT H (EDITOR)
PRICE CODE: E1

ESA BR-02 ECONOMIC BENEFITS OF ESA CONTRACTS - SUMMARY OF A STUDY CONDUCTED BY THE THEORETICAL & APPLIED ECONOMICS BUREAU OF THE LOUIS PASTEUR UNIVERSITY OF STRASBOURG FOR THE EUROPEAN SPACE AGENCY (OCTOBER 1979) (ALSO AVAILABLE IN FRENCH AND GERMAN)
EUROSPACE
PRICE CODE: E1

Scientific and Technical Memoranda

ESA STM-208 MISSION ANALYSIS FOR TERRESTRIAL SATELLITES AND PLANETARY ORBITERS: SOFTWARE DESIGN AND ALGORITHM DESCRIPTION (AUGUST 1979)
JANIN G
PRICE CODE: C1

ESA STM-214 MODELISATION DES TRANSFERTS THERMIQUES COUPLES PAR RAYONNEMENT ET CONVECTION: APPLICATION A LA CABINE DU SPACELAB (OCT 1979)
SAULNIER J B, ALEXANDRE A & MARTINET J
PRICE CODE: C1

Scientific and Technical Report

ESA STR-204 GEOS RESCUE - MISSION PLANNING AND IMPLEMENTATION IN NEAR-REAL-TIME (OCT 1979)
ROTH E A
PRICE CODE: C1

Procedures, Standards and Specifications

ESA PSS-51 GUIDELINES FOR SPACECRAFT CLEANLINESS CONTROL (MAY 1979)
PRODUCT ASSURANCE DIVISION, ESTEC
PRICE CODE: C1

Contractor Reports

ESA CR(P)-1183 SPACELAB FOLLOW-ON MISSION SUPPORT STUDY - FINAL REPORT VOLUME 1: SUMMARY; VOLUME 2: PAYLOAD DM1; VOLUME 3: PAYLOAD DM2; VOLUME 4: PAYLOAD D4; VOLUME 5: COST INDICES; VOLUME 6: RIDER (OCT 1978)
BRITISH AEROSPACE, UK

ESA CR(P)-1184 STUDY ON THE IDENTIFICATION OF SERVICES AND ORGANISATIONS INTERESTED IN THE USE OF THE SPACELAB METRIC CAMERA - FINAL REPORT (DEC 1978)
EUROSAT, SWITZERLAND

ESA CR(X)-1185 THE INTEROPERABILITY OF GPS NAVSTAR AND A PROPOSED CIVIL AERONAUTICAL SATELLITE - FINAL REPORT (SEP 1978)
BRITISH AEROSPACE, UK

ESA CR(P)-1186 DEVELOPMENT OF A COMPUTER SYSTEM FOR THE CALCULATION AND MANAGEMENT OF THERMAL MATHEMATICAL MODELS - STEP 2 (AUG 1978)
SEMA INFORMATIQUE, FRANCE

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ESA CR(P)-1188 DESIGN STUDY AND DEVELOPMENT OF A MAGNETIC BEARING SCANNING MECHANISM (MBSM) FOR OPTICAL SENSOR APPLICATIONS - PHASE 1 FINAL REPORT (JAN 1979)
BRITISH AEROSPACE, UK

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SEP, FRANCE

ESA CR(P)-1190 MILLIMETRE-WAVE LOW-NOISE FRONT END - FINAL REPORT (JUL 1978)
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ESA CR(P)-1192 STUDY OF SPACECRAFT ATTITUDE RECONSTITUTION USING THE ESA STAR MAPPER (DEC 1977)
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ESA CR(P)-1193 ASSESSMENT OF SHORT- AND MEDIUM-TERM IMPROVEMENTS TO THE SPACELAB POWER SYSTEM - EXECUTIVE SUMMARY VOLUMES I AND II (OCT 1978)
AEG-TELEFUNKEN, GERMANY

ESA CR(P)-1194 DESIGN AND DEVELOPMENT OF A HIGH-PERFORMANCE VARIABLE CONDUCTANCE HEAT PIPE - FINAL REPORT PHASE II (DEC 1978)
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ESA CR(P)-1195 ETUDE DE LA FAISABILITE DE L'OPACITE DE L'ECRAN ET DE LA COURBURE D'UNE GALETTE DE MICROCANAUX DE 40 MILLIMETRES DE DIAMETRE EN VUE D'UNE APPLICATION POUR UN TUBE INTENSIFICATEUR A COMPTAGE DE PHOTONS - RAPPORT FINAL (DEC 1978)
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ESA CR(P)-1199 FINAL REPORT ON THE STUDY OF THE DEFINITION OF A GROUND SAR PROCESSOR FOR SEASAT-A (UNDATED)
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ESA CR(P)-1201 ATMOSPHERIC PROPAGATION RESEARCH AT 20 AND 30 GIGAHERTZ - FINAL REPORT (OCT 1978)
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ESA CR(P)-1203 EVALUATION OF EPSILAM-10 MIC SUBSTRATE MATERIAL (DEC 1978)
FIAR, ITALY

ESA CR(P)-1204 OSCILLATEUR A ONDES ACCOUSTIQUES FONCTIONNANT AU VOISINAGE DE 1,5 GIGAHERTZ - RAPPORT FINAL (FEV 1979)
THOMSON-CSF, FRANCE

ESA CR(P)-1205 DYNAMICS OF A SYSTEM OF TWO SATELLITES CONNECTED BY A DEPLOYABLE AND EXTENSIBLE TETHER OF FINITE MASS - VOLUME 1: EQUATIONS OF MOTION; DIGITAL SIMULATION; PROGRAM DOCUMENTATION; USER'S GUIDE. VOLUME 2: VARIATIONAL FORMULATION; EQUATIONS OF MOTION INCLUDING TORSIONAL STIFFNESS; FINITE ELEMENT APPROACH; APPENDICES: SIMPLIFIED MODELS (OCT 1978)
ACM SCHANIS AG, SWITZERLAND

ESA CR(P)-1206 ON-BOARD SIGNAL PROCESSING TECHNOLOGY AND SYSTEMS - VOLUME 1: SIGNAL PROCESSING OPERATIONS; VOLUME 2: SIGNAL PROCESSING TECHNOLOGIES; VOLUME 3: SIGNAL PROCESSING APPLICATIONS; VOLUME 4: SIGNAL PROCESSING DEVICES (DEC 1977 - MAR 1978)
FERRANTI, UK

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AML, FRANCE

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EUROSAT, SUISSE

ESA CR(P)-1210 PALLET-ONLY CONFIGURATION IMPROVEMENT STUDY - TECHNICAL SUMMARY REPORT (JAN 1979)
BRITISH AEROSPACE, UK

ESA CR(P)-1211 SYSTEM STUDY ON NEAR-TERM SPACELAB FOLLOW-ON DEVELOPMENT ALTERNATIVES VOLUME 1: TECHNICAL REPORT. VOLUME 2: PROGRAMMATICS (DEC 1978)
ERNO, GERMANY

ESA CR(P)-1212 PERFORMANCE ANALYSIS OF A NONLINEAR SATELLITE CHANNEL USING VOLTERRA SERIES - FINAL REPORT (DEC 1977)
IST. ELETTRON. E TELECOM. POLITEC. TORINO, ITALY

ESA CR(P)-1213 DEVELOPPEMENT DE L'ARGENT-HYDROGENE - RAPPORT FINAL (JAN 1979)
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ESA CR(P)-1214 MISE AU POINT DE MATERIAUX COMBINANT LA QUALITE DE REFLECTEUR SOLAIRE ET UNE BONNE CONDUCTIBILITE ELECTRIQUE. TOME 2 - RAPPORT FINAL SUR LA PHASE 2 (FEV 1979)
ONERA, FRANCE

ESA CR(P)-1215 STUDY ON OPTICAL PROCESSING OF IMAGE DATA ON BOARD SPACECRAFT - FINAL REPORT (APR 1979)
BRITISH AEROSPACE, UK

ESA CR(P)-1216 CRYOSTAT A HELIUM SUPERFLUIDE POUR UTILISATION SPATIALE - PHASE 1 DOSSIER FINAL (FEV 1979)
SNIAS, FRANCE

ESA CR(P)-1217 SURVEY OF SPACE RADIATOR SYSTEMS - FINAL REPORT (NOV 1978)
AERITALIA, ITALY

ESA CR(P)-1218 PROCESSING OF METEOSAT ATTITUDE MEASUREMENT FLIGHT DATA AND EVALUATION OF THE PERFORMANCE OF AN ADAPTIVE FILTERING TECHNIQUE (DEC 1978)
NLR, NETHERLANDS

ESA CR(P)-1219 INNOVATIONS ET TRANSFERTS TECHNOLOGIQUES: LE ROLE DE L'AGENCE SPATIALE EUROPEENNE - VOLUME 1: RAPPORT FINAL; VOLUME 2: ANNEXES (FEV 1979)
UNIV. L. PASTEUR, STRASBOURG, FRANCE

ESA CR(P)-1220 ADVANCED POWER SUPPLY SYSTEM - ABSTRACT REPORT (JAN 1979)
ETCA, BELGIUM

ESA CR(P)-1221 FRICTIONAL TORQUE OF ANGULAR CONTACT BALL BEARINGS WITH DIFFERENT CONFORMITIES (JUL 1978)
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ESA CR(P)-1222 REPORT ON A STUDY AND IMPLEMENTATION OF AN ESA COMPUTERISED PLANNING SYSTEM VOLUME 1: PLANNING SYSTEM FUNCTIONS AND STRUCTURE; VOLUME 2: DATA FILES AND UPDATING; VOLUME 3: PROGRAM DOCUMENTATION; VOLUME 4: UPDATING OF SUBPROGRAMS ESA 1 - 5; VOLUME 5: PROJECT RETURNS AND BENEFITS; VOLUME 6: EXECUTIVE SUMMARY (JAN - DEC 1978)
GENERAL TECHNOLOGY SYSTEMS LTD, UK

ESA CR(P)-1223 THE CIRCUIT DESIGN OF A SATELLITE BATTERY DISCHARGE REGULATOR USING THE LIMIT CYCLE CONDUCTANCE CONTROLLER - FINAL REPORT (MAR 1979)
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MBB, GERMANY

ESA CR(P)-1226 GEOS-3 STUDY - FINAL REPORT (MAR 1979)
BRITISH AEROSPACE, UK

ESA CR(P)-1227 STUDY ON EVOLUTION OF COMMAND AND DATA MANAGEMENT ON SPACELAB - FINAL REPORT (NOV 1978)
MATRA, FRANCE

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MARCONI, UK

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FULMER RESEARCH INSTITUTE, UK

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