european space agency

esa bulletin

agence spatiale européenne

number 58

may 1989

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 Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Finland is an Associate Member of the Agency. Canada is a Cooperating State.

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 Inspector General; the Director of Scientific Programmes; the Director of the Earth Observation and Microgravity Programme; the Director of the Telecommunications Programme; the Director of Space Transportation Systems; the Director of the Space Station and Platforms Programme; the Director of ESTEC; the Director of Operations and the Director of Administration.

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 H. Grage.

Director General: Prof. R. Lüst.

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, l'Autriche, la Belgique, le Danemark, l'Espagne, la France, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse. La Finlande est membre associé de l'Agence. Le Canada beneficie d'un statut d'Etat coopérant.

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 satellite 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; de l'Inspecteur général; du Directeur des Programmes scientifiques; du Directeur des Programmes d'Observation de la Terre et de Microgravité; du Directeur du Programme de Télécommunications; du Directeur des Systèmes de Transport spatial; du Directeur du Programme Station spatiale et Plates-formes; du Directeur de l'ESTEC, du Directeur des Opérations et du Directeur de l'Administration.

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 H. Grage.

Directeur général: Prof. R. Lüst.

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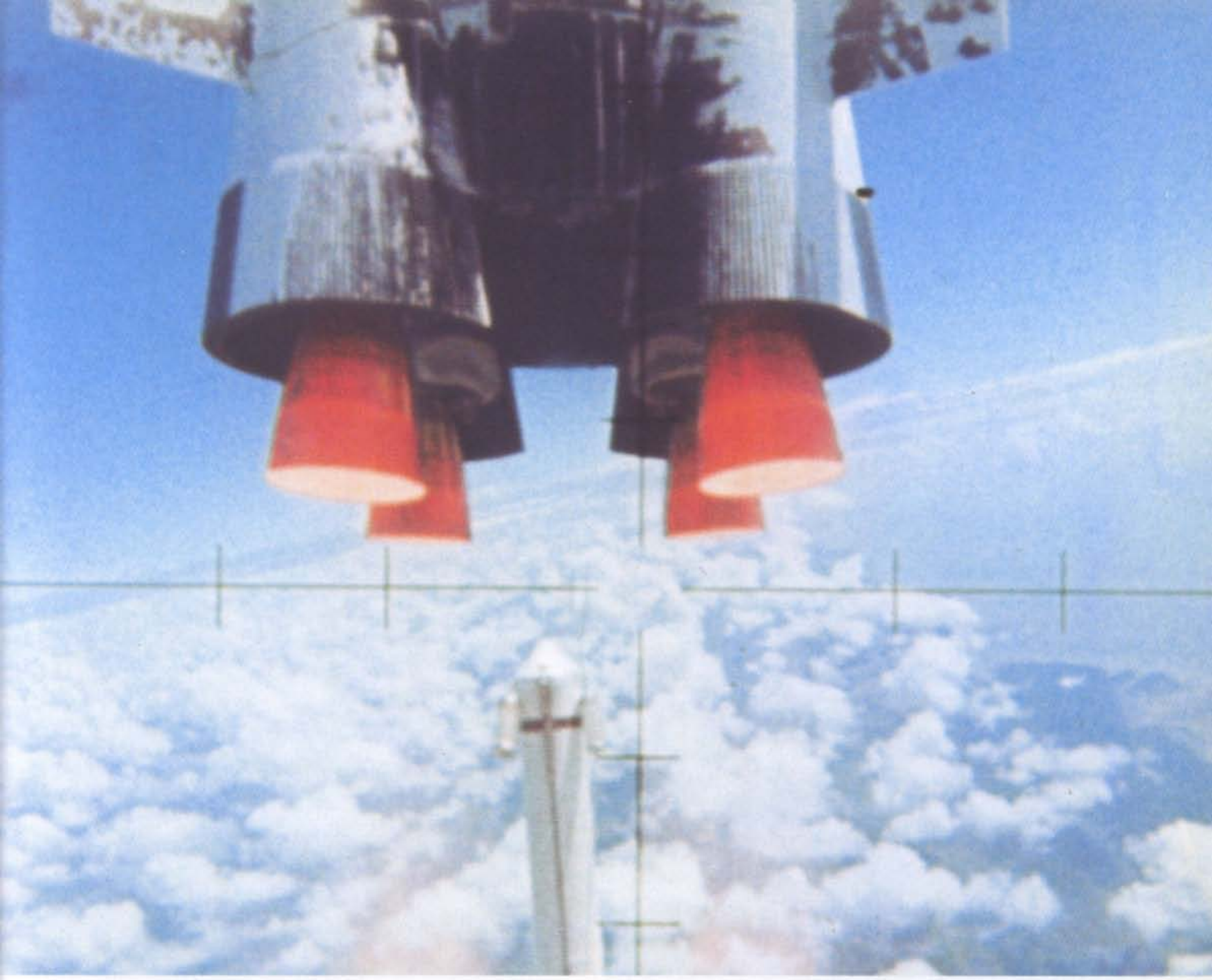

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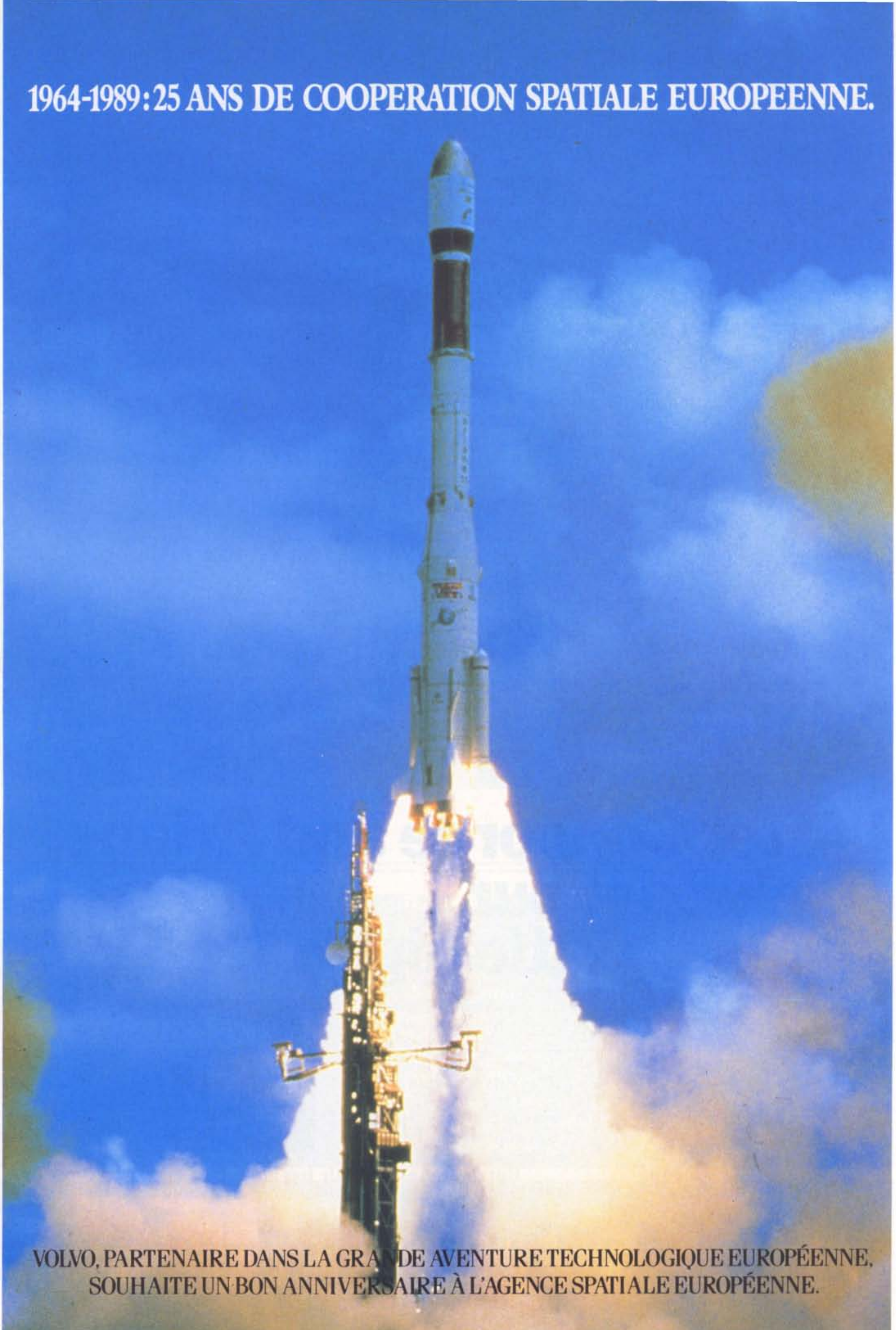
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CELEBRATORY CEREMONY
WEDNESDAY 19 APRIL 1989
AT THE
INTERNATIONAL CONFERENCE CENTRE
19 AVENUE KLEBER, PARIS

Foreword

A Silver Jubilee Celebration is both a time to reflect and a time to look ahead. For those who have lived close to European space events for the past twenty-five years, it is also a moment to wonder at their rapidity and growth in so short a time.

We have progressed from sounding rockets and small satellite payloads to the multiple launches of the heavy applications satellites of today; from the single-discipline satellite concepts to the wide-ranging plans for regularly manned space stations, and probes travelling far out into our solar system. Who can doubt that this will rank as one of the major scientific and technological achievements of this century.

That all of this has been achieved through the united efforts of nations and cultures long-split by enmity and suspicion is sometimes forgotten, yet European space ventures have shown just how barriers can be lowered in pursuit of peaceful objectives. That political will, scientific curiosity, and industrial know-how can be harvested for the common good.

This issue of the ESA Bulletin is made up of two elements. One contains the addresses given and speeches made by our distinguished guests at the Celebratory Jubilee Ceremony in Paris on 19 April 1989. The other consists of articles detailing the histories and development of four of the Agency's space projects with launches scheduled for this, the Agency's 25th year — Operational Meteosat (already launched successfully), Olympus, Hipparcos, and Space Telescope (Shuttle launch recently delayed until early 1990).

This Bulletin is therefore both a reflection on the Agency's past achievements, and a glimpse into its immediate future.

In this context, I would like to take this opportunity to thank all of those who have worked so hard in the last 25 years in the cooperative European space endeavour, and to wish them even greater success in the years to come.

Prof. Reimar Lüst
Director General, ESA

Address

Mr Wilfried Martens
Prime Minister of Belgium

It is already 25 years since the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO) and the European Space Research Organisation (ESRO) were set up; 25 years of making history together and developing a really coherent space policy for Europe.

I am most honoured this evening to be able to mention some of the attributes of this extremely active European cooperative venture, and I do so with great pleasure. In going over some of the aspects of developments in European space activities — which have not always been free of problems — I was once again able to note the consistency of Belgian policy in this field and the key role played by various Belgian Ministers at what were often crucial points in these developments.

Thus it was that, during the European Space Conference sessions held in Brussels in July 1970 and December 1972, with the Belgian Minister Théo Lefevre as Chairman, the decision was taken to merge ELDO and ESRO and set up a single space organisation within which European space policy was to be formulated and carried out from then on.

This decision was confirmed in 1973 at the next Ministerial Meeting, which was also held in Brussels, and was chaired on that occasion by the Belgian Minister Charles Hanin who, in September of the same year, was to sign the Spacelab Agreement between the United States and Europe on behalf of all the European countries.

After a whole series of difficulties, it was again in Brussels, under the chairmanship of Belgium — represented this time by Minister Gaston Geens — that in April 1975 the Ministers approved the Draft Convention for the establishment of a European Space Agency.

So three Belgian Ministers had the satisfaction, when chairing the Space Conference, of being responsible for three milestones essential to the setting up of our Space Agency and drawing up its first programme.

There is no doubt that we owe today's 25th Anniversary celebrations to the success of those Ministerial Meetings.

Allocution

M Wilfried Martens
Premier Ministre du Royaume de Belgique

25 ans ! 25 ans déjà nous séparent de la création de l'Organisation Européenne pour le Développement de Lanceurs (ELDO) d'une part, et de l'Organisation Européenne pour la Recherche Spatiale (ESRO) d'autre part.

25 ans d'histoire commune, 25 ans pendant lesquels l'Europe a pu développer une véritable politique spatiale.

Je suis très honoré de pouvoir, ce soir, être le premier à évoquer quelques aspects de cette composante très vivante de la coopération européenne. J'en suis également très heureux car, en rassemblant ces quelques éléments du développement de l'Europe spatiale — développement qui ne fut pas toujours sans problèmes — j'ai pu, à cette occasion, constater une fois de plus la constance de la politique belge dans ce domaine et le rôle moteur joué par différents Ministres belges à des moments souvent critiques de ce développement.

Ainsi, c'est lors de sessions de la Conférence spatiale européenne, tenues à Bruxelles en juillet 1970 et en décembre 1972, conférences que présidait le Ministre belge Théo Lefèvre, que fut décidée la création d'une organisation spatiale unique, formée par la fusion de l'ELDO et de l'ESRO, organisation au sein de laquelle la politique spatiale européenne serait désormais élaborée et exécutée.

Cette décision fut confirmée en 1973 lors de la réunion ministérielle suivante, également à Bruxelles et présidée par le Ministre belge Charles Hanin. Ce dernier devait signer, en septembre de la même année, et au nom de tous les pays européens, l'accord entre les Etats-Unis et l'Europe sur Spacelab.

Après bien des difficultés, c'est toujours à Bruxelles et sous présidence belge, en l'occurrence celle du Ministre Gaston Geens, qu'en avril 1975 les Ministres approuvent le projet de Convention portant création d'une Agence Spatiale Européenne.

Trois Ministres belges ont ainsi eu la satisfaction, en leur qualité de Président de la Conférence spatiale, de planter trois jalons essentiels pour la création de notre Agence spatiale et pour l'établissement de son premier programme.

C'est sans aucun doute grâce notamment aux succès de ces réunions ministérielles que nous pouvons aujourd'hui célébrer ce 25ème anniversaire.

Ce soutien belge au programme spatial européen dans les années 1970, je suis d'ailleurs fier de dire qu'il ne s'est pas démenti dans les années 80 lorsque, sur la base des succès obtenus, il s'est agi de définir et de concrétiser les nouveaux objectifs d'une politique spatiale européenne à long terme, politique visant à l'autonomie complète de l'Europe en matière spatiale, y compris dans le domaine des vols habités.

C'est ainsi que le Ministre Philippe Maystadt et ses successeurs, les Ministres Guy Verhofstadt et Hugo Schiltz ont, notamment lors des deux dernières Conférences Ministérielles de Rome et de La Haye, et au nom du Gouvernement belge, non seulement approuvé politiquement les programmes du nouveau plan à long terme mais, également, décidé d'amplifier notre soutien budgétaire à ces programmes: avec une contribution moyenne de plus de 4,5%, sensiblement supérieure à son PNB relatif au sein de l'Agence, la Belgique en sera le cinquième contributeur.

C'est à ce titre d'ailleurs que nous attachons un grand prix aux établissements de l'ESA sur notre territoire: la station de Redu, dont on vient de célébrer le 20ème anniversaire, I am also proud to be able to say that Belgium's support for the European space programme in the 1970s continued undiminished in the 1980s when, on the basis of the successes achieved, the time came to set and attain new objectives for a long-term European space policy, designed to make Europe fully autonomous in space activities, including crewed flights.

At the last two Ministerial Meetings, in Rome and The Hague, Minister Philippe Maystadt and his successors, Ministers Guy Verhofstadt and Hugo Schiltz, representing the Belgian Government, continued on the course that led to political approval of the programmes in the new Long-Term Plan. In addition, we took the decision to increase our financial support for those programmes to an average of over 4.5%, considerably more than the rate would be if geared solely to GNP. This makes Belgium the fifth largest contributor to the Agency.

This is, moreover, why we set great store by the ESA Establishments on our territory, i.e. the Redu Station, whose 20th Anniversary has just been celebrated, and the future Hermes Pilot Training Centre outside Brussels.

Why do we attach such importance to European space activities? The reasons are numerous:

- from the political viewpoint, they have provided, and continue to provide, an example of and focal point for European cooperation, and are therefore important for Europe's rank and image in the World;
- from the technological and scientific viewpoints, they enable our firms and researchers to take part in developments that it would be difficult for any one country to carry out on its own;
- from the economic viewpoint, they enable Europe, and with it Belgium in particular, to be autonomous in exploiting the possibilities offered by space technology.

And above all, we must not forget the growing interest being taken in the problems our planet is facing on a global scale — space technology will certainly have a major role to play in providing us with the data and, by implication, the key to solving them.

It is this combination of interests that leads me to conclude by saying that what can be achieved by space activities, and in particular by European cooperation in this field, is extremely important and justifies a considerable effort. I can assure you that Belgium is ready to play its part in this.

I believe that the decisions taken in The Hague are a sign that the vast majority of European States share this view.

It remains for me to express the hope that the intentions, which have been realised in the case of the 'infrastructure' programmes (Ariane-5, Hermes and Columbus), will likewise be given expression in the corresponding 'user' programmes. These are the programmes that really justify the need for Europe to be autonomous, not only for its own requirements, but also for the services it can offer the World as a whole and the Developing Countries in particular.

et le futur centre de formation des pilotes d'Hermes dans les environs de Bruxelles.

Pourquoi accordons-nous une telle importance aux activités spatiales européennes ? Les raisons en sont multiples:

— sur le plan politique, elles ont constitué et continuent à constituer un exemple et un creuset de la coopération européenne et, en conséquence, un élément important de la place et de l'image de l'Europe dans le monde;
— sur les plans technologiques et scientifiques, elles permettent à nos industriels et à nos chercheurs de participer à une évolution difficilement concevable sur le plan national;
— sur le plan économique, elles permettent à l'Europe, et donc à la Belgique en particulier, d'exploiter de façon autonome, toutes les possibilités offertes par les techniques spatiales.

Et n'oublions surtout pas l'intérêt croissant pour les problèmes globaux de notre planète: les techniques spatiales contribueront certainement très largement à nous en fournir les données et donc les éléments de leur solution.

C'est cette combinaison d'intérêts qui me permet de dire — et ce sera ma conclusion — que les enjeux des activités spatiales, et, en particulier, de la coopération européenne dans ce domaine, sont extrêmement importants et justifient un effort considérable auquel, pour ma part, je peux vous assurer que la Belgique est prête à participer.

Les décisions prises à La Haye m'indiquent que la très grande majorité des Etats européens partagent ce point de vue.

Il me reste à souhaiter que les volontés exprimées et concrétisées pour les programmes dits 'd'infrastructure' (Ariane-5, Hermes et Columbus) se concrétisent de la même manière pour les programmes dits 'utilisateurs' de cette infrastructure. Ce sont ces derniers, en effet, qui justifient en réalité la nécessité de l'autonomie européenne, non seulement pour ses besoins propres mais également pour les services qu'elle peut offrir à la communauté mondiale et, en particulier, aux pays en voie de développement.

TO PREPARE FOR
THE 21ST CENTURY
25 YEARS OF EUROPEAN
COOPERATION IN SPACE

1964
1989

25 ANS DE COOPERATION
SPATIALE EUROPEENNE
POUR PREPARER
LE 21EME SIECLE

European Cooperation in Industry

Dr Pehr G. Gyllenhammar
Chief Executive Officer, Volvo, Sweden

It is perfectly possible to convey the important industrial impact and future potential of the European Space Agency's programmes, but such a message may not be adequate in itself. Initiatives and programmes such as those of ESA, CERN and EUREKA have come to symbolise European cooperation at its very best.

Perhaps I can explain better with reference to Jean Monnet and a gearbox — yes a gearbox!

At the recent ceremonial in Paris for the centennial of the birth of Jean Monnet, President Mitterrand spoke of Europe's need to offer great examples, such as Monsieur Monnet, to its youth. Europe is not lacking in great examples, but perhaps we in industry do not fully recognise the need to offer such great examples. We have one in the European Space Agency, and particularly in the Ariane Programme.

All of us present today will remember 10 September 1982. In the early hours of that day, what the press called 'a somewhat unorthodox European gearbox' became internationally famous (eventually featuring in lead articles in the Financial Times, Le Monde and Newsweek). When it became famous — or rather infamous — this gearbox was in an unusual place, working hard. It was 200 km up in the air, travelling at 25 000 km/h and running a turbopump which was turning at 61 000 rpm to power liquid hydrogen and oxygen into the third stage of an Ariane rocket on its first operational flight. Then came the malfunction involving the gearbox — just 14 minutes after lift-off, the Ariane rocket and its two-satellite payload fell into the ocean.

1982 was a bad year for Europe as a whole. The Ariane failure seemed to capture and summarise what was called 'Europessimism'. As preparations got under way for the next (June 1983) Ariane launch, Newsweek magazine commented '...the Ariane project has come to symbolise the promise — and problems — of European cooperation in high technology. Should Ariane's June test go wrong, it would signal not only the flameout of another joint European venture, but the failure of Europe's technology to reach the heights'. Europe's and ESA's competitors were watching and waiting for June 1983 — probably with some unavoidable element of schadenfreude.

The critical June 1983 Ariane flight was a success, and since then the programme has gone from strength to strength. Ariane now claims almost half the global market for commercial satellite launches, making it a World leader in this segment.

The total space segment of the European aerospace industry is admittedly small — currently worth around 2.5 billion ECUs of output, or nearly 6% of the total European aerospace business. But its growth rate has been impressive — around 20% per annum in real terms in the 1980s, to date. And we are set for a significant further expansion in the 1990s with the new ESA budgets for the Ariane Programme and projects such as Hermes and Columbus.

Nonetheless, despite the new funding, we still have something of a 'David and Goliath' situation when we compare European space activities with those of the US or the USSR. Funding for non-military programmes under NASA auspices in the USA, for example, is running at about 10 billion ECUs per annum, whereas ESA's budget is projected to rise to around 3 billion ECUs a year by the mid-1990s. Hence even if we add other European national funding for civil space programmes to the ESA budget figure, we still fall far short of the NASA financial effort. In fact, the total 1988 budget for US space activities, military and commercial, was

30 billion ECUs, or more than ten times our joint efforts.

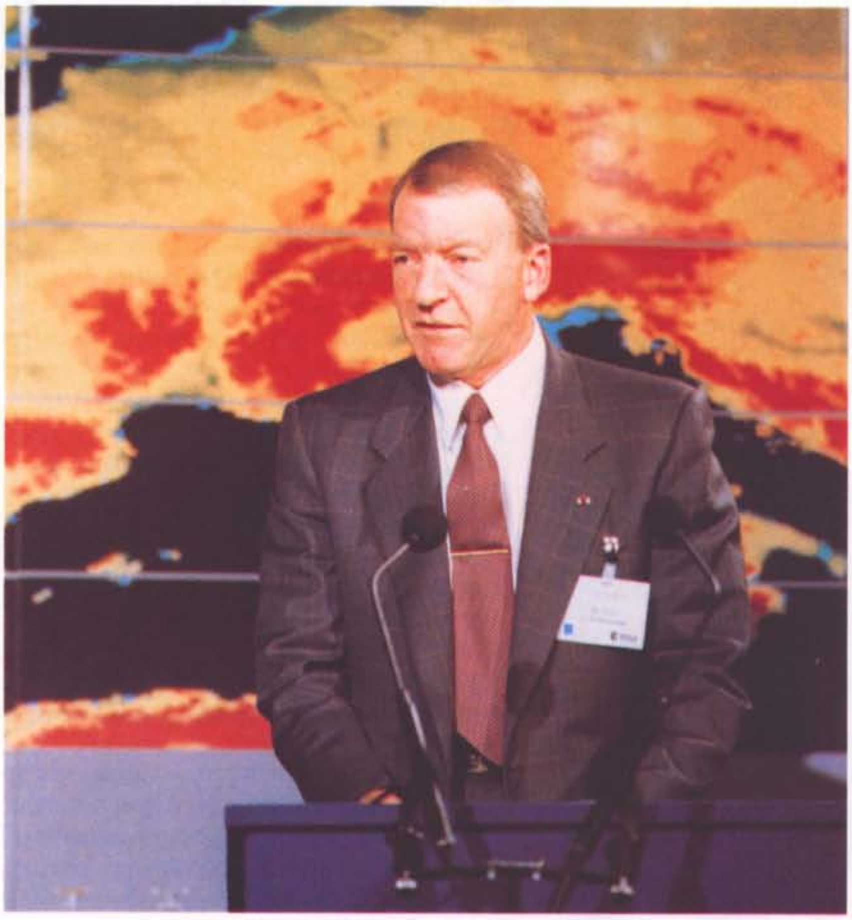
This David and Goliath situation is worrying because of the strategic technological and industrial importance of the space business (which can be described as 'leading edge' or 'spearhead'). The space business can both pull and push industrial development elsewhere. Space activities provide an important outlet for many industries — telecommunications, computers, electronics, chemical combustion motors, scientific instruments — and are a source of much innovation. Rigorous disciplines in quality control do widen participating companies' knowledge and improve their competitiveness elsewhere. International consortium programmes provide invaluable, rewarding challenge and stimulus for engineers. This we know from experience.

From another standpoint, the principle of giving all European governments the opportunity of membership of ESA is of great importance for smaller countries such as Sweden. The high competence in certain fields that some of the smaller European countries possess can only be fully applied, exploited and further developed in partnership programmes.

When we hear the frequent question 'Does European cooperation work?', we can now answer in three words: 'European Space Agency'. We have an incontestable success on our hands, which makes this 25th Anniversary of ESA such a pleasure and a privilege to attend. But we have to spread the good news as part of our efforts to capitalise on success; to bring more success.

Opinion leaders and formers face a major challenge in the 1990s; this is the challenge of securing economic growth and environmental protection. All of us here today understand the potential of the space business in terms of economic progress and environmental protection programmes. Perhaps this could be one of the many examples we need to offer?

On the much wider subject of European integration and cooperation, ESA can lay claim to be a practical example of what Europe means by 'successful variable geometry'. It can also represent a specification for those so-often ill-defined knowledge- and skill-intensive industries of the future. If we can get European public opinion to appreciate what is at stake in the space programme, we will be in a better



position to give our 'David' some extra resources for future meetings with the 'Goliaths', which could well include Japan and China.

I began my address by mentioning Jean Monnet — and a gearbox! Some, if not all of you must have wondered what flight of the imagination could possibly link the two. It was certainly not an Anglo-Saxon reference to the multiple meaning of l'engrenage! The story of what drove Monsieur Monnet must be told to Europeans, particularly young Europeans. The story of what drove the Ariane Programme after the gearbox incident must also be told. We need the examples. And we need not just the stories of the past, but also those of the future.

It is said that Monsieur Monnet sometimes quoted his American friend, Dwight Morrow, who told him that there were two types of people in this World — those who want to be someone, and those who want to do something. In fact, there is a third type — those who want to do something, go on to do it, and as a result become someone. Monsieur Monnet and all the people involved in the European Space Agency's achievements are examples of the 'third type'.

European Cooperation in Science

— CERN: A Seedbed of Ideas for the Construction of Europe

Prof. Carlo Rubbia
Director General, CERN, Geneva

The 25th Anniversary of the European Space Agency is an occasion of very great significance for our family of European scientific organisations. CERN, which was founded in 1954, is the oldest member of this family. It is, therefore, in the guise of elder brother, if I may put it that way, that I have the honour of addressing you today.

When discussing international cooperation in the field of science, there is always a danger of lapsing into platitudes. Science is nothing if it is not international. When human reason is rewarded for its efforts by the discovery that the Earth is round, or that the Universe is 15 billion years old, or that matter is made up of quarks and leptons, such truths become firmly rooted, irreversible, inalienable, and enter into the common stock of property, so to speak, owned by the whole of humanity. This self-evident fact has always spurred 'men of science' to cooperate across national frontiers. From the birth — in Europe, let us not forget — of modern science, from the days of Galileo, Descartes or Newton, the free exchange of ideas was always the natural way, and the only organisations necessary then were the embryonic Academies. Subsequently, when the nation states developed in 19th-century Europe, scientists' natural propensity to share knowledge was restricted, although never totally suppressed. It was not to be until our Continent had been devastated by two World Wars that the humanistic value of a fresh approach to international scientific cooperation gained currency.

The creation, starting in the 1950s, of the leading international scientific organisations in Europe, stemmed from the confluence of two currents:

(i) the desire to take action, to enable the people of Europe to recover from the devastation of war, by engaging in peaceful endeavours that would restore an essential part of their heritage and their contribution to World civilisation;

(ii) the very nature of the development of certain sciences, demanding instruments and resources that were increasingly beyond the range of individual countries.

To get a better understanding of how this came about, let us look briefly at the circumstances, almost 40 years ago, that led to the birth of CERN. In telling you about this, I shall be following the time-honoured practice of elder brothers, who talk about practically nothing but themselves, when they are supposed to be wishing their siblings a happy birthday!

It was in 1950, at a Unesco meeting in Florence, that a distinguished American physicist, Isidore Rabi, was struck by the contrast between the enormous intellectual and scientific potential latent in the countries of Europe, and the fact that none of these countries, laid waste by war, would ever again be able, on its own, to afford the increasingly costly facilities needed to conduct research on the structure of matter. He saw this as a threat to the future of World science — and for American science itself, which would go into decline, if there was no-one else in the field and it had to carry on this research alone. So, he persuaded the United States' delegation to back a draft resolution calling upon the European countries to pool their resources in order to create a research establishment with the necessary facilities.

This resolution came at a time when, not only in scientific circles, Europe was looking out for joint projects. Less than three years later a Convention was signed by twelve European countries. This was brought about by the efforts of a small number of individuals, two of whom were Pierre Auger from France and Edoardo Amaldi from Italy.

Remarkably enough, both these men also had a hand in the developments leading up to the foundation of the European Space Agency. Edoardo Amaldi had been an advocate of European cooperation in space back in the 1950s, while Pierre Auger, as you know, was Director General of ESRO, one of ESA's immediate forebears.

Our mission, as you will be aware, is research into the ultimate constituents of matter and their interactions. This calls for a powerful array of equipment. Particle accelerators are to us what telescopes and space probes are to astronomers. We are penetrating smaller and smaller distances, and that, according to the Heisenberg uncertainty principle, necessitates particles with more and more energy. Not content with probing space, however, we are also travelling back in time! With collisions of very high-energy particles, it is possible to create forms of very unstable matter that have not been present in the Universe since the very earliest instants of its existence, 15 billion years ago. This is another respect in which parallels can be drawn between our concerns and those of astronomers.

Today, Europe's physicists have largely fulfilled the most ambitious hopes of those visionaries of the 1950s. CERN now has a whole series of accelerators for the various stages of the particle acceleration process. This summer we hope to bring into service the biggest of the lot, the LEP, an accelerator ring 27 km in circumference, which will collide electrons and positrons. There is, therefore, an analogy of sorts between the accelerators at CERN and the vehicles used to launch satellites into space, in which acceleration of the payload is achieved by means of a series of stages.

Fourteen countries participate in the CERN programme: ten EEC countries and four others — Switzerland, Austria, Sweden and Norway. They contribute to the budget in proportion to their GNP. The four largest contributors, in order, are the Federal Republic of Germany, France, Italy and Great Britain. The funding arrangements are different, as you know, but it is interesting to note the almost exact match between ESA's membership and CERN's (Portugal is a Member State of CERN only, and Ireland of ESA only).

One of CERN's original features is that, although the majority of its researchers are scientists trained at institutes and universities in its Member States, some of them received their training in other countries. It has about 5000 users, over 20% of them from countries outside Western Europe. CERN has become a research establishment of importance, not only in Europe, but throughout the World.

European physicists have now progressed far beyond the stage of being the acceptable talking partners that their American godfathers of the 1950s saw them to be!

There are currently more young American physicists coming to Europe for training than Europeans going to the United States. The contrast with the post-war period could not be more marked. Pierre Auger, whose 90th birthday we were celebrating the other day, recalled the concern of the more far-sighted Europeans in the 1950s to stem the brain drain. Thanks to CERN, ESA and many others, that aim has been largely achieved and Europeans can now look to the future with confidence.

It is interesting to note that it took a certain amount of time before this became true. The first two decades were a period of renaissance in European science. Europeans regained some confidence in themselves and the respect — a little condescending on occasion — of their American colleagues. That was a normal progression, and I don't doubt that your experience has been similar.

Nevertheless, material achievements are not enough to bring real worldwide pre-eminence: there also has to be the courage to pursue innovative ideas. CERN owes its success of the 1980s first and foremost to the fact that we in Europe plumped for a new and extremely bold technical option when we went in for colliders, whereas the Americans and Soviets had, historically, distinguished themselves in the tradition of fixed-target machines. As a result, Europe had the basis on which to meet the challenges of the early 1980s, when it became clear that the key to our theoretical understanding of matter was an amount of energy available to create particles that was greater by an order of magnitude than what could be achieved with a fixed-target machine.

As has been known in principle for years, what has to be done is to bring about a frontal collision between two moving particles, so as to recover all the energy released by the collision. When it came to the technology, however, the challenges were enormous, chiefly because beams of particles are much less dense media than solid targets. Solutions were tested in Europe: in Italy and France with electron-positron rings back in the 1960s, and at CERN in 1970, with the construction of ISR proton-proton storage rings.

Without going into details here, I would say that the investment put into construction of the LEP is going to keep alive Europe's chances of retaining its worldwide competitiveness if it now undertakes expenditure on a far more modest scale. The LEP is an evolutive machine, and we are hoping to be able to install a second ring of superconducting magnets in the tunnel, towards the middle of the next decade, so as to be able to investigate the same physical phenomena as the SSC (US Superconducting Super Collider) years in advance of the United States and at a quarter or a fifth of the cost and, here again, it is our much more advanced technology that makes the difference.

I am struck by the analogy between the situation in our field and in European space activities, the achievements of which we are celebrating today. Back in the 1970s, the Cos-B satellite demonstrated the possibilities opened up by observation of high-energy gamma rays, both for very bright sources and for diffuse interstellar matter. Cos-B supplied about ten times as much data as its American predecessor, SAS-2. We can compare this with the valuable high-precision work done with our SPS, which consolidated and lent additional depth to the work on muon and neutrino beams that had started in the United States and (like Cos-B) laid the foundations for future successes. I note that the Americans did not believe in the Giotto programme and took no part in the study of Halley's Comet. This perhaps takes on its full significance when seen in the context of the European programmes now being prepared.

Europe is currently working on ISO, which will be the biggest infrared space observatory ever launched, and Hipparcos, the only astrometric satellite. These projects seem to me to share the same spirit of innovation as our collider physics.

When CERN was created in the 1950s, many people were sceptical about the ability of scientific teams drawn from countries with different languages and customs to interact and work together.

CERN was a pathfinder in that regard, setting an example which demonstrated that cultural diversity could be a fertile asset when used to good effect in a joint project. Nowadays, the point hardly seems worth making, when so many other European cooperative ventures in science and industry, foremost among them the aerospace industry, have been operating successfully. My impression is that we in our field, and you in space physics, have shown the way, and I believe that the spread of this kind of cooperation, in all areas where it is warranted by the scale of projects, will help to shape a European profile and to gather together the talents that will bring success.

Clearly, the idea of creating CERN won acceptance so quickly in the 1950s because there was a more general desire among Europeans to build something that would cement the reconciliation of our peoples following the war. That is no longer so much of a factor now that Europe is perceived as a tangible presence in so many fields. But let us not forget the division of Europe at Yalta. As matters stand today, all the signs are that the status quo might not be all that permanent. In my opinion, there could be another instance of a coming together of scientists heralding a more general political coming together.

The time has come to conclude. ESA today is in an even better position than CERN was ten years ago when it celebrated its 25th Anniversary. The instruments available to European scientists then gave them the status of respected colleagues, with the prospect of better things to come in the near future.

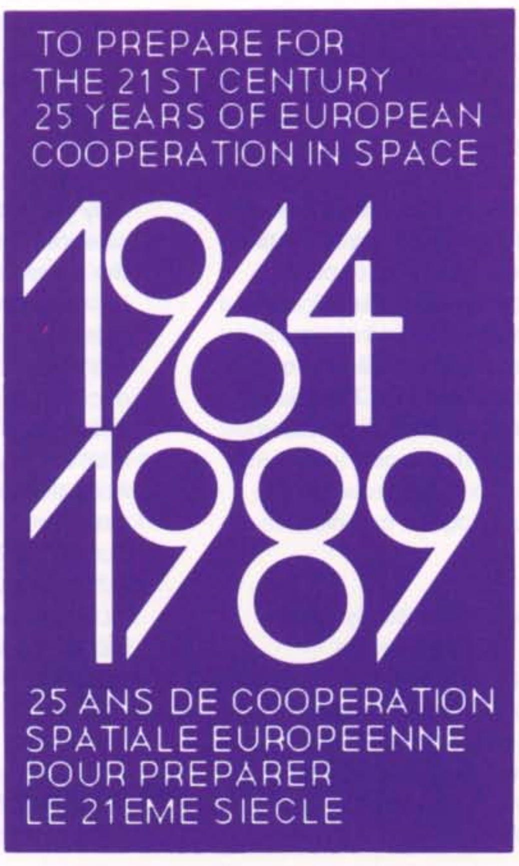
Director General, your Agency has an ambitious programme ahead. With Columbus and the Hermes spaceplane, it is going to give Europe the means to operate in all areas of space activity. With the creative dynamism of the Continent's 350 million people, there will be no limits to what you can achieve. On behalf of our Organisation and all its Members, may I congratulate you, Director General, on all the magnificent accomplishments of these 25 years and wish you every possible success for the period you are now embarking upon.

European Cooperation in Space

Prof. Reimar Lüst
Director General, ESA

A quarter of a century is a rather short time compared with the scope of the historical events being celebrated in France this year. However, 25 years of successful European cooperation do mark an important milestone, since we are still at the beginning of the formation of a unified Europe.

25 years is a time span the early days of which are still in the memories of quite a number of those present today. For me, these rooms bring back vivid memories of 23 March 1964, when I attended the first meeting of the Council of the European Space Research Organisation (ESRO). That was the formal beginning of Europe in space.



Those of us who had taken part in the preliminary work, in my case as Scientific Director from 1962, knew that those would be exciting times. Science was once more on the move, quietly overcoming cultural and linguistic barriers, as it sought further knowledge on the Earth, the Sun, the Planets, and the entire Universe.

The placing of instruments in orbit beyond the inhibiting effects of the Earth's atmosphere must rank as one of the most significant advances in the history of science; and Europe was determined that its long tradition of scientific discovery should continue in this field.

Certainly, it was not all smooth sailing: we were young and full of enthusiasm and imagination, rather than experienced in the organisation and administration of such an international venture. Few, if any, of the proponents of a joint European venture could have predicted the number of successes in just 25 years. We faced scepticism, even from well-known scientists, but perhaps that only spurred us on.

The collaborative spirit of the scientists all over Europe was backed by the skill and hard work of the engineers and technicians in the new technical centres of ESRO. We were also fortunate in that our governments listened to the scientists, and accepted that science should prevail over political considerations in the choice of the first European space activities.

While it would be going too far to say that the governments have always taken our advice, it is true that — whatever their political persuasion — they have seen the advantages of a joint European effort in space, culminating in the political will to announce, as a future objective, European autonomy in space.

These 25 years of European cooperation in space were started by two organisations — the European Space Research Organisation, ESRO, and the European Launcher Development Organisation, ELDO, and have been continued by ESA from 1975. We might ask: What advantages have they brought to Europe, to its people, its governments and its industries?

(i) It has been successfully demonstrated that a European community in science does exist and many new and fascinating scientific results have been obtained, for example with the Giotto spacecraft, named after the Italian 14th-century painter Giotto di Bondone. Thanks to Giotto, European scientists obtained the first picture of the nucleus of a comet, Comet Halley, the tail of which has been observed by man for more than 2000 years, at intervals of 76 years each time Halley approaches the sun.

In addition to the important scientific results, these scientific missions paved the way for many fields of applications. Communication via satellite is now taken for granted — operated by Eutelsat, the European organisation for space telecommunications — due mainly to the pioneering work by ESA. Furthermore, one should not forget the reliable telephone communications with ships on the high seas, which have been established using ESA's two Marecs satellites, leased for operation to the international maritime organisation Inmarsat.

The European meteorology satellites merely marked the beginning of Earth observation and monitoring of our environment from space. After all, every one of us is already used to seeing satellite images of Europe daily in our television weather forecasts. The four Meteosat spacecraft that deliver these photographs were developed and built by ESA, and are now operated by the European meteorological organisation Eumetsat.

We are becoming increasingly aware that our planet is facing severe environmental problems. Climatic changes and pollution are a threat to everybody, not only here in Europe but around the World. Since these are global problems, they need to be studied and solved with the help of global data sets, for which observation from space is essential. Satellite data can thus assist governments in making the necessary, and hopefully the right, decisions.

(ii) So much for the direct impact of European cooperation in space. Beyond this, ESA and its predecessors have demonstrated that European industry and European engineers can work together effectively in the field of high technology.

One demonstration of this is the 25 satellites — 14 scientific and 11 applications spacecraft — that have been developed by ESA and constructed by European industry: they have all worked according to specification, most of them for much longer than their original design lifetimes.

Another demonstration of what can be achieved jointly in Europe is the Ariane launcher. In the course of the last 20 months, it has successfully put 19 satellites into orbit. Marketing and sale of the Ariane launchers was commercialised quite some time ago.

25 years of cooperation in space have made the common European market, at least in the space sector, a reality for several years already. This has certainly contributed quite a lot to the present competence and scope of European industry.

(iii) European cooperation in space has not only proved our ability to collaborate in science, in space applications, and in the development of new technologies, it has also demonstrated the existence, in spite of the different national interests, of a common political will in Europe. The decision by the Ministerial Council in The Hague establishing our Long-Term Plan leads us into the next century. According to this Plan, space will be used for the benefit of the people of Europe. Europe can and must become autonomous in space in all fields, including the possibility of sending man into space whenever it is necessary or useful.

For Europe, autonomy means becoming a competitive partner for wider international cooperation. The Space Station, which ESA will jointly construct

with the United States, Canada and Japan, is only one example of such broad international cooperation. We are also looking forward to much wider cooperation with the Soviet Union in particular, and with all other space nations.

Last but not least, we want to lend a hand to all the developing countries. Remote sensing of natural resources and teaching via satellite are good examples of space applications that could be of particular benefit to them.

It gives me great pleasure to thank everybody who has contributed to these efforts in the course of the past 25 years: in particular the governments of Europe for their support and financing; European industry for its noble and precise work; Europe's scientists for their efficient collaboration; and last but not least all our present and former staff for their dedication and devotion to Europe in space.

Let me finally get back to the subject of cooperation in Europe. During these 25 years of close involvement, I have often been reminded of a statement by Robert Schuman who, at the beginning of the fifties, together with Jean Monnet, introduced the first plan for European cooperation. At the time he wrote: 'Europe will not be achieved overnight, and not all at once. It will gradually come to exist as a result of practical achievements which in the first instance give rise to real solidarity'.

It remains to be judged by you, Europe's politicians, industrialists and scientists, whether we, ESA, have contributed to this goal or not. Of all our achievements, this one would certainly give us particular satisfaction.

Address

Dr Helmut Kohl
Chancellor of the Federal Republic of Germany

We are today celebrating the 25th Anniversary of European cooperation in space. Over the last 25 years, the European Space Agency has rendered outstanding services, both in the opening up of space and in organising Europe's contribution to that process.

As a result of the Agency's efforts and achievements, Europe has now taken on a leading role in the drive towards a future in which space-related science and technology will play a decisive part.

Thanks to ESA, Europe is well to the fore in many areas of space technology — for example, communications, meteorology and satellite launch systems.

In its missions so far, European space research has also achieved major scientific breakthroughs at international level.

On the basis of the impetus created by ESA's programmes, European space industry has achieved considerable maturity. It has made its mark on the World market in a number of areas and has qualified Europe for crewed space flight.

European space industry is bringing into our national economies innovations and technologies of such a high level as to guarantee that Europe will be able to maintain its position in the future and ensure its continued prosperity.

But space is not only of scientific, technological and industrial importance. It is also helping to unite Europe by means of joint, forward-looking ventures.

The joint European conquest and utilisation of space also strengthens the European identity, and this makes ESA's activities a major factor in building Europe as a political entity.

European unification is more than a matter of declarations. It must also prove itself in a field like space, which is so important for the future.

The continuation of our successful cooperation with our American friends is part of this, but the future will also see increased cooperation with other partners.

The decisions you took in 1987, to develop

Allocution

Dr Helmut Kohl
Chancelier de la République fédérale d'Allemagne

Nous célébrons aujourd'hui le 25ème anniversaire du début de la coopération européenne dans le domaine spatial.

Au cours de ces 25 années, l'Agence spatiale européenne a fait progresser la conquête de l'espace, tout en assurant à l'Europe la place qui lui revient dans ce domaine.

Ses efforts et ses succès ont permis à l'Europe de jouer désormais un rôle de premier plan au seuil d'une ère nouvelle dans laquelle les sciences et les techniques utilisant des véhicules spatiaux auront une importance décisive.

Grâce à l'ESA, l'Europe occupe aujourd'hui une place de choix dans de nombreux secteurs de la technologie spatiale : je me contenterai de citer à ce propos les télécommunications, la météorologie et les lanceurs de satellites.

Avec les missions qu'elle a à son actif, la recherche spatiale européenne a enregistré des succès scientifiques de tout premier plan, même à l'échelle internationale.

Les programmes de l'ESA ont stimulé notre industrie spatiale européenne, qui bénéficie désormais d'un excellent niveau de maturité. Elle a pu ainsi s'imposer sur le marché mondial dans de nombreux domaines et est maintenant apte à s'engager dans des vols spatiaux habités.

L'industrie spatiale européenne fait bénéficier notre économie d'innovations et de technologies dont le niveau élevé offre à l'Europe la garantie de pouvoir préserver son rang et sa prospérité à l'avenir.

Toutefois, l'espace n'a pas que des incidences scientifiques, technologiques et industrielles. Il contribue également à assurer la cohésion de l'Europe par la poursuite d'objectifs communs, orientés vers l'avenir.

La conquête et l'exploitation en commun de l'espace renforcent également l'identité européenne. Les activités de l'ESA représentent donc une contribution importante à la construction d'une Europe politique.

L'union européenne ne se réalise pas par des déclarations, mais doit également se vérifier dans un secteur porteur d'avenir, comme celui de l'espace.

C'est dans cette optique que s'inscrit la poursuite de notre coopération fructueuse avec nos amis américains. Nous serons également conduits à l'avenir à collaborer plus étroitement avec d'autres partenaires.

La réalisation d'une infrastructure spatiale européenne autonome, que vous avez décidé d'entreprendre en 1987, de même que la participation de l'ESA au programe de la Station spatiale internationale témoignent de la volonté d'autonomie de l'Europe, qui est également prête à une coopération à l'échelle transatlantique et mondiale.

De ce fait, l'Europe apparaît comme un partenaire intéressant pour d'autres pays, notamment ceux du tiers-monde, mais aussi pour d'autres puissances spatiales, comme l'Union soviétique.

L'espace ne joue pas seulement un rôle important pour notre avenir dans les domaines scientifique et technologique. Il conditionne également notre politique en matière d'environnement, de communication et aussi de sécurité.

La conquête de l'espace n'est pas pour l'Europe une question de puissance ou de prestige. Elle représente à nos yeux bien plus un défi à relever pour résoudre les an autonomous European space infrastructure, and to participate in the international Space Station Programme, testify both to Europe's will to achieve autonomy and to its readiness for transatlantic and worldwide cooperation.

Europe is becoming an attractive partner for other countries too, for example in the Third World, as well as for nations with a developed space capability, like the Soviet Union.

The importance of space for our future is not only scientific and technological. It also has consequences for environmental and media policy, and indeed for security.

For Europe, the conquest of space is more than a question of power and prestige. It is a challenge to solve the great problems of the Earth's future: the mastery of energy resources, exploration for new raw materials, and the conquest of poverty.

In this endeavour, we shall also be striving to make a major contribution to achieving a stable peace.

I should like to stress above all the importance of space technology in solving the ecological problems facing our planet.

It is not enough to conjure up the spectre of the destruction of the environment. Action is needed and it is precisely modern technologies such as space technology that will put us in the position to identify, monitor and solve environmental problems.

Let me briefly mention the keywords 'climate' and 'ozone'. Here humanity is looking to space technology for a special contribution to the solution of the problem of how our Earth's limited resources can be used responsibly, in a way that does not damage the environment.

The express reference in the ESA Convention to the exclusively peaceful purposes of your Agency sets clear limits on the choice of future activities.

Nevertheless, we must not fail to recognise the importance of space in safeguarding peace. For example, European observation satellites could enable us, in the future, to monitor compliance with arms control agreements using our own resources.

In the coming years too, the European space endeavour has major tasks before it. We must, above all, think in terms of the future, but without losing sight of what is realistic.

I am confident that, thanks to your efforts, Europe will continue to play a leading role in a future in which space technology will be a determining factor.

In so doing, we shall be able to fulfil our duty to the younger generation to meet the challenge of progress, while at the same time maintaining the environment intact and safeguarding peace and freedom.

problèmes majeurs auxquels la planète devra faire face : protection de l'environnement, approvisionnement énergétique, prospection de matières premières, lutte contre la pauvreté.

Dans cette optique, notre intention est d'apporter une contribution essentielle au maintien de la paix.

Je tiens tout particulièrement à souligner l'importance que revêt la technologie spatiale dans la résolution des problèmes écologiques de notre planète.

Il ne suffit pas de condamner la destruction de l'environnement. Nous devons agir et les technologies modernes, comme les techniques spatiales, nous offrent les moyens de mettre en évidence les problèmes d'environnement, de les contrôler et de les résoudre.

Je me contenterai à ce propos de citer deux mots : climat et ozone. C'est dans ce contexte que l'humanité attend de la conquête spatiale qu'elle contribue notamment à résoudre les problèmes que pose une utilisation raisonnable des ressources limitées de notre planète, dans le respect de l'environnement.

Les objectifs pacifiques de votre organisation, expressément consignés dans la Convention de l'ESA, imposent des limites claires et précises pour le choix des activités futures.

Nous ne devons toutefois pas méconnaître le rôle qui incombe à l'espace pour garantir la paix. A titre d'exemple, des satellites d'observation européens nous donneraient à l'avenir la possibilité de vérifier par nos propres moyens le respect des accords sur le contrôle des armements.

L'Europe spatiale aura encore d'importantes missions à remplir au cours des prochaines années. Il est nécessaire, à cet égard, de penser en termes de secteurs porteurs d'avenir tout en conservant à l'esprit le sens des réalités.

Je fais confiance à l'Europe pour continuer à jouer, grâce à ses efforts, un rôle de premier plan dans la période future où l'espace est appelé à occuper une place de choix.

Nous aurons ainsi assumé nos responsabilités vis-à-vis des jeunes générations en favorisant le progrès et en préservant l'intégrité de notre environnement et le maintien de la paix dans la liberté.

Address

Mr François Mitterrand
President of the French Republic

I am quite simply happy to celebrate with you this 25th Anniversary of the European Space Agency.

What could be more symbolic and more encouraging than to celebrate the anniversary of a body whose statute was, from the outset, European, and whose success in meeting its aims in a highly competitive field has been even greater than hoped for. Thanks to your Agency, this Europe of ours has become a space power respected, and sometimes even feared, by its competitors.

You will remember that in the wake of the second World War, European science had been drained of its life blood. Many European scientists, among them Einstein, Fermi and Bethe, had stayed on in the United States, to which they had had to emigrate.

The countries of Europe decided at that time to unite their efforts, as has already been mentioned by other speakers, in three exemplary scientific fields: particle physics, the astronomy of the southern hemisphere, and the conquest of space.

As a result of these initiatives, major breakthroughs have been achieved by Europe's scientists and technologists. I would like to mention here Prof. Carlo Rubbia, Nobel Prize winner for physics, and Director General of CERN, the European nuclear research centre in Geneva, who has reminded us of the success achieved in particle physics in 1983.

The same scientists — Pierre Auger of France, Edoardo Amaldi of Italy, etc. — were the founding fathers of both CERN and the European Space Agency. And shortly after the launch of the first Sputnik in October 1957, the US space agency, NASA, was set up. The countries of Europe did not wish to stand on the sidelines as the Soviet Union and the USA embarked on the ensuing space race, and therefore decided to work together on space exploration.

Allow me to remind you of the first Intergovernmental Conference, attended by twelve countries, which in November 1960 decided to set up a European Preparatory Commission for Space Research. And of the two European organisations which came into being just twenty-five years ago — a space research organisation specialising in the satellite field and a more technical organisation dedicated to the launch of spacecraft.

And it was in May 1975 that these two organisations merged to form the Space Agency whose anniversary we are celebrating today. Several of the countries gathered here today are no doubt founding members of the Agency. The Federal Republic of Germany and France, which make up 54% of the budget, but other countries too, which, though not in a position to contribute as much, make up for this in the quality of their input — and that is difficult to calculate. We are delighted that these countries are involved in this endeavour and that they are working

Allocution

M. François Mitterrand
Président de la République française

Je suis très simplement heureux de célébrer avec vous ce 25ème anniversaire de l'Agence spatiale européenne.

Quoi de plus symbolique et de plus encourageant que de fêter un organisme dont le statut fut, dès l'origine, européen et qui atteint ses objectifs dans un domaine extrêmement compétitif avec un succès qui dépasse même les espérances. Grâce à votre Agence, notre Europe est devenue une puissance spatiale respectée, parfois même redoutée par ses concurrents.

Vous vous souvenez qu'au lendemain de la dernière guerre mondiale, l'Europe scientifique était exsangue. De nombreux savants européens, je citerai Einstein, Fermi, Bethe demeuraient aux Etats-Unis d'Amérique où ils avaient dû émigrer.

Nos pays d'Europe ont alors décidé d'unir leurs efforts comme cela vient d'être rappelé par d'autres que par moi. Dans trois domaines scientifiques exemplaires: la physique des particules, l'astronomie de l'hémisphère austral et la conquête de l'espace.

Grâce à ces initiatives, les scientifiques et les techniciens ont obtenu de grandes réussites. Je citerai Prof. Carlo Rubbia, Prix Nobel de Physique et Directeur général du Centre Européen de Recherches Nucléaires, le CERN à Genève qui a rappelé le succès de 1983 en physique des particules.

Ce sont les mêmes savants, Prof. Pierre Auger, Français, Prof. Edoardo Amaldi d'Italie, etc. qui sont à l'origine du même CERN et de l'Agence spatiale européenne. Et peu après le lancement du premier Spoutnik en octobre 1957 a été créée l'Agence spatiale américaine, la NASA. Dans cette course vers l'espace à laquelle se sont alors livrés Soviétiques et Américains, les Européens ont voulu être présents et c'est pour cela qu'ils ont décidé de travailler en commun à l'exploration de l'espace.

Je vous rappellerai la première Conférence Intergouvernementale qui a regroupé 12 pays en novembre 1960 et décidé la mise en place d'une Commission préparatoire européenne pour les recherches spatiales. Deux organisations européennes ont vu le jour, il y a tout juste 25 ans: une organisation scientifique appelée à exercer son activité dans le domaine des satellites et une organisation plus technique destinée à s'occuper du lancement d'engins spatiaux.

Et c'est en mai 1975, je cite ces dates qui sont dans vos mémoires, pour bien marquer la progression, que ces deux organisations ont fusionné pour donner naissance à l'Agence spatiale que nous célébrons aujourd'hui. Les Etats membres fondateurs de l'Agence sont sans doute plusieurs des pays ici rassemblés, la République fédérale d'allemagne, la France qui représentent 54% du budget. Mais d'autres pays qui ne sont pas en mesure de fournir autant apportent en qualité ce qu'ils représentent. Et là le calcul deviendrait difficile. Nous nous réjouissons que ces pays soient associés et finalement qu'ils travaillent fraternellement. Je citerai d'abord la Belgique et je salue son Premier Ministre que j'ai grand plaisir à retrouver ici depuis les années que nous sommes amenés à nous rencontrer. La Belgique, l'Italie, le Danemark, l'Espagne, l'Irlande, les Pays-Bas, le Royaume-Uni, la Suède, la Suisse et, en 1986, l'Autriche, la Norvège auxquels se sont associés la Finlande, le Canada.

L'exploration de l'espace, vous l'avez dit, M. le Directeur général, c'est d'abord une meilleure connaissance de l'Univers qui nous entoure. Je citerai un grand responsable politique français, Georges Clémenceau, qui écrivait ceci: 'Il y a quelque chose de moi dans l'étoile que je ne verrai jamais; il y a together in a spirit of solidarity. First of all I would like to mention Belgium, and I greet its Prime Minister, whom I am very pleased to meet here once again, after so many meetings over the years, Italy, Denmark, Spain, Ireland, the Netherlands, the United Kingdom, Sweden, Switzerland and, in 1986, Austria and Norway, and the associate members, Finland and Canada.

Space exploration is, first of all, as you have said, Director General, a better understanding of the Universe surrounding us. I would like to quote a great French statesman, Georges Clémenceau, who wrote 'there is something of me in the star I shall never see; there is something of it deep within me'.

Clémenceau was shown to be right by the astronomers who proved that we are made of the same substance as stars, and the European Space Agency is today revealing to us stars that our ancestors could not see.

You have referred to the Giotto probe as one of the Agency's most outstanding missions. I well remember the day when you visited me to present the results of your work, and since then I have had the opportunity to see an authentic and original Giotto painting on which you modelled the logo for your mission to Halley's Comet. There was no small element of risk when the probe passed by Halley's Comet in March 1986, and it is thanks to that probe that European astronomers have acquired the greatest knowledge of a comet, which for centuries now, and each time it has passed close to Earth, has fascinated mankind.

It is a fact that the Universe bathes us in radiation. The ultraviolet rays emitted by all hot stars, from which we seek to shield ourselves, and which are being analysed by the International Ultraviolet Explorer (IUE), and the X- and gamma-rays, used in radiography, have been observed thanks to two other satellites, Exosat and Cos-B. Finally, the future Infrared Space Observatory (ISO) will provide the most effective means of detecting infrared radiation, which is invisible from the ground.

The Agency is of course, quite rightly, working together with the United States of America on the development and use of a Space Telescope that will be launched on 11 December 1989 and will circle the Earth in a high-orbit 500 km above the ground. This will enable it to observe stars one hundred times less bright than those that can be seen from the Earth's surface. We will then see very distant galaxies, which is to say galaxies that have existed since the earliest time, and also planets orbiting other suns.

All this cannot but fill the mind with wonder and scientists with delight. But it will also be of great benefit to humanity as a whole, whose destiny it is to master all aspects of matter.

You have, Ladies and Gentlemen, many other projects for astronomical satellites that will explore the planets and the electromagnetic environment of the Sun. I believe you refer to these fundamental projects in your Science Programme as 'Cornerstones'.

As our countries' leaders, we are bound to contribute to your work, give you encouragement and provide you with the resources to succeed.

I would like to say a word on meteorology, a subject that is closer to the everyday concerns of individual Europeans. The Meteosat-1 and -2 satellites are at work, and the climatic conditions in the Earth's atmosphere are being monitored by satellites which form a very coherent whole with our national Spot Programme. Space research does not, however, stop there, as of course you realise. It includes microgravity research, materials science, fluids physics, biology and space medicine. Experiments first performed on the Spacelab platform will be carried out on a larger scale on the Columbus Space Station, on which Europe is working with the USA.

All this amounts to an ambitious programme, complemented by the current telecommunications satellite programmes, the culminating point of which is at present the Olympus satellite.

Access to space is not only a means of better admiring the heavens, but also of improving meteorological monitoring and, hence, surveillance of the Earth's climate. And the work you have done in advanced technological research and you are pursuing in the best telecommunications and television systems is a shining example of intellectual rigour.

Since the organisation specialising in launcher development became a part of the Agency, the latter has established a technology programme devoted to the development of platforms and launchers. This quelque chose d'elle au plus profond de moi'.

Les astronomes ont donné raison à Clémenceau en démontrant que nous sommes fabriqués de la même matière que les étoiles et l'Agence spatiale européenne nous révèle aujourd'hui les étoiles que nos anciens ne voyaient pas.

Parmi les belles missions de l'Agence, vous avez cité la sonde Giotto, je me souviens du jour où vous êtes venu me voir pour me présenter les résultats de vos travaux et j'ai d'ailleurs eu l'occasion de voir depuis un authentique et original tableau de Giotto dont vous vous êtes inspiré pour le logo de votre entreprise sur la comète de Halley. En effet cette sonde s'est approchée, non sans risque, en mars 1986 de la comète de Halley et grâce à cette sonde les astronomes européens ont acquis la meilleure connaissance de la comète qui, depuis des siècles, et à chacun de ses passages, continue de fasciner les hommes.

C'est vrai que l'Univers nous baigne de ses rayonnements. L'ultraviolet dont nous cherchons à nous protéger mais qui est émis par toute étoile chaude et qui est analysé par le satellite international IUE, les rayonnements X et gamma, utilisés en radiographie, ont été observés grâce à deux autres satellites, Exosat et Cos-B. Quant aux infrarouges, le futur observatoire spatial infrarouge ISO constituera le meilleur moyen de déceler ces rayonnements invisibles depuis le sol.

Certes l'Agence, et elle agit bien, collabore avec les Etats-Unis d'Amérique à la réalisation et à l'exploitation du télescope spatial qui sera lancé le 11 décembre 1989 et qui évoluera autour de la terre à une orbite haute de 500 kilomètres, lui permettant ainsi d'observer des astres cent fois moins lumineux que ceux que l'on aperçoit aujourd'hui depuis le sol. Alors nous verrons des galaxies très éloignées et donc formées depuis l'origine des temps, ainsi que des planètes qui tournent autour d'autres soleils.

Voilà ce qui peut émerveiller l'esprit, ce qui peut plaire aux savants et ce qui sera fort utile à l'humanité tout entière dont le destin est de maîtriser tous les aspects de la matière.

Vous avez, Mesdames et Messieurs, bien d'autres projets de satellites astronomiques pour explorer les planètes, l'environnement électromagnétique du soleil et je crois que vous donnez le nom de 'pierres angulaires' à ces projets fondamentaux de votre programme scientifique.

Nous, responsables de nos pays, nous ne pouvons qu'y contribuer, vous encourager et vous donner les moyens d'aboutir.

Je dirai un mot de la météorologie comme cela vient d'être fait, plus proche des préoccupations quotidiennes, de chaque Européen. Les satellites Météosat-1 et 2 sont à l'oeuvre, les climats de l'atmosphère terrestre qui sont surveillés par des satellites qui forment un ensemble très cohérent avec notre programme national Spot. Enfin, la recherche spatiale ne s'arrête pas là et ce n'est pas à vous que je l'apprendrai. Elle inclut la microgravité, la science des matériaux, la physique des fluides, la biologie, la médecine spatiale. Des expériences d'abord réalisées sur la plate-forme Spacelab seront entreprises à plus grande échelle sur la station spatiale Columbus à laquelle l'Europe collabore avec les Etats-Unis d'Amérique.

Voilà un programme ambitieux qui se complète par les programmes de satellites de télécommunications en préparation dont le point culminant actuel est le satellite Olympus.

L'accès à l'espace ne permet pas seulement de mieux admirer le ciel mais d'améliorer la surveillance de la météorologie, donc des climats terrestres. Et ce que vous avez entrepris en matière de recherches technologiques poussées que vous réalisez dans les meilleurs systèmes de télécommunication et de télévision est un exemple de rigueur de l'esprit.

Depuis la fusion de l'organisation spécialisée dans la réalisation des lanceurs à l'intérieur de l'Agence, celle-ci a établi un programme technologique de réalisation de plates-formes et de lanceurs que je crois tout à fait réussi et dont nous sommes très fiers, dont vous êtes, j'imagine, avec nous très fiers.

Il s'agit assurément du programme Ariane dont le premier lancement fut effectué en 1979, succès qui pratiquement est total si l'on compte les quelques déboires qui ont certainement contribué à la connaissance de ces choses comme en matière scientifique cela arrive le plus souvent.

D'ailleurs on me disait, alors que je venais ici précisément vous rencontrer, que la société Arianespace vient de signer le contrat le plus programme is, I believe, a complete success, one of which we are very proud, a pride I imagine you share.

I am, of course, talking about the Ariane Programme, which began its series of launches in 1979 and which has been a virtually total success, despite the few setbacks that undoubtedly contributed to the understanding of these matters, as is often the case where science is concerned.

And just now on my way to meet you, I was advised that Arianespace has just concluded the biggest ever launch contract with Intelsat, the telecommunications satellite organisation. This is a further success, on which I congratulate you.

Ariane — which of us has not dreamt of taking this kind of project further? What has already been done is in itself a precious achievement. Thus, twenty-five years after the founding of the two organisations to which I referred, and which were later to merge to form the Agency, we are able to affirm the excellence of a body of scientific and technological endeavour which today puts Europe in the forefront of space exploration.

It has to be accepted that Europe is not just a collection of countries each with its own culture, language and particular customs, united by no more than economic and commercial interests. Those who think that are on the wrong track and in the end will have to recognise that, if that were the case, the whole project would fall apart. Their desire to straitjacket Europe would backfire. We are talking about a civilisation.

Ladies and Gentlemen, you have played a part in developing, in giving birth to this civilisation — which is to say, you have projected human intelligence, imagination and expertise across the vast reaches of space.

This Agency's scientists, engineers, and technologists work in such a variety of places as Paris, Noordwijk in the Netherlands, Darmstadt in the Federal Republic of Germany, Frascati in Italy, Kourou in French Guiana, etc. I should like to extend a greeting to all of them and to thank them one and all. We are greatly indebted to them and it is important they should know this, even if we know that tomorrow morning they will be back at work without further thought to the compliments made, but firm in the conviction that their duty is clearly mapped out.

I was visiting yesterday, in the company of some of the people I see here today, an exhibition entitled 'Science and the Revolution' currently taking place at the Cité des Sciences et de l'Industrie at La Villette. And I was absolutely astonished — I should have known it, and no doubt I did know it, but I had not given it enough thought — to see how fantastic a flowering of scientific discoveries and technical achievements occurred in the last decade of the eighteenth century. And although I am talking about my own country, it was not alone in this. I could mention twenty or so of the greatest names in our scientific history, whose achievements were concentrated in this short period of time, in part perhaps because intellectual excitement and the desire for freedom implicit in great movements of ideas have a chain effect across all intellectual fields. I would like to hope that the construction of Europe will produce a similar shock, if of a different order, which will have a persuasive and infectious force and generate in the last ten years of this century a determination that will carry all before it. The scientists are there; we have the technologists. What is perhaps lacking is a surge of enthusiasm. Enthusiasm that produces resolve, always remembering that scientific resolve cannot do without political will, as it is this that decides the fate of nations.

Would you not agree that it is that fate which is decided in the fields we call culture and science, which all too often are ignored or neglected. For my part, I am convinced this is so. All the rest is to the good, all the rest is necessary. What will bind Europe together will be the development of science in association with culture; in short, all the functions of the mind. Seen from space, Europe is showing the way forward by its actions.

I am sure all Europeans would have to agree with this. And this is being done by scientists, technologists and researchers, men and women who have decided to devote their lives to research that is often severely demanding, and strewn with disappointments with, from time to time, the great happiness that comes from a success that is no more than an accident and was only made possible by the chain you have built between yourselves. A chain across time, but also across space; European space which is now an indivisible part of universal space. All this proves that it is right to believe in the future. Ladies and Gentlemen, let us jointly affirm our belief in it at this gathering.

important de lanceurs avec l'organisation Intelsat de satellites de télécommunication. Voilà un succès nouveau dont je vous félicite et sur lequel je comptais m'arrêter un moment, mais le temps passe.

Je ne continuerai pas sur cette lancée. Ariane, qui d'entre nous n'a pas rêvé de mener plus loin ce type d'expérience? Ce qui est, représente déjà un acquis. Voilà que 25 ans après la création des deux organismes que j'ai cités, qui après devaient fusionner dans l'Agence, voilà que nous pouvons constater l'excellence d'une activité scientifique et technologique et qui nous permet de dire que l'Europe est désormais au premier rang de l'exploration spatiale.

Il faut bien se rendre compte que l'Europe n'est pas simplement une collection de pays avec chacun sa culture, son langage, ses moeurs spécifiques, unis par une communauté réduite à des intérêts économiques et commerciaux. Ceux qui s'imaginent cela font fausse route car il faut bien qu'ils se convainquent que si c'était cela, cela ne tiendrait pas. Ils seraient floués dans leur volonté de cantonner l'Europe. C'est une affaire de civilisation.

Mesdames et Messieurs, vous avez contribué à développer, à faire naître cette civilisation. C'est-à-dire vous avez projeté les capacités de l'intelligence et de l'imagination et de la compétence humaine sur l'immensité de l'espace.

Les scientifiques, les ingénieurs, les techniciens de cette Agence travaillent un peu partout dans des lieux aussi divers que Paris, Noordwijk aux Pays-Bas, Darmstadt en Allemagne Fédérale, Frascati en Italie, Kourou en Guyane française, etc... Je voudrais les saluer tous, les remercier tous et chacun. Nous leur devons beaucoup et il faut qu'ils le sachent même si l'on sait qu'ils reprendront demain matin leur travail sans plus s'occuper des compliments, mais avec le sentiment que leur devoir est tout tracé.

Je visitais hier, en compagnie de quelques-unes des personnes que j'aperçois ici, une exposition qui se déroule actuellement à la Villette, à la Cité des Sciences et de l'Industrie, qui se nomme 'La Science et la Révolution'. Et j'étais absolument stupéfait, j'aurais dû le savoir, je le savais sans doute, mais je n'y avais pas suffisamment réfléchi, à quel point les dix dernières années du XVIIIème siècle ont connu — je parle pour mon pays, pas le seul — une prodigieuse floraison de découvertes scientifiques et de réalisations techniques. J'aurais pu citer au cours de cette Exposition une vingtaine des plus grands noms de notre histoire scientifique accumulés simplement sur cette courte période, peut-être aussi parce que l'effervescence intellectuelle, les aspirations de liberté de grands mouvements de pensée a une valeur d'entraînement dans tous les domaines de l'esprit. Là je ne peux que rêver que la construction de l'Europe puisse provoquer un choc, d'un autre ordre sans doute, mais une valeur de persuasion, d'entraînement, de contagion, une volonté victorieuse dans les dix dernières années de ce siècle. Les savants sont là, les techniciens, nous les possédons. Ce qui manque peut-être c'est l'élan. L'élan qui est générateur de la volonté, étant entendu que la volonté scientifique ne peut pas se passer de la volonté politique puisque c'est ainsi que se décide le sort des nations.

Et, ne croyez-vous pas qu'il se décide ce sort là dans des domaines trop souvent ignorés ou délaissés que l'on appelle la culture et la science. Moi, j'ai cette conviction. Tout le reste est bien, tout le reste est nécessaire. Le ciment de l'Europe, ce sera le développement de la science associée à la culture. Bref, toutes les fonctions de l'esprit. Vu de l'espace, l'Europe agit de telle sorte que l'exemple est montré.

Je pense que tout Européen ne peut que s'en convaincre. Et le fait que ce soit des savants, que ce soit des techniciens, des chercheurs, que ce soit des femmes et des hommes qui ont décidé de consacrer leur existence à des recherches souvent éprouvantes, parsemées de déception avec de temps à autre la merveilleuse joie d'une réussite qui n'est qu'un accident et que vous n'avez pu réussir qu'en créant la chaîne entre vous. La chaîne à travers le temps, mais la chaîne à travers l'espace. L'espace européen qui se confond désormais avec l'espace universel. Tout cela montre bien que l'on a raison de croire en l'avenir. Mesdames et Messieurs, croyons-y en cette heure où nous sommes ensemble.

Dr K.-E. Reuter (ESA) escorting Prof. P. Auger and Mrs F. Perrin

Mr G. van Reeth (ESA) escorting Prime Minister Martens and Vice Prime Minister Schiltz of Belgium

Dr P.G. Gyllenhammar, Prof. R. Lüst (ESA), Dr J. Morgan and Prof. C. Rubbia

Mr J.A. Dinkespiler, Prof. G. Puppi, Mr R. Gibson and Mr M. Depasse

Arrival of President Mitterrand of France and Chancellor Kohl of the German Federal Republic

Prof. R. Lüst (ESA) addresses the assembled guests

Photography: S. Vermeer, ESA

Chancellor Kohl signs the Agency's Silver Jubilee Commemorative Book

President Mitterrand receives a copy of the Silver Jubilee Album from Prof. R. Lüst (ESA)

After-Dinner Speech

Dr Heinz Riesenhuber
Minister for Research and Technology, Federal Republic of Germany

Thank you very much for inviting me to say a few words on behalf of the nations that are members of ESA's Ministerial Council. The first thing I want to say is 'thank you' to everybody here in this room. I think all of you have contributed to ESA's success; you have all contributed your time today, or will contribute in the future to what we are going to do — and this in a good spirit.

Four hundred and ninety-eight years ago, on 3 August, Columbus started out on his trip over the darkness of the oceans, following the Sun to new horizons, and bearing in mind why he was sent there — namely to spread the word of God, and to fight for the interests of Isabella of Castile and Ferdinand of Aragon. This was the official mission, but I think the real idea behind it was different: namely the fact that there was a new horizon, that there was the challenge of the unknown, that there were new worlds to be discovered, since the beginning of mankind. I think this was the main challenge, and it was rationalised in different ways.

We are always facing a new challenge. Prime Minister Martens described the very difficult time when ESA took up the challenge of space 25 years ago — nobody knew where the way might lead. There were doubts as to whether those were the right questions to address; there were doubts as to whether Europe was suited to tackling such large tasks. What has been set up over the last 25 years is a good organisation with an excellent staff, and we have been lucky in having excellent Directors General. Without going into detail, Professor Lüst, you are going to leave the Agency all too quickly, so we are praising you now for what you have already done. I know you enjoy the challenge, the pressure of engaging in new tasks. Also, for what the staff have done in the past, I have to thank you all, in Noordwijk, in Darmstadt, and wherever you may be, and, of course, here in Paris.

I think that what has grown up at the same time has been the spirit of a sound community, integrating administrations, scientists, engineers and enterprises to meet the challenge of the future. This has been achieved as a community and its spirit reaches beyond what we are doing in space. I have to thank especially some of the grey, grand old men among us today who began what we are currently pursuing, who built up what is now being exploited and carried forward into the future. I am not going to mention any names, but I was very impressed today to meet some of these gentlemen, legendary names who laid the foundation for the future.

We have heard brilliant speeches today; we have heard many words of pride and of encouragement — of pride in what we have achieved together, in fields that we know are beyond the reach of any of us single-handedly. But together we can achieve our goals and pursue these ideas, from which Europe can grow. We can discuss the successes in basic research, in Earth observation, in technology, in large projects, in Ariane, in Spacelab. We can talk about the plans for Hermes and Columbus and Sänger — but the other factor is the spirit in which we are creating the future.

Knowing that we have to understand the new technologies, that we have to integrate them, even more so that we have to identify the new challenges, to take responsibility for our confined Earth — this vulnerable Earth, the ecology of which we have yet to understand — we will have to use the best possible technologies to find out what is happening and again, jointly, take the right precautions in due course to cope with the problems. The challenges of science, the origin of the solar system, the formation of the stars, the future of the galaxy, are all basic questions that have been occupying mankind since the very beginning of life —

now we have a new level of understanding. The sole result of this new understanding is the creation of new questions, which lead mankind towards a future of unlimited striving for understanding, not least of ourselves. This is an open-ended world that continually develops, and we discover in these details that we can only develop in it if we do it jointly — jointly in Europe to achieve the best technology, the best science, the best preparedness. But even then, success is something beyond the figures you leave behind in the balance sheets.

Success is also measured in terms of the spirit in which we proceed, by our ability to show that we can cope with the most complex challenges and, as far as technology is concerned, the complexity of integrating different sciences; there is no challenge like that of the space technologies.

What is developing now is worldwide cooperation. What we are discovering now, even outside Europe, is that there are tasks that are beyond the reach even of continents acting alone, and that we can take up space tasks that might be beyond our present imagination. Many years ago, Tchaikovsky said that 'Earth is the grey home of humanity', but nobody told us that mankind should always remain in the grey! This seems to be beyond our imagination, beyond any reasonable thinking, but the more we understand that this might be attainable if mankind sticks together, the better we might cross new frontiers, beyond the frontiers we have now. This calls for peace in the world. But knowing that we have such skills is an excellent basis for peace. Peace is not based on compromises; peace is not based on negotiations; peace is based on the knowledge that we have tasks ahead of us for which we need each other, and I think that ESA has taken up its work in this spirit. ESA, young as it is — 25 years is not really very old — may lead Europe towards a good future in a very important field.

In partnership, in cooperation, in competition and with the challenge always to be the best, but also with the awareness of our overall responsibility — in this spirit, I hope that ESA — I wish that all of us, responsible in different fields, in science, in industry, in ESA, in politics, wherever — will cooperate for the future, that we will cooperate and contribute what we can towards establishing a peaceful, successful world. In this spirit, I wish you another good 25 years, and then let us meet again.

After-Dinner Speech

Mr Henrik Grage
Chairman of ESA Council

It is a special pleasure for me to speak on this enjoyable occasion commemorating a great event in the history of European efforts in space.

By the time a person has reached the age of 25, a new individual has been established, physical maturity has been achieved, and important experiences have been undergone. There will have been some successes and some disappointments. Most important of all, a unique entity with an as yet largely undetermined potential will have come into being.

On its 25th birthday, the European Space Agency is just such an entity. Just as with a 25-year old person, we have a certain amount of learning experience behind us; we have tasted both remarkable successes and some failures, though happily more of the former than the latter. In particular, the initial years were difficult as the fledgling Agency sought to find a firm footing on the new and uncertain ground of space exploration.

In the midst of such technical achievements over the past 25 years, we must not forget the human endeavours at the heart of all our successes. It is human success that we celebrate today.

The past successes were achieved thanks to the spirit of European cooperation among all the Member States. ESA has shown, and continues to show, that scientists, engineers, industries and governments can overcome national and institutional prejudices and ambitions, to join in a cooperative venture that has secured a prominent position in space for Europe.

We owe much to the staff members of the Agency, who gave of their time and energy so unsparingly during that period. Their partners included many thousands of others, working in industry and the academic community, and not least our delegates from the various government bodies and agencies.

In an international organisation like ESA, progress can be made only by agreement through compromise. Those who have attended a meeting of the ESA Council, or a European Space Conference, will know that it is no easy task to reconcile the divergent views and desires of 13 Member States. Delegates sometimes have to persuade their Ministers back home who, whatever their personal enthusiasm for space, are faced with competing demands for government funds from other areas; I am thinking particularly of information technology, energy, biotechnology and the like.

Often the positive decisions have been due to the personal dedication of individual delegates who, whenever possible, have put the European interest before the national interest.

I believe it is fitting on this occasion to pay tribute to all those who, by their competence, their patience and their dedication, have helped to overcome obstacles that could have prevented us from continuing on the successful path we have followed.

Taking part in space activities is often regarded as a visible sign of a country's ability to compete internationally. Coming from a 'not so large' member country, I know how valuable it can be, because of the opportunities offered at the scientific and industrial level, for the smaller countries to participate in ESA's programmes, which strike a balance between infrastructure and user programmes.

On this Anniversary, as we contemplate the solid achievements that European space cooperation can demonstrate, I feel confident that the spirit that led Europe into space in the early sixties is with us again, perhaps more mature, and if anything even better justified, and that a promising future is opening up for the Agency.

Exactly as with a person, the future looked at from the perspective of a 25-year old is full of challenge, excitement and opportunity. I would only ask you to consider, for example, that during the 12 months that follow our 25 th Anniversary, we shall see, among other events:

— the launch of Olympus-1
— the launch of Hipparcos, and
— the launch of the Hubble Space Telescope.

May the next 25 years be as successful as the last!

After-Dinner Speech

Prof Henk van de Hulst
The Netherlands

Let me say two serious things before I start; the first is: 'Thank you, Reimar'. At that time, to which you just referred, your first assignment — I was a bit jealous I remember — was to travel around to European capitals to find out what everybody was doing and was planning to do in space. That was in early 1960, I think. Generally, it is inadvisable for somebody who knows the organisation's history as well as you to be in a highly responsible position later, but your example shows that this is not always true. The second serious thing I want to say is: 'Happy Birthday, ESA'. It hasn't been said yet, but Happy 25th Birthday!

I would like to take this opportunity to recall a few things from the old days. I have a vivid memory of that rectangular, white marble table around which we were standing in a conference room in Nice during a lunch break, when Pierre Auger said to about ten of us there, 'Let's do something in Europe'. That was the beginning of what later became ESA.

I also have a distinct memory of later that same year, still in 1960 — in November or December — when the formal meeting was called at Meyrin at the home of CERN. It was one of those rare days on which, from that meeting room, you could see Mont Blanc in all its splendour. But I also remember from that meeting that we spent several days arguing, my older colleague Van der Maas from Holland and I, that there should be 'technology' in the preamble to the Convention of the preliminary organisation (COPERS). Now it is really hard to believe that there were certain people then who said that the Organisation should do only science and never do technology. We argued that one of the aims mentioned in the preamble should be technology. Well, now we have it!

The rest of what I would like to say is largely a vote of thanks, not to anyone in particular, but to all of you. What comes to mind is the Chilean song 'Gracias a la vida que me ha dado tanto', and there follows in one of the strophes 'que me ha dado la risa y ha dado el llanto'. We therefore have both the laughs and the tears, and there have been plenty of each during those thirty years of space research in Europe. I have been personally very happy to have been able to participate in the birth of new fields: first radio astronomy, and then space research. Fortunately, the computer industry has come just some five or ten years too late for me, so I have never become a computer freak, and I still do my integrals by counting squares on graph paper.

I think Cos-B deserves highlighting more. It was not only one of ESA's most successful satellites, it was also the first that was not a multi-experiment satellite, where one of the experiments might fail, but the others still work and provide useful data. Cos-B was one concept, one way to get at gamma rays, which required different parts of the instruments built in different laboratories to work flawlessly together, or we would have had nothing. Our American friends said: 'You are crazy to try to build such a joint instrument with people from five laboratories speaking four different languages — how can that ever work?' Well, it worked — it even worked for far longer than we had planned. I will come back to the languages in a moment.

I was also happy today to walk around this building again and to recall the niche in the corridor where Freddy Lines and I once had a two-hour discussion about the concept of the Blue Book that was to contain the plans of what ESRO was going to do; one of many personal nostalgic memories.

In the formal sessions of Council and later of the Scientific Programme Committee, I often felt like Margaret Mead, or a person of that type, with never a dull moment. There was always some strange ritual going on, and in order to understand it well you had of course to live in this community and to participate fully in this ritual, and so I did.

I noticed I had scribbled in my notes for today the name 'Auger'. But the scribble was not very neat, and it looked like 'anger', so let us consider anger! As one of the emotions that may easily flare up during such meetings, it is an interesting example. My first time in the chair was probably in this building. Sir Harrie Massey was chairing the meeting and was getting more and more fed up. At a certain moment — it was about five in the afternoon — he couldn't take it any longer; he just stalked out of the room and said, in passing, to me 'You take the chair!', because I was Vice-President. A minute later, he had to send somebody into the meeting room to get his glasses, which he had forgotten — that is how angry he was!

The first intervention once I was in the chair was from another angry Delegate — I don't remember from which country — who asked whether the last remark of yet another Delegate was a new proposal or an amendment. Well, that is how I started — and that was long before you could measure the anger of the Spanish Delegate by simply counting the number of times the word 'Villafranca' occurred during his speech!

Only much later was I to learn some of the tricks of being in the chair. Here I really have to give a sincere vote of thanks to the Executive, by which I mean all the people who draw up all the Committee papers and make sure there are no errors in them. I found out that on the penultimate page of those papers, there always is something that the Council, or the Committee, is asked either to take note of or to approve. So, when a discussion began to be more and more confused, I could always add a seeming remark of wisdom by choosing the right moment to say 'But, gentlemen, listen, on page so-and-so it says the Committee is asked simply to approve. So let us approve', and then proceed to the vote.

I am not trained to be an actor, so I cannot really demonstrate *how* people get angry — some go white, some go red, some talk a lot, and some suddenly stop talking — there are all kinds of ways. But *why* do they get angry? Now, one thing I have been able to diagnose is that people get angry because they are frustrated. That does not happen often during these organisational meetings, but I have seen it in scientific meetings since.

People get frustrated because they have been working for years and years on a project, and finally that project is not chosen. Although it has been explained hundreds of times that there is competitive selection and only one project will eventually be chosen, still it is taken as a personal insult and people remain angry for a long long time.

On these occasions, apple blossoms always come to mind — I think of the thousands of apple blossoms, and the couple of hundred apples that finally mature on the tree. How should the other blossoms feel, should they all feel frustrated? But, by and large, I have not been able to trace why people get angry. Here songs and poetry help — I won't sing! One of the Beatles' songs has a line 'I said something wrong, what it was she didn't say'. A much more poetic expression is to be found in one of the poems of Shelley, where the three beautiful words 'some rich anger' appear. The context is: 'and when your mistress some rich anger shows, emprison her soft hand and let her rave, and feed deep, deep upon her peerless eyes'. Well, that is not literally applicable to the ESA Council, but to let the people rave is sometimes good! That is a piece of good

TO PREPARE FOR
THE 21ST CENTURY
25 YEARS OF EUROPEAN
COOPERATION IN SPACE

1964
1989

25 ANS DE COOPERATION
SPATIALE EUROPEENNE
POUR PREPARER
LE 21EME SIECLE

counsel. And also Chaucer, well before Giotto in the 12th century, wrote a ballad of 'bon conseil', of which I remember one line very clearly: 'Tempest thee not all crooked to redresse', i.e. 'don't try to put all crooked things straight'. That is sometimes also a useful piece of advice!

Now I said earlier I would return to the question of languages, but I first wish to thank also all the interpreters — who have been busy, as always, throughout the afternoon striving at what is often an almost impossible task — for all the work they have done. I normally prefer to listen to the speakers as they speak, even if I don't understand, because you get the gist of it. I would like to make a philosophical point here, and that is that one of the blessings for Europe is that we have many languages. People think of that as a disadvantage and, of course, when you look at finances, all those translation costs and so on, it is a disadvantage. However, by and large, I think one should look at it as an asset.

Sometimes, in my more gloomy moods, I have compared the space effort to building the Tower of Babel. The analogy is not very far-fetched, because it was a tower reaching into Heaven. As you know, at a certain moment it didn't work any more because people didn't understand each other due to the fact that they were speaking different languages. Funnily enough, when I make the analogy with the space situation, I always think of NASA, and not of ESA, and I wondered how come? I think that the biggest danger is that you all think you talk the same language, which of course the Americans think. In Europe we know we don't talk the same language, so we make a much greater effort to understand and to explain what we really mean, and that is really an incentive to understand.

I remember M. Lévy once, chairing one of the more emotional meetings, used the word 'mandarins'. Occhialini didn't like it, and returned after the lunch break carrying two volumes under his arm; one was the latest edition of the 'Dictionnaire des mots nouveaux', and he was quoting from there what the word 'mandarin' meant.

Anyhow, a real linguistic effort is required to try to reach understanding, and this adds a certain flexibility, it adds a certain shock-absorbing effect. It's like riding on rubber tyres instead of on the rattling iron wheels of an old wagon, the way in which these different languages force you into a moment of reflection.

Well, I have tried to deliver these words a bit in the spirit of Erasmus, who had to come back from Italy and, travelling all the way on horseback, wrote to his friend, Thomas Moore in England, 'Riding on this horse, I didn't feel like doing anything serious, so I conceived a little booklet' — and that was the 'Stultitiae Laus' for which Erasmus has become most famous!

Erasmus tells us that prima donna Folly has several ladies in waiting, one of whom is Flattery, whose function is to keep up what in modern language would be called a 'mutual admiration society'. But, Erasmus continues, do not think that this is a bad thing; it is normal. For what is more efficient than when 'muli mutuum scabunt', i.e. 'when mules mutually scrub'. Well, I would now like to say, but I didn't have time to look up what the perfectum of 'scabere' is, that 'I have scrubbed', but instead I will say 'I have spoken', dixi!

Prof. Reimar Lüst introducing the after-dinner speakers

Prof. Minoru Oda, Prof. Roger Bonnet, Prof. Bengt Hultqvist and Mr Charles Bigot

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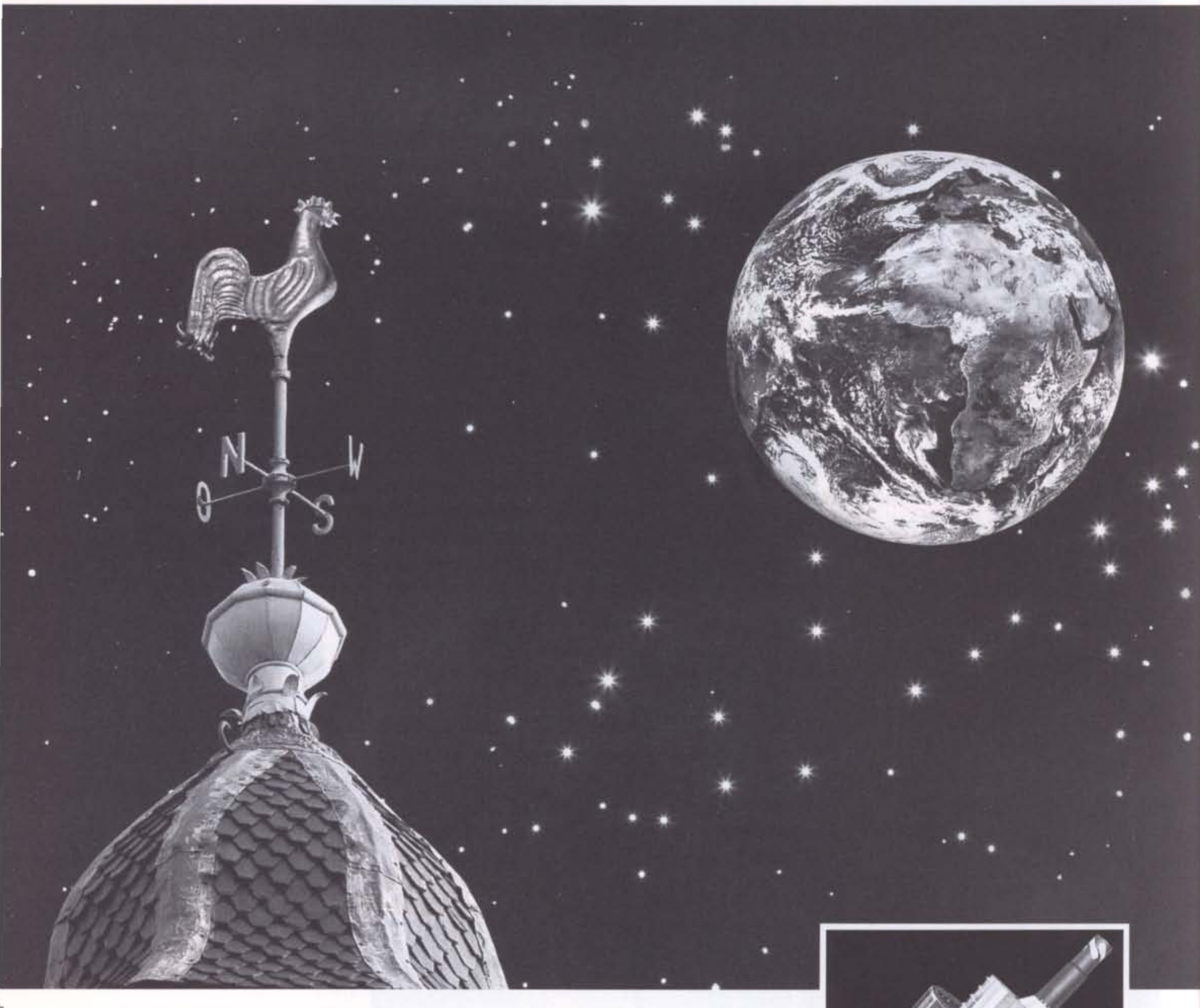

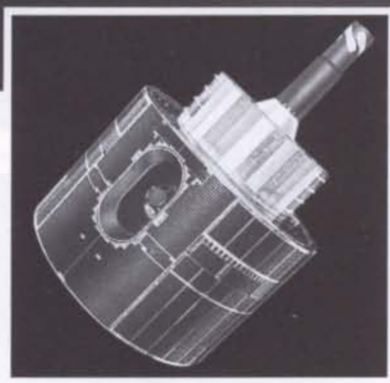

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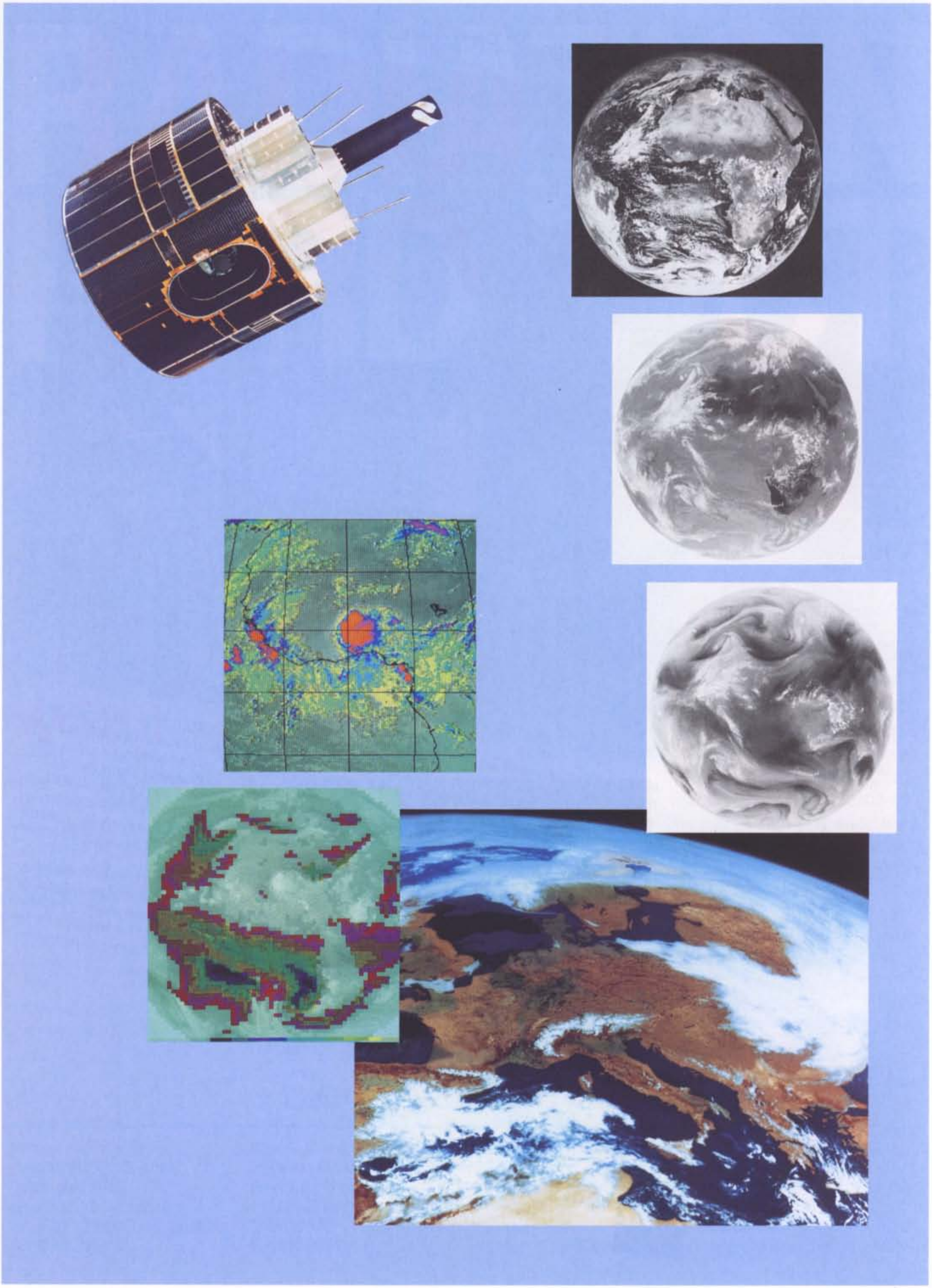


The Meteosat Programme

R. Tessier
Meteosat Operational Programme, Directorate of Earth Observation and Microgravity Programmes, ESA, Paris

ESRO, one of the two predecessor organisations of ESA (together with ELDO), was first set up in the early sixties to develop and exploit scientific satellites. In approximately the same time frame, space technology was starting to be used in the USA for applications that would 'benefit mankind', particularly telecommunications satellites and meteorological satellites. Other more complex applications, such as Earth observation and environmental monitoring, were also already being contemplated.

The future significance of these so-called 'applications missions' did not go unnoticed in Europe, with the result that considerable efforts were made at the European Space Conferences in Rome in 1967 and in Bad Godesberg in 1968, to broaden ESRO's mandate to include space applications as well as scientific activities. One of ESRO's first and most successful applications programmes to date was to turn out to be Meteosat.

The beginnings of European space meteorology

In early November 1968, a meeting took place in Stockholm at which the Directors of Western Europe's weather services discussed European involvement in space meteorology for the first time. Two prime objectives of that meeting were: to evaluate the desirability of Europe getting involved in space meteorology, and to make the policy makers conscious of it.

Some of the ten countries participating in the Stockholm meeting could already claim to be active in exploring the possibilities of space meteorology, but none of their satellite feasibility studies had yet reached the developmental stage. France had its 'EOLE' spacecraft under development (a position-locating satellite coupled with a fleet of balloons to study wind fields), and the United Kingdom was providing a sounder for the American Nimbus satellite's payload. For its part, ESRO presented a concept for European Atmospheric Research Satellites, or 'EARS', carrying radiometers, photometers, ozone monitors, ultraviolet sensors, etc. (Fig. 1).

The results already being achieved with the American Tiros satellite series, the first of which had been launched in 1960, helped to convince European meteorologists of the usefulness of space-acquired data. The Stockholm meeting therefore concluded almost unanimously that:

- the feasibility of a European meteorological satellite programme should be urgently explored;
- the first satellite should be simple and suitable for launch by a Scout rocket no later than 1973;
- the payload should include an atmospheric sounder and perhaps an infrared imager;
- a longer term programme should be prepared for a launch in 1975;
- a body of representatives from the national Meteorological Services should be formed to advise ESRO on these programmes.

During the meeting, the French Delegation described a national proposal, already under consideration by their authorities, which included a geostationary satellite and two near-Earth satellites, one in an equatorial and one in a high-inclination orbit.

The advisory body recommended at the Stockholm meeting was duly formed, and convened for the first time in June 1969; it was known as the 'Ad-hoc Group on Space Meteorology'. The existence of this Group gave the Directors of the Meteorological Services who were its members the opportunity to discuss other problems also. This in turn fostered wider cooperation between meteorologists at the European level, and this was later formalised as the 'Conference of European Meteorological Services Directors'.

To avoid duplication with the existing French geostationary-satellite project and with a small orbiting satellite (X4) then under

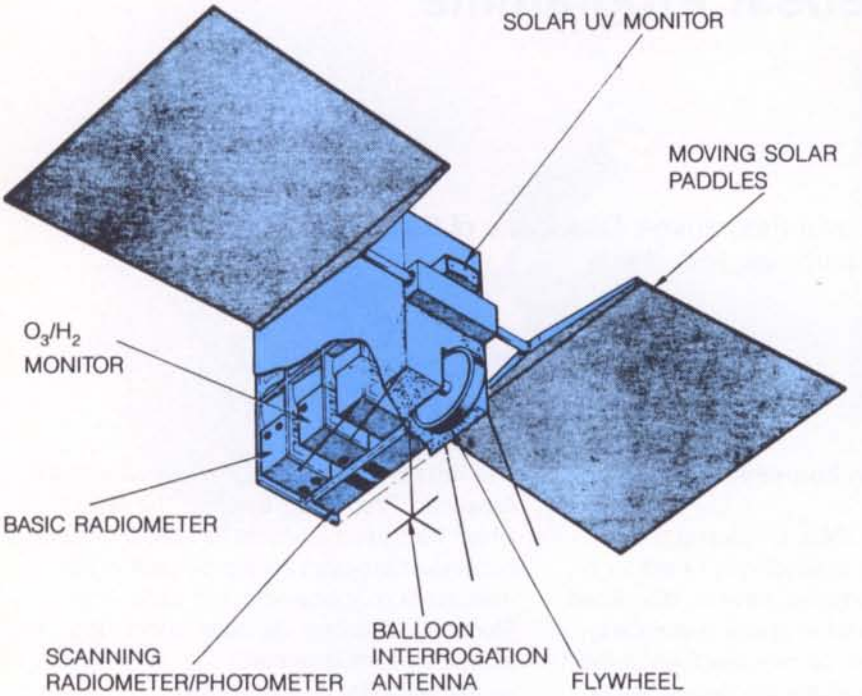


Figure 1. One of ESRO's earliest meteorological satellite concepts, EARS-I, presented in 1969

consideration in the United Kingdom, the Ad-hoc Group initially advised ESRO to concentrate its activities on the definition of a large polar spacecraft that would be of interest for both scientific and operational meteorology. This was the origin of the EMOS (European Meteorological Operational Satellite) project, developed in-house by ESRO and first presented in October 1970 (Fig. 2). A variant of this project was based on re-use of the TD1 scientific satellite's design, with a view to reducing costs.

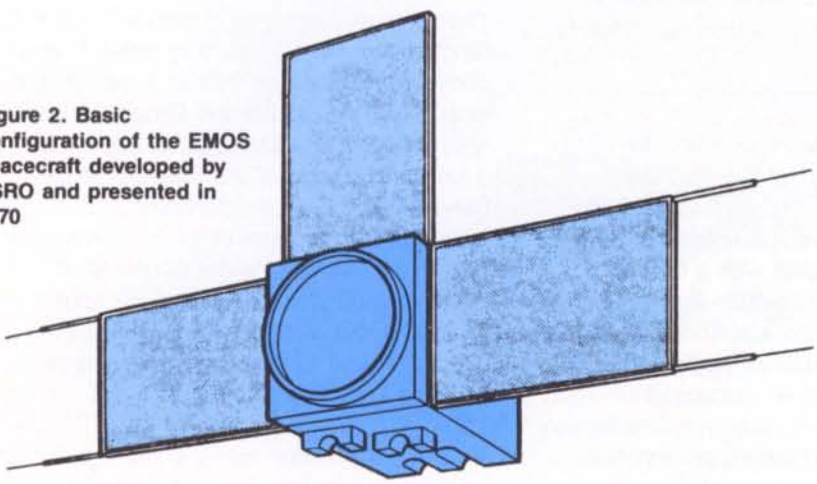
In the meantime, the Ad-hoc Group had continued to study the future European programme and had become convinced that the emphasis needed to be put on the operational aspects. They also concluded that the large polar spacecraft agreed upon at their first meeting was not in fact the highest of the priorities for their countries, when the World Meteorological Organisation's (WMO's) World Weather-Watch Programme — an international undertaking to monitor the state of the Earth's atmosphere — was taken into account.

By that time, two Itos (improved Tiros) polar-orbiting spacecraft were available, but no geostationary spacecraft comparable to the planned American SMS/GOES (Synchronous Meteorological Satellite) was available to cover the European longitudes. Since the geostationary satellite announced by France at the Stockholm meeting had been confirmed to be an experimental venture, the Ad-hoc Group concluded that there was scope for a Geostationary European Meteorological Satellite (GEMS).

This provisional conclusion was confirmed in February 1971 during discussions between members of the Ad-hoc Group and ESRO staff, and representatives from NASA and NOAA. The Americans keenly supported the European initiative, pointing out that there was already an overabundance of polar-satellite data.

This basic change in orientation of the European programme was confirmed more and more firmly during 1971. The ESRO study programme was redirected to take this change into account; in particular, studies of temperature sounding, space-to-space data relay (with a polar spacecraft) from geostationary altitudes, as well as a suitable ground data-processing system, were initiated. However, the co-existence of the French project and the European geostationary project was creating growing difficulties which were jeopardising European cooperation.

Figure 2. Basic configuration of the EMOS spacecraft developed by ESRO and presented in 1970



The Europeanisation of Meteosat

The first proposal for a national geostationary meteorological satellite had been made by the French national space agency (CNES) in February 1969, following internal studies on imaging from space with radiometers. Its mission was defined by July of the same year. Payload and platform studies were conducted and, by June 1971, CNES had invested about 35 man-years and placed some 15 contracts with French industry. Little had been done on the ground-segment side, however, as it was assumed to be the national meteorological service's responsibility to attend to data management and ground processing. The launch was supposed to be provided free of charge by the Americans on a Thor-Delta vehicle. A final decision by the French Government was awaited by July 1971.

The parallelism between the definition of this French 'Meteosat' project and the Ad-hoc Group's decision in favour of Geostationary European Meteorological Satellites (GEMS) became ever more apparent during this period (Fig. 3). Clearly, there was going to be some redundancy if these two projects were to proceed in the same time frame. This duplication was emphasised even further by the compatibility needed at an international level with other projects of the same kind, such as the American SMS/GOES mission.

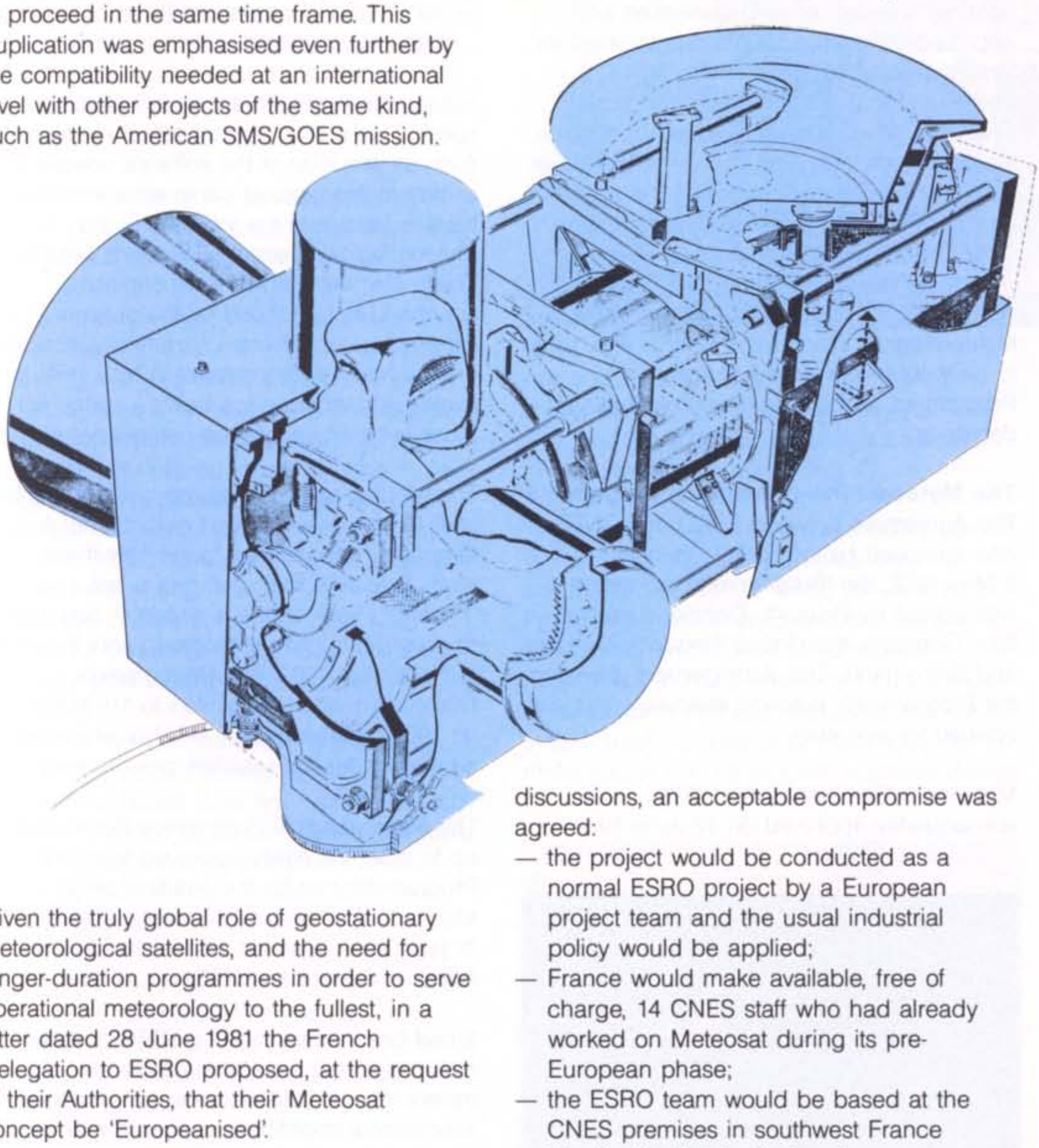


Figure 3. Concept for the imaging radiometer for the GEMS satellite, presented in 1971

Given the truly global role of geostationary meteorological satellites, and the need for longer-duration programmes in order to serve operational meteorology to the fullest, in a letter dated 28 June 1981 the French Delegation to ESRO proposed, at the request of their Authorities, that their Meteosat concept be 'Europeanised'.

This proposal served to combine the best of both worlds: on the one hand, the expertise that had already been developed in the French national space agency (CNES) would be made available to Europe; on the other, the much enlarged international participation would provide the best possible basis for supporting the project in both the medium and long term.

At this stage, four tasks had to be completed:

— negotiation of the best organisational scheme for the project;
— analysis of the technical feasibility of the French proposal;
— completion of the mission studies made under French auspices, as well as enlargement of the mission's scope to meet the wider European needs;
— definition of a European ground segment.

The organisational scheme proved to be the most controversial issue but, after protracted discussions, an acceptable compromise was agreed:

— the project would be conducted as a normal ESRO project by a European project team and the usual industrial policy would be applied;
— France would make available, free of charge, 14 CNES staff who had already worked on Meteosat during its pre-European phase;
— the ESRO team would be based at the CNES premises in southwest France (Centre Spatial de Toulouse).

The technical feasibility of the Meteosat mission was confirmed by an ESRO team in November 1971. Completion of the mission-related task had been rather straightforward as the European users' needs had already been defined in detail.

The detailed definition of the meteorological ground segment took more time, because this was an entirely new and complex

venture; there were long discussions concerning the optimal configuration. A centralised ground-segment approach was finally adopted for three principal reasons:
— to avoid wasting the geostationary spacecraft's data-dissemination capabilities;
— to economise on operational exploitation costs;
— to foster system security and reliability.

By December 1971, the ESRO Council had adopted a reform of its Organisation and approved three applications programmes for further consideration (aeronautical, telecommunications and meteorological). Given the advanced state of definition of the meteorological proposal, therefore, there was an immediate need to formalise the situation by establishing an Agreement between the participating Member States and ESRO, as well as between ESRO and CNES. This Agreement provided for the setting up of a Meteorological Programme Board, which was to be responsible for the Meteosat Programme and for the taking of all related decisions.

The Meteosat Pre-operational Programme
The Agreement between ESRO and CNES was approved by the ESRO Council on 9 May 1972; the 'Programme Declaration' was signed by Belgium, Denmark, France, Italy, Germany, the United Kingdom, Sweden and Switzerland. The 'Arrangement' covering the Programme's practical execution was also opened for signature.

Meteosat's 'Europeanisation' was subsequently approved on 12 June 1972.

Figure 4. Construction of the 15m-diameter Meteosat antenna (for data acquisition, telecommand and tracking), in the Odenwald, W.Germany

Acknowledging the importance of the French initiative, the European Delegations analysing the programme proposal decided to retain the name Meteosat, and to abandon the GEMS acronym.

The Arrangement covered:
— the development of the satellite;
— the procurement of two flight units;
— the launching of one flight unit;
— the production of a central ground facility and of prototype user stations;
— six months of operations following Meteosat's launch.

Initially, the Arrangement excluded some specific tasks of a meteorological nature, such as provision of the software needed to extract meteorological parameters from the satellite data, and the interface to the meteorological telecommunications network. These elements, which were originally supposed to be funded by the national meteorological services, were finally included in the Meteosat Programme in May 1973, to avoid any further delays being incurred whilst those services sought the necessary funding.

The funding of operations beyond six months after launch was left open at that time. A temporary solution was found only three years later, with the signing of a first 'Protocol'. A second one was later negotiated to cover Meteosat's exploitation until the end of November 1983. The Programme's financial envelope amounted to 115 MAU* (at 1972 price levels), 53 MAU of which were earmarked for the satellite's procurement.

The Meteorological Programme Board, set up to steer the newly approved Meteosat Programme, met for the first time on 21 March 1972. It was subsequently assisted in its tasks by a Scientific and Technical Advisory Committee (STAG).

It had been recognised by ESRO at a very early stage that the global nature of meteorological satellites required a specific international coordination scheme with the other entities around the World involved in the provision of similar spacecraft, particularly in the USA, Japan and the USSR. ESRO therefore suggested the creation of an informal international body to study compatibility-related matters; the first such 'Coordination Meeting on Geostationary Meteorological Satellites' (CGMS) was

* MAU = Million Accounting Units.

organised in Washington in September 1972 by the US participants — the 18th CGMS meeting is currently in preparation!

Meteosat-1 (F1)
Most of 1973 was devoted to a detailed definition of the Meteosat system in accordance with the mission requirements confirmed by the Meteorological Programme Board and its Scientific and Technical Advisory Group. For the space-segment definition phase (Phase-B), contracts were awarded to two European industrial consortia, COSMOS and MESH, resulting in two competitive offers for the subsequent satellite design and development phases (Phases C and D).

The Meteosat ground segment, the most complex for an ESRO programme thus far, was defined by an in-house effort.

Design and development of the Meteosat system started at the end of 1973 with the awarding of the satellite's main development to Aérospatiale (Cannes), as COSMOS prime contractor. Almost simultaneously, the first contracts were placed with European industry for the design, development and installation of the various ground-segment elements. Manufacture was started of the satellite engineering model (P1), integration of which was carried out in 1975, following successful completion of structural- and thermal-model tests (Fig. 5).

1975 also saw the finalisation of the long-awaited Meteosat 'Protocol' by the Programme Board. This first Protocol, which had been signed by all participating Member States except Sweden, assigned ESRO, which by this time had become ESA, the task of operating the Meteosat system for three years after the first successful launch. During this period, ESA was not only to be responsible for the satellite, but also for the processing and archiving of the data and the extraction of meteorological parameters on behalf of the users.

In the course of 1976, the satellite protoflight model (P2, later launched as Meteosat-3; see below) was integrated, the hardware for the two flight models F1 and F2 (Fig. 6) was manufactured, the major part of the ground segment was successfully tested, and ground/space compatibility tests were started.

During 1977, the system and environmental tests on both the P2 and the flight-model (F1) spacecraft were completed. Towards the end of that year, on 23 November, Meteosat-1 was successfully launched by a Thor-Delta rocket from Eastern Test Range in the USA. This was the first ESA satellite to be injected into a geostationary orbit (Fig. 7).

Figure 5. Integration of the Meteosat engineering model (P1) at SNIAS, in Cannes (F)

The primary objectives in the months after launch were to provide a useful daily contribution to WMO's World Weather Watch Programme and to prepare the system for participation in the First GARP Global Experiment (FGGE). Meteosat-1 successfully achieved both of these objectives and the system made a substantial contribution to meteorology and other Earth sciences during

Figure 6. Work in progress on the Meteosat radiometer

Figure 7. Launch of the Meteosat-1 spacecraft, on 23 November 1977

Figure 8. First image (visible band) received from Meteosat-1, on 9 December 1977

its two years of operation, until 24 November 1979. At that time, an on-board component failure (a resistor in a protection device!) put the satellite's imaging and data-dissemination system out of action. The spacecraft's Data-Collection Mission, however, continued unimpaired.

Meteosat-2 (F2)

In early 1977, convinced that the Programme's success would be greatly enhanced by a longer exploitation period, the Meteosat Programme Board approved the launch of Meteosat-2 as principal passenger on the third Ariane test flight (LO3) in the early eighties. This decision was the first confirmation that the Meteosat-1 launch might indeed not represent a singular event, but rather be the start of a European meteorological programme relying on geostationary satellites.

Meteosat-2 was, in fact, launched from ESA's launch base in Kourou, (Fig. 9) French Guiana, on 19 June 1981. It began routine operations on 12 August and was used in this role until 11 August 1988. However, due to a failure in the satellite's Data-Collection System (DCS) during launch, measures had to be taken to exploit the still operational DCS element of Meteosat-1. From October 1985 until July 1988, this backup role was served by an American GOES-4 spacecraft.

In the period between Meteosat-1's launch in 1977, and 23 November 1983, when it officially came to an end, the Meteosat Pre-operational Programme both fulfilled the needs of its scientific users working in the fields of climatology and atmospheric physics, and provided a wealth of meteorological data for use in operational meteorology. Moreover, it had also become clear that Meteosat, as a remote-sensing system for operational meteorology, had a range of applications far beyond those initially foreseen.

Meteosat-3 (formerly P2)

By early 1976, ESA was already deeply involved in trying to convince the meteorological community that decisions were required on the prolongation of the Meteosat Programme in order to avoid having a major discontinuity in the space-provided data. It was, of course, extremely difficult to convince this community to continue a programme that at that time (Meteosat-1 was not launched until 23 November 1977) was still to provide its first data!

Figure 9. Meteosat-2 being readied for its launch (Ariane flight L03), together with India's Apple satellite (centre) and the Ariane Technological Capsule (below)

The first obvious proposal was the extension of the Meteosat series with two more flight units. A much more modest proposal aimed at upgrading the P2 prototype to flight specification and taking advantage of an Ariane test flight for its launch also received a limited amount of study.

By the early eighties, the problem of data continuity was becoming very acute. In conjunction with the preparatory discussions on the Meteosat Operational Programme (discussed below), it was once more agreed that launching of the upgraded P2 spacecraft was the only viable solution for filling the gap between the end of Meteosat-2's expected lifetime and the availability of the first satellite in the Meteosat Operational Programme (MOP-1).

A small supplementary programme was therefore organised which took advantage of the first test flight of the new Ariane-4 launcher. The old P2 prototype, upgraded and now called Meteosat-3, was launched on Ariane flight 401 on 15 June 1988. On 11 August last year, it replaced Meteosat-2 as the primary Meteosat satellite. When Meteosat MOP-1 (Meteosat-4), launched on 6 March 1989, is commissioned in orbit, Meteosat-3 will assume a backup role. As Meteosat-3, however, also carries a laser-based clock-synchronisation experiment (LASSO)(Fig. 10), it will continue to be used for these non-meteorological studies, including clock synchronisation across the Atlantic.

The Meteosat Operational Programme

The prospects offered by the Pre-operational Meteosat Programme, and its subsequent success, encouraged many European countries to increase their efforts to agree upon a new programme that could extend the project beyond the two initial satellites. This also meant that users would be called upon to support the financial burden of the new programme. To be able to do so, they had to organise themselves into a suitable legal framework.

The need for a special operational European meteorological organisation had already been acknowledged during the Europeanisation of the Meteosat project in the early seventies. By June 1976, a Space Meteorology Working Group (SMWG) had been set up within ESA to formulate proposals for future space-meteorology programmes. In mid-1977, another attempt at the setting up of such a European organisation was initiated at the request of the Conference of Meteorological Services Directors. Two avenues were explored:

- the creation of a legal entity in accordance with either international law or the national law of a particular State;
- the use of an existing legal entity, i.e. a Meteorological Service, the European Economic Community (EEC), the World Meteorological Organisation (WMO), the European Centre for Medium-Range Weather Forecasting (ECMWF) or the European Space Agency (ESA).

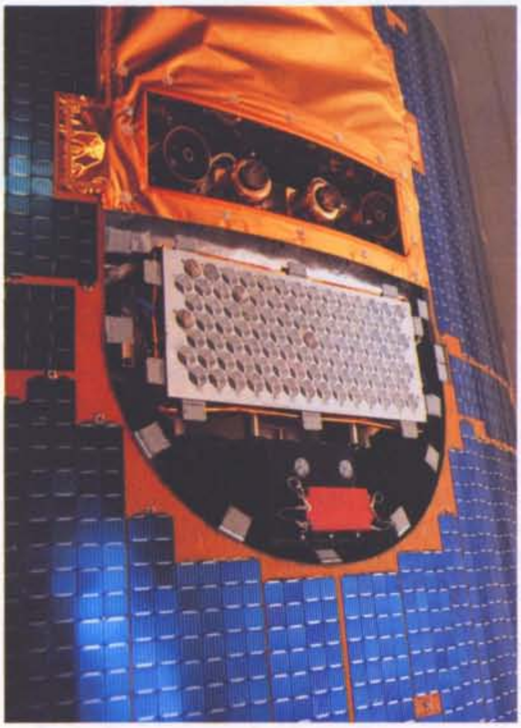


Figure 10. LASSO retroreflector (centre) on the Meteosat-3 satellite

After more detailed studies of the ESA and WMO options, both of which had declared their willingness to host the new structure, and after further consideration of the ECMWF option, the idea of a new independent organisation was again floated and an in-depth study made. In March 1979, the decision was taken to prepare a Draft Convention for the establishment of a European Meteorological Satellite Organisation (EUMETSAT). This was a big step forward, although quite disparate views still abounded regarding the legal identity of the future setup. By June 1980, a complete Draft Convention was available.

Figure 11. Meteosat-2 image of the Earth's disc

For its part, ESA was busy preparing a proposal for the space system due to take over from the pre-operational satellites and a Protocol concerning the setting up and exploitation of an Operational Meteosat System was drafted. This proposal involved the launching of five satellites closely related to the pre-operational spacecraft, as well as an upgrading of the ground segment. A complete proposal, including the financial considerations, was issued by August 1980 for consideration by the European Meteorological Services and their governing bodies.

Three programme options were considered which were directly based upon the available Meteosat design, with operations beginning in early 1983:
- three spacecraft with an overall 6.5 yr period of operation;
- five spacecraft with an overall 10 yr exploitation period;
- three improved spacecraft designed for an overall 8.5 yr of exploitation.

The Inter-Governmental Conferences

While the legal and technical matters relating to continuation beyond the Meteosat Pre-operational Programme were making significant progress, it became obvious that a formal step was required to provide the necessary high-level political support.

At its June 1980 meeting, the ESA Council decided that the Agency should host an Inter-Governmental Conference of potentially interested European States to discuss the feasibility and means for creating an operational meteorological satellite system. Seventeen countries eventually participated in this Conference, which was held at ESA's Headquarters in Paris on 28–29 January 1981; they were: Austria, Belgium, Denmark, Spain, France, Germany, Greece, Ireland, Italy, Norway, the Netherlands, Portugal, Sweden, Switzerland, Turkey, the United Kingdom and Yugoslavia.

The results of the preliminary studies and proposals mentioned above were presented to the Conference. All participants agreed that the creation of an operational space system would bring substantial advantages and would constitute a worthwhile contribution by Europe to the Global Observing System of the World Weather Watch of WMO. They also accepted the principle of a 'EUMETSAT' organisation endowed with legal responsibility.

They also decided to set up a Meteosat Operational Programme Working Group to be charged with elaborating system requirements and recommending the most appropriate legal framework for the Programme's establishment. The conclusions of this Group were to be presented at a second session of the Inter-Governmental Conference.

Although it started working almost immediately after the Conference's closure, progress by the MOP Working Group proved to be much slower than foreseen. About twenty-five meetings of the Group and of its sub-groups were needed to complete the tasks delegated by the first Conference. If agreement was soon reached on the technical aspects of the Operational Programme (three improved satellites option), the setting up of the European meteorologists' organisation was a much more contentious matter. Long sessions had to be held to overcome strong nationally oriented positions, and to hammer out the final details of the EUMETSAT Convention.

In parallel with this Group's activities, ESA was preparing a complete technical proposal for the system agreed upon. As the Agency was to be committed for a comparatively long period, every effort was made to ensure that this proposal was of the highest quality.

A Draft Convention that was finally considered acceptable was achieved in February 1983. Consequently, the second session of the Inter-Governmental Conference could not take place until 21–23 March 1983 (Fig. 12).

These transitional measures were based upon the ESA Council's willingness to initiate the MOP as an 'Optional Programme' of the Agency. A Programme Declaration had been opened for signature and ESA had undertaken the very difficult task of obtaining financial commitments from national participants.

The Conference adopted the Working Group's recommendation according to which execution of the Operational Programme was to be entrusted to ESA. It endorsed the Draft EUMETSAT Convention and also welcomed the starting up of an interim ESA Optional Programme, pending the entry into force of the EUMETSAT Convention proper. It also urged the Governments that had not yet signified their intention to contribute to the Programme to do so.

Figure 12. Second Inter-Governmental Conference in session at ESA Headquarters in Paris in March 1983

This second session of the Conference was presented with:
- the conclusions of the MOP Working Group;
- ESA's technical and financial proposals;
- the Draft EUMETSAT Convention.

The Conference was also presented with a series of transitional measures aimed at initiating the Meteosat Operational Programme without delay. This was necessary because the EUMETSAT Convention had to be ratified by national Parliaments before entering into force, and this process was expected to take approximately two years.

To help get the EUMETSAT organisation on its feet as it awaited Parliamentary ratification, ESA proposed the setting up of a EUMETSAT interim unit, part of which it hosted at its own premises.

As a side issue, the ESA proposal to fill the probable gap in exploitation between Meteosat-2's end-of-life and the availability in orbit of the first MOP spacecraft, was also accepted. (This resulted in the upgrading of the P2 spacecraft and its launch on the first Ariane-4 test flight, discussed earlier).

The second session of the Inter-Governmental Conference also agreed to the calling of a Conference of Plenipotentiaries for the signing of the EUMETSAT Convention. This Conference was to take place on 20 May 1983 in Geneva. On that day, thirteen Plenipotentiaries signed the Convention: Belgium, Denmark, Spain, France, Germany, Italy, Norway, The Netherlands, Portugal, Sweden, Switzerland, Turkey, and the United Kingdom. Finland, Greece and Ireland attended as observers (Fig. 13).

Figure 13. Celebration of the signing of the EUMETSAT Convention, in Geneva, on 20 May 1983

By mid-1983, the Meteosat Operational Programme had thus received the green light, after seven years of constant effort on the parts of a wide community of scientists, engineers, meteorologists and politicians. The Meteosat Operational Programme was at last under way.

By June 1986, fourteen countries had ratified the EUMETSAT Convention. A special Conference of Participating States noted that all necessary conditions for entry into force of the Convention had been fulfilled and this was confirmed on the 19th of that month.

In January 1987, EUMETSAT took over the overall and financial responsibility for the Meteosat Operational Programme (MOP). ESA continues to play the role to which it committed itself in its 1983 proposal, and the European meteorological community therefore now has at its disposal all the major elements that it needs to achieve full maturity in the domain of space meteorology.

The Meteosat operational spacecraft

The Meteosat system has been the subject of a large number of publications over a period of almost twenty years. Satellite and system descriptions are available in many publications; in particular, an excellent summary is to be found in the document 'Introduction to the Meteosat Operational System', available from ESA Publications Division (ESA BR-32). A brief résumé of the basic features of the system, both space segment and ground segment, is provided in the accompanying panels.

The Meteosat Operational Programme, approved by 1983, covered:
— the development and launching of three MOP spacecraft of an improved design compared with the pre-operational satellites;
— the construction of a complete set of spares;
— the exploitation of one spacecraft independently of its origin (Pre-operational or Operational Programme) from November 1983 until November 1995.

The new features of the operational Meteosat satellites compared with their forerunners are as follows (Fig. 14):
— all three imaging channels (visible, infrared, and water-vapour) are redundantly configured, and not just the infrared channel;
— the water-vapour channel becomes fully operational without any time sharing with other channels;
— all image data are 8-bit encoded, not just the infrared channel;
— a black body is available for the calibration of the water-vapour channel;
— the raw data rate is doubled (333 kbit/s);
— S-band telecommunication is used for tracking, telemetry and control (TTC) instead of VHF;
— the payload includes a new Meteorological Data Dissemination mission (MDD);
— the original interrogation capability of the Data-Collection Platforms (DCPs), which was never used, has been dropped;
— the spacecraft design lifetime is now five years instead of three.

Meteosat-3 (formerly P2), not being an operational spacecraft, does not incorporate these improvements.

Conclusion

An attempt has been made here to provide a comprehensive insight into the lengthy and often quite involved process that led to the establishment of the Meteosat satellites in orbit. Although the impression gained may be one of an overly detailed presentation of events, many have in fact been omitted. The author's prime objective was to underline the critical role of European cooperation in what has now become the obvious success of the Meteosat Programme.

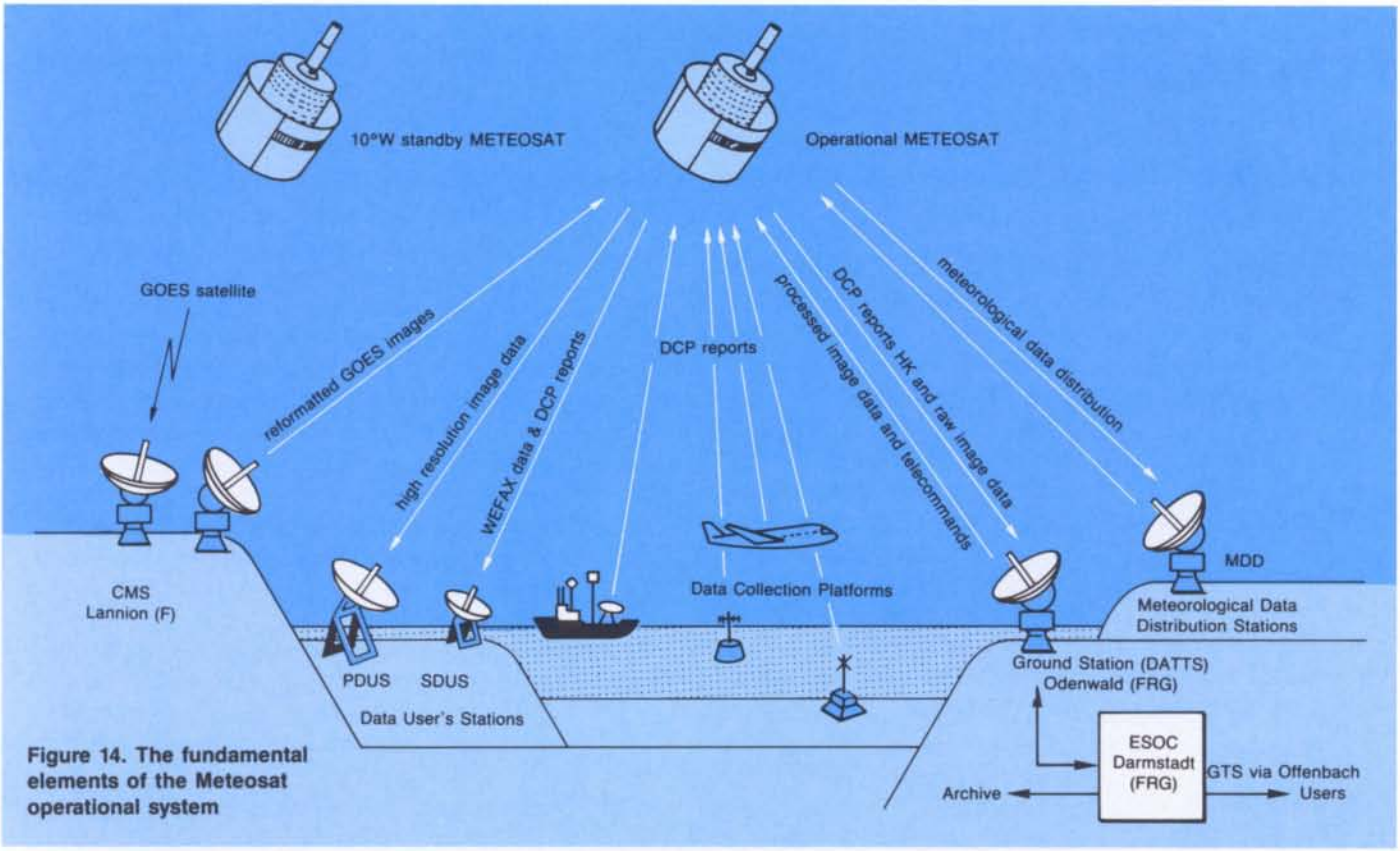


Figure 14. The fundamental elements of the Meteosat operational system

It is important that we reflect from time to time on such successes, which should never be taken for granted. Programmes were no easier to initiate when Meteosat was conceived than they are now, when the European ideal is much more to the forefront.

For ESRO, later ESA, Meteosat was a first in many respects. It was the first applications programme to be undertaken by Europe. It was also the first European geostationary satellite project; the first spacecraft injected into geostationary orbit by ESOC; the first and largest family of operationally exploited European satellites; and its ground system was one of the most advanced, non-military data-processing facilities to be installed in Europe.

Further satisfaction can be drawn from the fact that Meteosat is by far the best known of ESA's satellite programmes. Beyond its value to the professional meteorologist, its data are presented daily to the general public by most of the European television networks.

On the institutional side, the Meteosat Pre-operational and Operational Programmes have fundamentally promoted the development of European meteorology. The instigation of cooperation between the European Meteorological Services was a byproduct of these Programmes, along with the global cooperation within the CGMS framework. One might say that ESA nursed the European space-meteorological family to the point where EUMETSAT has been able to provide it with a permanent home!

The next chapters in the history of European space meteorology will be written by that new organisation, to which all we veterans who have been involved in Meteosat's birth wish lasting success.

Figure 15. The Meteosat Control Centre, at ESOC in Darmstadt, W. Germany

The Meteosat System

The two major components of the Meteosat System are the space segment and the supporting ground segment (Fig. 14).

The space segment consists of one or more spin-stabilised Meteosat satellites in geostationary orbit at an altitude of 35 800 km over the Gulf of Guinea. The primary satellite is located at the intersection of the equator and the Greenwich meridian (0°N, 0°E).

The main components of the Meteosat ground system are the Data Acquisition, Telecommand and Tracking Station (DATTS), the Meteosat Ground Computer System (MGCS), the Meteosat Operations Control Centre (MOCC), and the Meteorological Information Extraction Centre (MIEC). The MGCS, MOCC and MIEC are all located at ESA's European Space Operations Centre (ESOC), in Darmstadt, near Frankfurt. The DATTS is located in the Odenwald, about 40 km from Darmstadt.

The primary goals of the Meteosat Operational Programme are:
- Earth imaging
- dissemination of imagery and other meteorological data
- data collection and distribution,

together with the additional tasks of meteorological processing and data archiving and retrieval.

The spacecraft
Each Meteosat is 2.1 m in diameter and 3.2 m high. Its weight at the beginning of its life in orbit is 320 kg, including 39 kg of hydrazine propellant to be used for orbital manoeuvring. Once in orbit, the satellite spins at 100 rpm about its longitudinal axis, which is aligned almost parallel with the Earth's north-south axis.

Figure 16. Meteosat P2

Meteosat's main cylindrical body contains most of the satellite subsystems, as well as the prime payload element, the multispectral (four-channel) imaging radiometer.

The main spacecraft body's cylindrical surface is covered with solar cells, to provide the necessary electrical power. The surface of the smaller, upper drum-shaped element of the spacecraft carries an array of dipole antenna elements. Electronics within the drum activate these individual elements in sequence, in reverse order to the satellite's sense of spin, thereby providing an electronically despun antenna (S-band). The two thinner cylindrical units on top of the spacecraft are toroidal antennas for S-band and low-UHF transmissions.

Meteosat's multispectral radiometer allows continuous imaging of the Earth's disc in three spectral bands:
- 0.5—0.9 microns (visible band)
- 5.7—7.1 microns (infrared water-vapour absorption band)
- 10.5—12.5 microns (thermal-infrared band).

With every rotation of the spacecraft, the radiometer's telescope makes a new line-scan approximately 5 km north of the previous scan line. The telescope can be made to scan through an angle of 18° from south-to-north, thereby producing a full Earth scan of 2500 lines in 25 min. East-to-west scanning is provided by the spinning motion of the satellite (Fig. 17). A new image of the Earth's disc can be acquired in three spectral bands once every half an hour (5 min is required for the telescope to return to its start position and for the optics to stabilise).

The radiometer telescope can also be commanded to scan smaller areas than the full Earth's disc, allowing more frequent images to be obtained between selected latitude limits.

Image dissemination
Meteosat is equipped with high-power amplifiers to allow its imagery and other meteorological data to be relayed to small user reception stations. The data transmitted are mainly processed Meteosat image data, but also include conventional meteorological charts received at ESOC from the German Weather Service and images of the Western Atlantic and the Americas generated by the US GOES satellites.

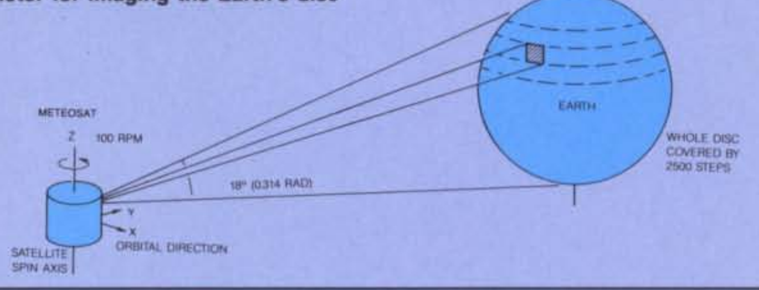
Two forms of image transmission are used: high-resolution digital data, for reception by Primary Data User Stations (PDUSs), and analogue (WEFAX) data, for reception by Secondary Data User Stations (SDUSs).

Data collection and distribution
Meteosat has a total of sixty-six telecommunications channels, designed for the collection of environmental

data from automatic or semi-automatic Data-Collection Platforms (DCPs). These may be located on ships, buoys, balloons or aircraft anywhere within the Meteosat coverage area.

Meteosat acts simply as a relay station in these cases, so that environmental data transmitted by the DCP are passed on to ESOC, from where they can be redistributed in a variety of different ways.

Figure 17. Scanning geometry used by Meteosat's radiometer for imaging the Earth's disc



Meteorological processing

Another role of the Meteosat system is the extraction of meteorological parameters from the basic image data, and their distribution. The Meteorological Information Extraction Centre (MIEC) at ESOC routinely produces and disseminates seven meteorological products:

- cloud-motion winds
- sea-surface temperatures
- cloud-top-height maps
- cloud-coverage data
- upper-tropospheric humidity values
- a basic climatological data set
- precipitation indices.

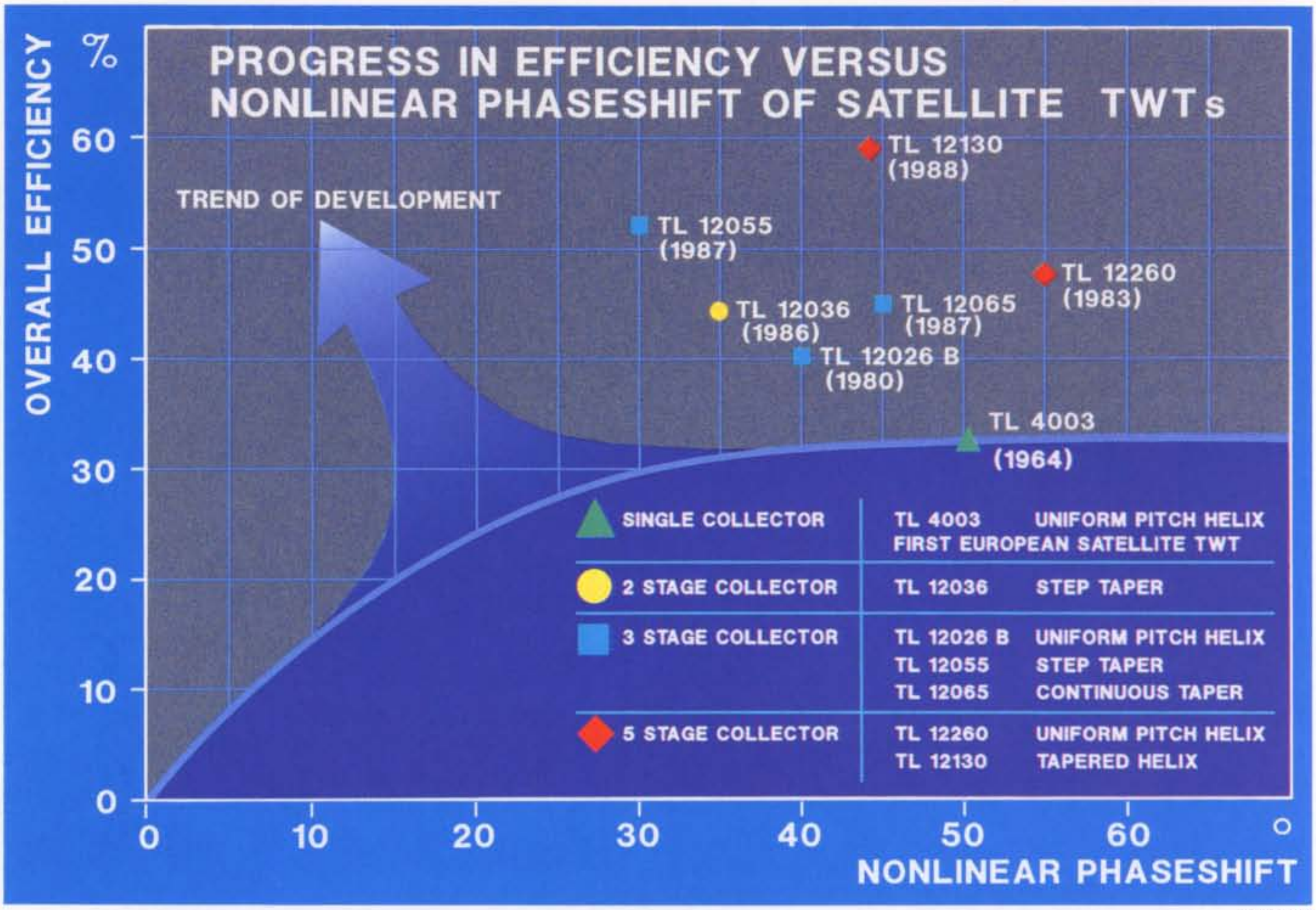
The resolution of the cloud-top-height maps is about 20 km, while the other products are based on a grid with approximately 200 km resolution.

Archiving and retrieval

The Meteosat System's objectives are completed by the requirement to archive all images, image-related data, and meteorological products. Each raw image consists of some 300×10^6 bits of information, and so there is a vast amount of data to be archived.

The primary archive medium is currently 9-track, 6250 bit/inch computer-compatible magnetic tape. Twelve tapes are needed to store the data from one day of Meteosat operation. Individual images can be retrieved from this archive and used as input to a laser-beam recorder which produces high-quality photographic images (see Fig. 18).

Figure 18. First image received from the Meteosat-P2 satellite, at 13.30 GMT on 29 June 1988



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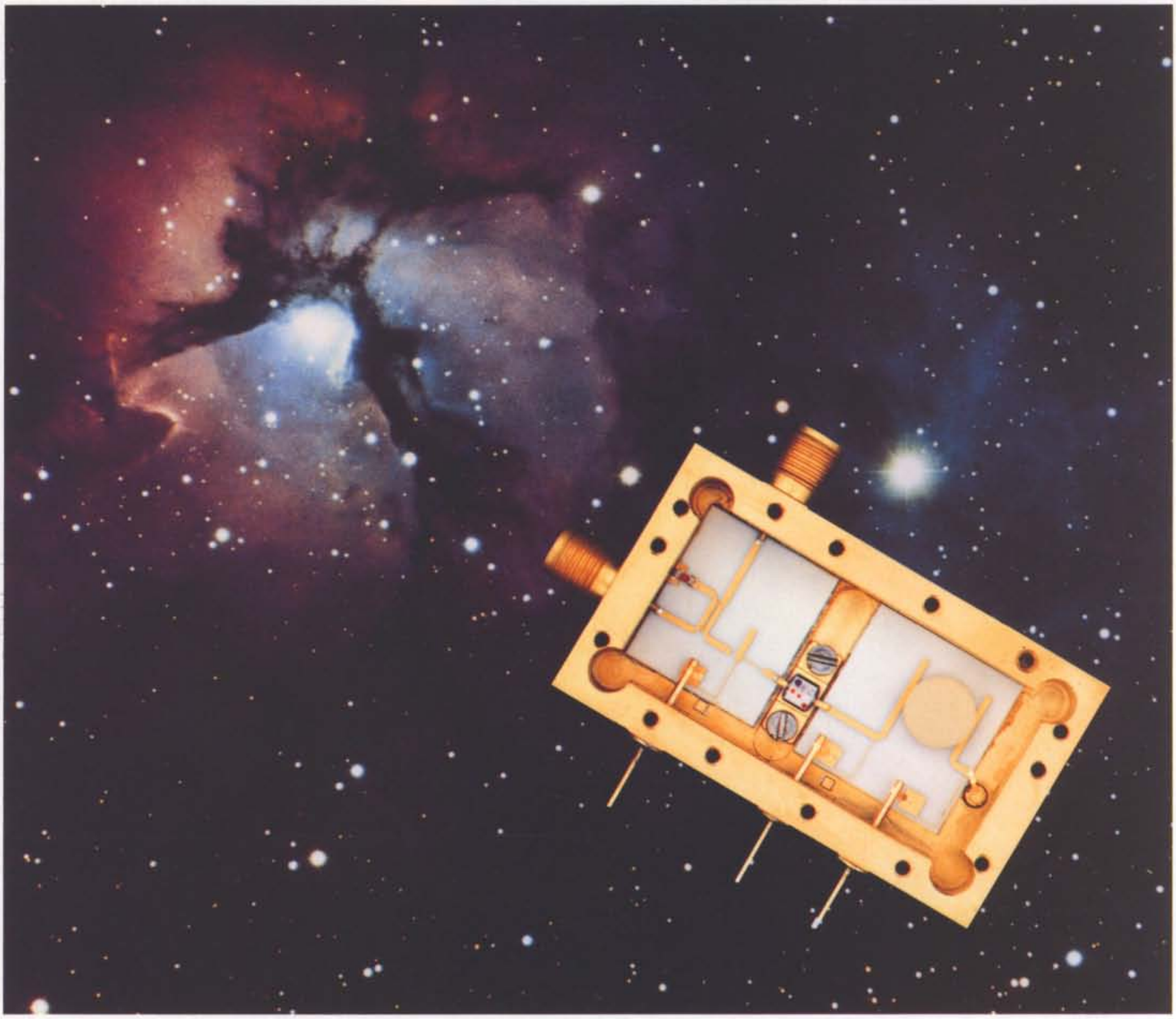

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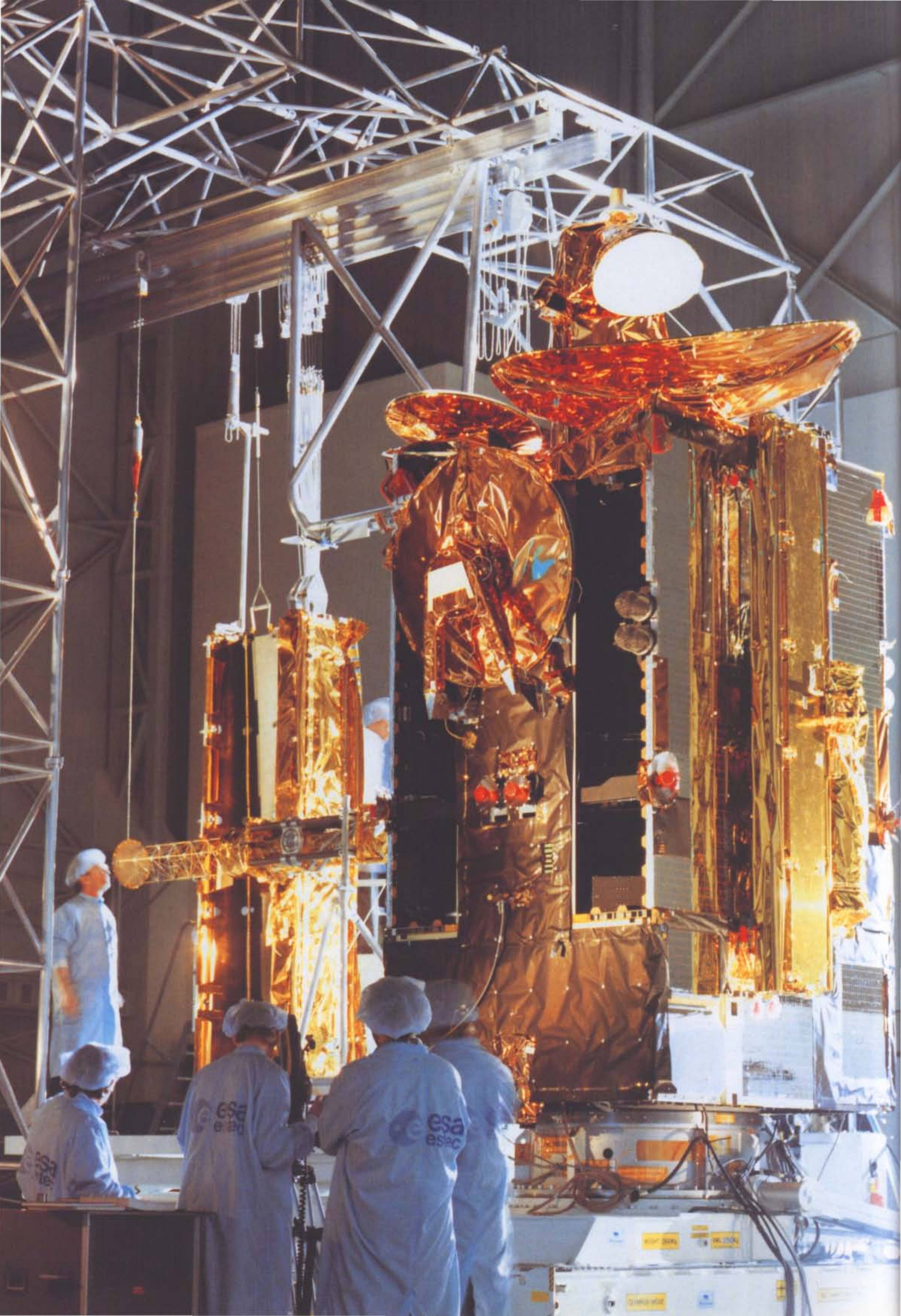
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The Large Telecommunications Satellite 'Olympus'

J.H. Paul
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ESTEC, Noordwijk, The Netherlands

Following the launch of a number of European experimental and pre-operational communications satellites between 1974 and 1978 (Symphonie-1 and -2, Sirio and OTS), ESA embarked on the construction of a series of medium-sized operational satellites to support the planned Eutelsat, Inmarsat, and French Telecom-1 systems. ESA had already anticipated the need for a larger class of communications satellite, and studies of the so-called 'heavy satellite', or 'H-Sat', consisting of a full Ariane-1 class platform associated with a mainly direct-broadcast (DBS) payload, were under way. An accelerated programme of supporting research and technology-development contracts was also started.

In 1979, however, work on H-Sat was terminated due to the Franco-German decision to develop the operational TV-Sat series on a bi-lateral basis. ESA then conducted a more general and extensive survey of the future market for large telecommunications satellites, and concluded that a larger class of satellite would be needed for a number of reasons. These included: the introduction of new types of satellite-based services operating with small ground terminals, putting greater demands on the space segment; the use of a single satellite to support several payloads dedicated to different types of services, to gain economic advantages; and a general increase in capacity requirements for satellites dedicated to a particular type of service.

After design studies by industry (so-called 'Phase-B'), the declaration for the development phase of the 'L-Sat' or 'Large Satellite' Programme as it was then called, later to become the Olympus Programme, was approved in January 1982 by eight of ESA's Member States: Austria, Belgium, Canada, Denmark, Spain, Italy, The Netherlands and the United Kingdom.

The goals of the large-satellite (L-Sat) development phase approved in January 1982 were defined as:

- The development, launch, and in-orbit operation of a multi-purpose large platform, designed for a range of future telecommunications applications, on a basis that would maximise the future competitiveness on the world market of the industries involved.
- The development, in conjunction with the spacecraft platform, of a series of telecommunications payloads, and their in-orbit operation, to advance industry's technological capabilities, stimulate users, and promote new market applications through a comprehensive test, demonstration and utilisation programme.

At the time the declaration was approved, the first launch of an 'L-Sat', Olympus-1 as we now call it, was foreseen to take place before Ariane-4 would be operational. To make it compatible with the Ariane-3 vehicle's lesser lift capability, Olympus-1 was therefore conceived as a demonstration mission with reduced power and mass, carrying the following payloads:

- A 12/20/30 GHz Propagation Package to complement and verify propagation statistics in the higher frequency ranges.
- A 12/14 GHz Specialised-Services Payload for advanced communications experiments between small earth terminals.
- A Direct-Broadcast Payload with two channels, one for pre-operational Italian use, and the other for European use.
- A 20/30 GHz Communications Payload for point-to-point and multipoint teleconferencing and other experimental applications.

The full capabilities of the Olympus design, referred to as 'Olympus-Max', and those of Olympus-1, currently scheduled for launch on 22 June 1989, are compared in Table 1.

Industrial arrangement

British Aerospace (Space Systems) Ltd. (UK) is the prime contractor for Olympus-1. Selenia Spazio of Italy is responsible for coordination of the four communications payloads, including the design and development of the television Direct-Broadcast and the 20/30 GHz-Communications Payloads.

Table 1 — Comparison of Olympus-1 with Olympus-Max

		Olympus-Max	Olympus-1
Mission life		10 years*	5 years
Launch vehicle		STS and Ariane-3	Ariane-3
Mass	Total	3300 kg	2600 kg
	Payload	600 kg	360 kg
Array power (end of life)		7.0 kW	3.5 kW

* All Olympus equipment designed for a 10 year orbital lifetime

Marconi Space Systems (UK) is responsible for the 12/14 GHz Specialised-Services Payload, and BTM (B) for the Propagation-Package Payload.

SPAR Aerospace Ltd. (Can.) has overall responsibility for the solar arrays, with major subcontracts to AEG (D) and Fokker (NL). The combined propulsion system has been integrated and tested by SNIA-BPD in Colleferro, Italy, and environmental and final testing of the satellite has been conducted at the Canadian Government's David Florida Laboratories in Ottawa.

Not counting parts suppliers, a total of more than sixty companies have been involved in the production of equipment for Olympus-1.

Platform description

An exploded view of the Olympus satellite is shown in Figure 1, which also indicates the antennas used by the various subsystems. The spacecraft structure (Fokker, NL), which uses conventional materials throughout, is designed to withstand both Ariane and Shuttle launch loads.

The spacecraft itself consists of three main modules: the 'Service Module', containing the majority of the platform equipment; the 'Propulsion Module', containing the propellant and pressurant tanks and associated pipework; and the 'Communications Module' comprised of the north and south radiating panels (Aeritalia, I) and the Earth-facing floor, which provides the majority of the payload mounting area. The east and west faces of the spacecraft carry the European broadcast-beam and specialised-services antennas.

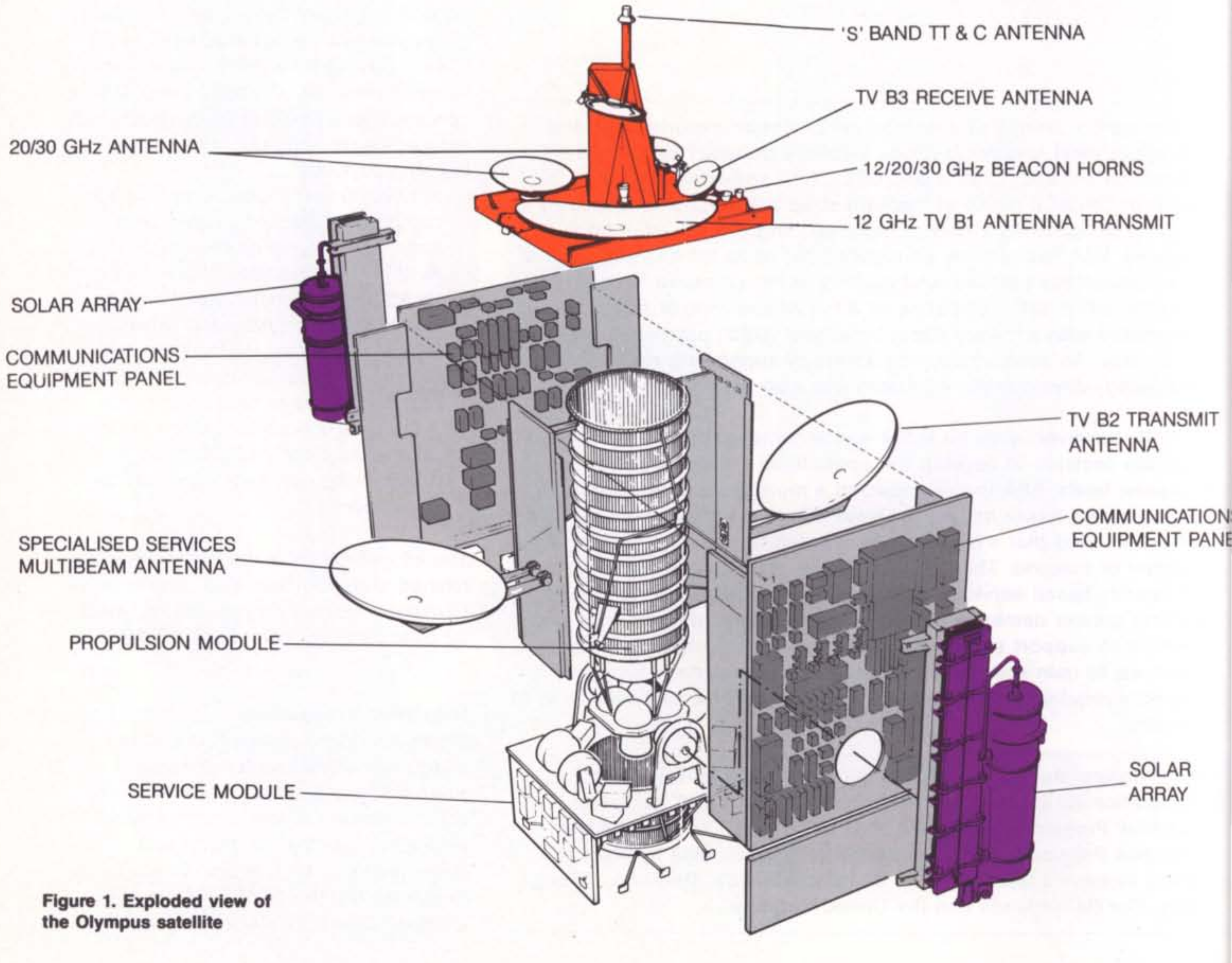

Figure 1. Exploded view of the Olympus satellite

Passive thermal control (Aeritalia, I) is used, with mirror radiators on the spacecraft's north and south faces, and with Mylar and Kapton electrically conductive multilayer insulation blankets for internal equipment and for the other four spacecraft faces. Constant-conductivity heat-pipe assemblies are mounted on the honeycomb north and south faces in areas carrying equipment requiring high heat dissipation, such as the travelling-wave-tube amplifiers (TWTAs). Batteries are mounted on separate north-south oriented radiator panels carrying cutouts or honeycomb radiators. Electrical heaters are used where necessary, controlled either automatically or by telecommand.

Special attention has been paid to eliminating the risks of electrostatic discharge: in addition to the use of conductively coated material for the thermal blankets, conductive thermal paints have also been applied.

Spacecraft attitude control (British Aerospace) is based on a zero-momentum system employing reaction wheels for each of the three axes. This system is tolerant to the inertia changes that will result from the use of different sizes of solar arrays in the future (output powers ranging from 2.0 to 7.0 kW) and from other mission-specific mass changes, without modification to the system hardware. Changes to suit different missions need to be made only in the software of the microprocessor-driven control electronics. The reaction wheels and thrusters are controlled by a microprocessor unit, which receives its inputs from infrared sensors, Sun sensors, gyroscopes and telecommands (certain functions can be telecommanded independently of the microprocessor).

New equipment has not been developed for Olympus except where absolutely necessary. The infrared Earth sensor, Sun acquisition sensor, digital Sun sensor and gyroscopes have all been used in previous ESA programmes. Other equipment has also been derived directly from previously used items.

The Olympus-1 solar (Fig. 2) array is sized to produce 3.5 kW of power, compared with the 7.0 kW foreseen for Olympus-Max. To provide this flexibility, the array's design concept must be easily adaptable, with minimum design impact resulting from changes in array power requirements. Accordingly, the concept that has been selected employs flexible panel arrays, using well-proven solar cells (AEG, D) bonded to a glass-fibre/Kapton laminate that forms the substrate. The panel is extended using an Astromast (Spar Aerospace, Can.), based on designs developed for various NASA programmes, including Voyager. Unlike some applications of this boom, however, the Olympus Astromast is extended using a motor drive rather than a motorised release mechanism. This eliminates the need for the deployed part of the mast to rotate and ensures that the deployed elements are rigidly configured.

At launch, the solar array will be stowed in a folded concertina form. Both the primary and secondary deployments will take place

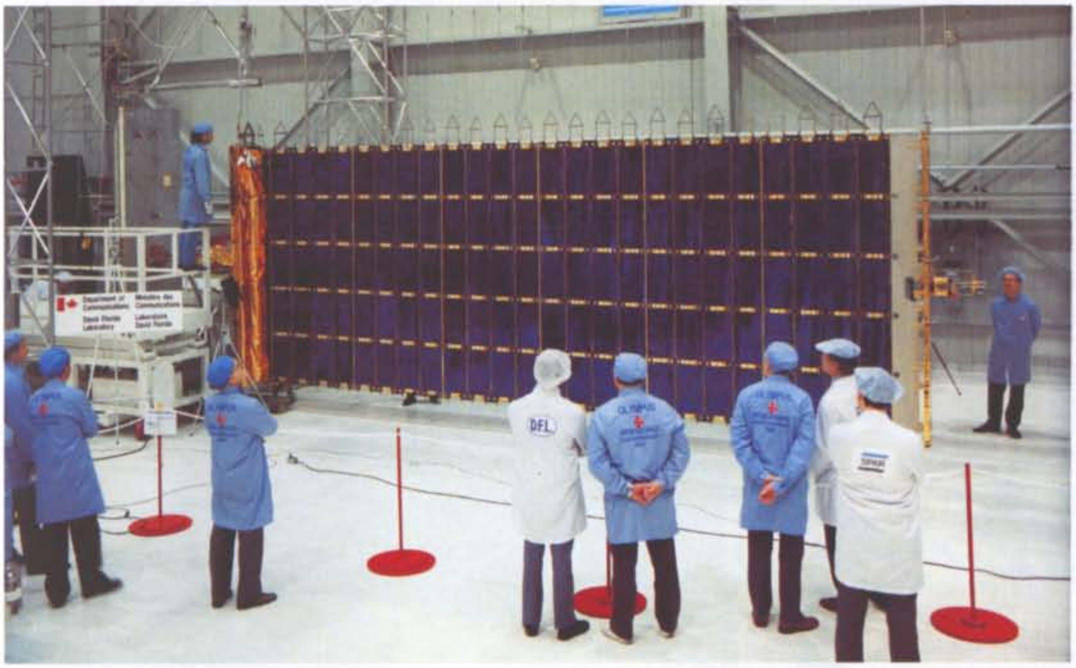

Figure 2. One wing of the Olympus solar array during deployment testing at the David Florida Laboratories in Ottawa, Canada. The array is supported by complex ground equipment that simulates the zero-g deployment environment in space (photo courtesy of CRC, Ottawa)

before Olympus's apogee engine is fired. Extensive tests have been conducted on representative models for all the deployments, including the primary release, which has also been performed under thermal-vacuum conditions on the flight spacecraft.

The reverse side of the array in its fully deployed condition is shown in Figure 3. The Astromast that deploys and supports the solar array is clearly visible. The heritage of this array can be found in CTS-1, the Canadian satellite launched in 1976, and the Spot-1 and Space-Telescope arrays, as well as NASA's SAFE experiment.

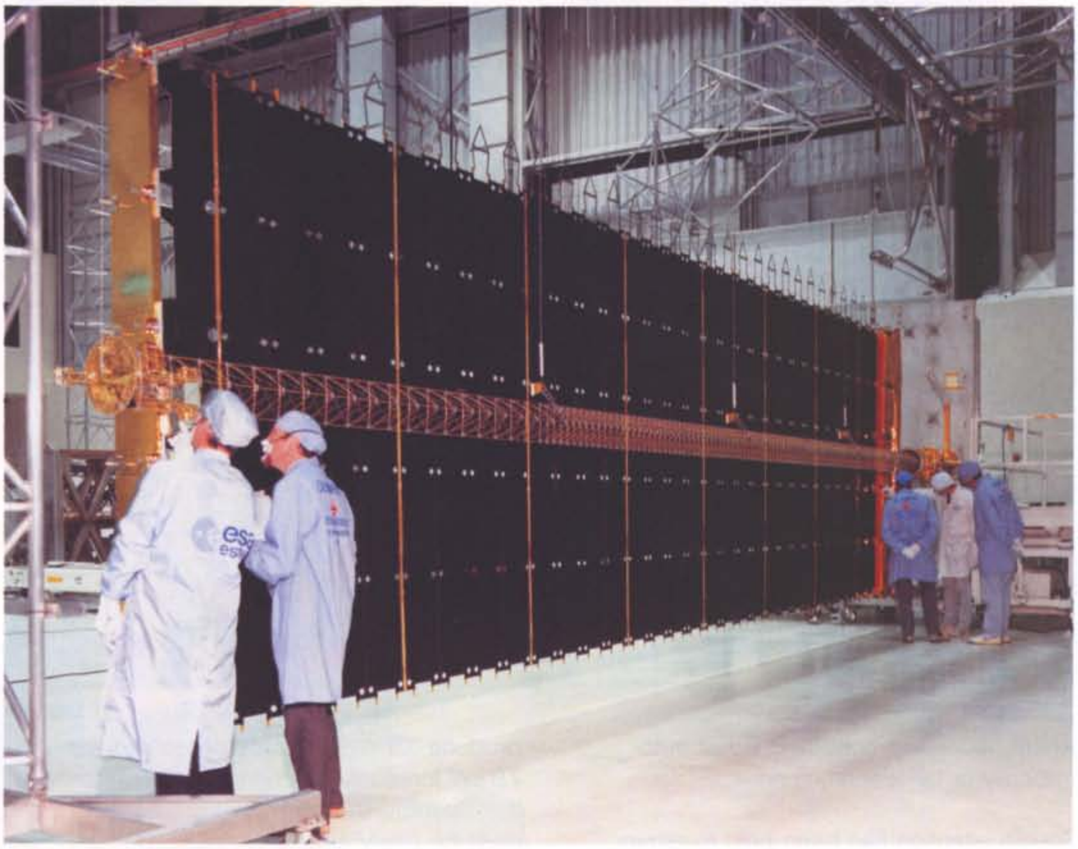

Figure 3. Reverse side of the fully deployed solar array (photo courtesy of CRC, Ottawa)

The Olympus power subsystem (British Aerospace) is similar to that used on the Agency's OTS-Marecs-ECS series of telecommunications satellites, with a single fully regulated 50 V power bus. As for ECS, many additional controls and reliability features are incorporated in the system. Up to four batteries may be carried, using either nickel-cadmium (NiCd) or nickel-hydrogen (NiH_2) cells, or a combination of both (typical capacities 60–70 Ah per battery).

Olympus-1 carries two batteries, one NiCd and one NiH_2. Battery charging and discharging are controlled and monitored by a Battery Management Unit, which also provides subsystem protection.

The combined propulsion system is a bi-propellant system using monomethyl hydrazine (MMH) and nitrogen tetroxide (NTO). It combines the functions of apogee injection using a 400 Newton engine, and station acquisition, station-keeping and momentum dumping using smaller 22 Newton engines. The propulsion system's construction is designed to minimise the number of joints, and titanium tanks and pipework are used. The spherical tanks can be extended by inserting cylindrical sections to provide increased propellant capacity for larger versions of the satellite.

The firing of the apogee engine is accomplished in an active-pressure-regulated mode, which is inhibited once the apogee manoeuvres have been completed. Orbit insertion will be achieved with a single apogee-engine firing, although a second burn opportunity is provided for in the sequence of mission events.

The Olympus tracking, telemetry and command subsystem (British Aerospace) operates at S-band and employs conventional technology. It is highly redundant and uses dual receive/transmit transponders working through an axiallyslotted cylindrical antenna mounted on the tower. A fill-in antenna is mounted on the opposite face of the spacecraft body.

The payloads

The prime purpose of the Propagation-Package Payload (BTM, B) is to gather reliable information on signal attenuation, depolarisation and any other signal impairment introduced by the propagation of radio waves through the Earth's atmosphere. Direct measurements will be made of signals from stable beacons at 20 and 30 GHz, whilst a 12.5 GHz beacon will serve the study of frequency scaling of propagation characteristics.

The 12/14 GHz Specialised-Services Payload (Marconi, UK) consists of a multiple-beam antenna providing five beams in both receive and transmit bands, and a repeater with four receive chains and four transmit chains interconnected by a programmable switching system for Satellite-Switched Time-Division Multiple Access (SS-TDMA) experiments. Frequency re-use by spot-beam discrimination assisted by polarisation discrimination is incorporated.

Power dividers in the receive chains and a multiplexer in the output network allow both television distribution and multipoint video-teleconferencing experiments between small earth stations (using Frequency-Division Multiple Access, or FDMA). Input and output waveguide switching networks provide flexibility and redundancy.

The antenna has a simple offset parabolic reflector, which is folded against the east face of the satellite body during launch and then deployed in-orbit. Five identical hexagonal transmit/receive feed horns each serve one of the five beams. The antenna reflector is mounted on a pointing mechanism, which allows the whole five-beam cluster to be moved from the nominal pointing over Europe to any other point on the Earth visible from the satellite's planned station at 19°W longitude.

The Direct-Broadcast Payload (Selenia Spazio, I) contains two transmit channels, one to be used by the Italian Television Agency RAI for a pre-operational Italian service, and the other for European programme experiments. The steerable elliptical reflector for the RAI channel, designated TVB1 in Figure 1, is shaped for optimal Italian coverage. The European beam antenna, designated TVB2, is also steerable. The common receive function is provided by a dedicated receive antenna, TVB3, generating European coverage.

Figure 4. The Olympus flight-model satellite in production at British Aerospace in Stevenage (UK) (photo courtesy of BAe)

A radio-frequency sensing subsystem provides a closed-loop pointing facility for the TVB1 antenna during on-station operations. A beacon signal transmitted from the ground in Italy will be processed onboard the satellite in such a way that information about the antenna boresight direction with respect to the beacon is continuously available. The loop will stabilise the radio-frequency boresight of the antenna with respect to the ground station to within 0.2°, irrespective of changes in orientation of the spacecraft body during station-keeping manoeuvres.

The 20/30 GHz Communications Payload (Selenia, I) has been designed in cooperation both with industrial contractors and an Ad Hoc Group of interested parties. This Ad Hoc Group, with members drawn from governments, telecommunications administrations, research institutes and industries in the ESA Member States (primarily those participating in the Olympus Programme), envisages a range of experiments, including:
- point-to-point video teleconferencing
- multi-point video teleconferencing
- tele-education
- data and video transmission.

Wideband transmission experiments using the full inherent bandwidth of the transponder (some 700 MHz) have also been proposed, and the necessary payload switching has been incorporated.

The payload includes two independently-steerable transmit/receive spot-beam antennas generating 0.6° nominal-coverage spot beams, two wideband receive chains, three transmit chains, and an arrangement of interconnecting switches and filters.

Testing

At the time the Olympus Programme was planned, it appeared that sufficiently large environmental test facilities would not be available soon enough for satellite-level testing to take place in Europe. The environmental and system test programme has therefore been conducted in the David Florida Laboratories of the Canadian Government in Ottawa, with the initial solar-simulation testing being carried out at Jet Propulsion Laboratory in Pasadena, California.

Figure 5. The Olympus flight-model spacecraft being unloaded from its Belfast transport aircraft at Ontario International Airport, Los Angeles, en route for JPL in Pasadena

This is the first time that final integration and testing of an ESA satellite have taken place outside Europe, and this posed some significant problems in terms of logistics and communications for both ESA and industry. To be able to support ongoing activities at short notice, ESA has maintained a small resident staff at the David Florida Laboratories since the spacecraft arrived there in mid-1987. This was augmented by additional engineering staff from ESTEC for specific reviews and meetings. British Aerospace, the prime contractor, has maintained a permanent staff in Ottawa of between 40 and 50 people during the same period.

Figure 5 shows the Olympus flight model in its shipping container being unloaded from a Belfast aircraft in the United States, en route from Europe to JPL in Pasadena. Figure 6 shows the satellite during later testing in the anechoic chamber at the David Florida Laboratories in Ottawa.

Earth stations

In general, earth stations will be provided by the user organisations, but several transportable units have been built for loan to experimenters as part of the Olympus development programme.

As part of the coordination activities proceeding under the auspices of the Olympus Propagation Experimenters Group (see ESA Bulletin No. 54), a great deal of thought has been given to the design of suitable beacon receivers for the propagation payload. This has resulted in a 'Handbook for Beacon Receiver Design', which has been endorsed by the Group as a whole and widely distributed. Most of the scientific establishments involved will at least partially construct their own receiving stations. Various industrial companies have, however, already designed Olympus reception stations that can be purchased either as a complete unit or in component form, depending on the wishes and resources of the experimenter concerned.

For the 12/14 GHz Specialised-Services Payload, ESA has procured two transportable earth stations, called Test and Demonstration Stations-4 (TDS-4), which can be used to access the payload from anywhere inside the coverage area. These stations, manufactured by British Aerospace, have antenna diameters of 3.5 m (Fig. 8). There are also a number of other ground stations available from PTT administrations which will be used, in particular, for SS-TDMA experiments with this payload.

For the Direct-Broadcast Payload, ESA has procured a 4 m-diameter, transportable earth station (TDS-5) from Selenia Spazio (I), which can be used to send television signals to either of the Olympus repeaters. This TDS-5 station (Fig. 9) will be available on a loan basis to broadcasters who wish to run pilot experiments to assess the benefits of direct television broadcasting in their region. The station's first application will be to uplink programmes and data from London on behalf of the BBC and groups of British distance-

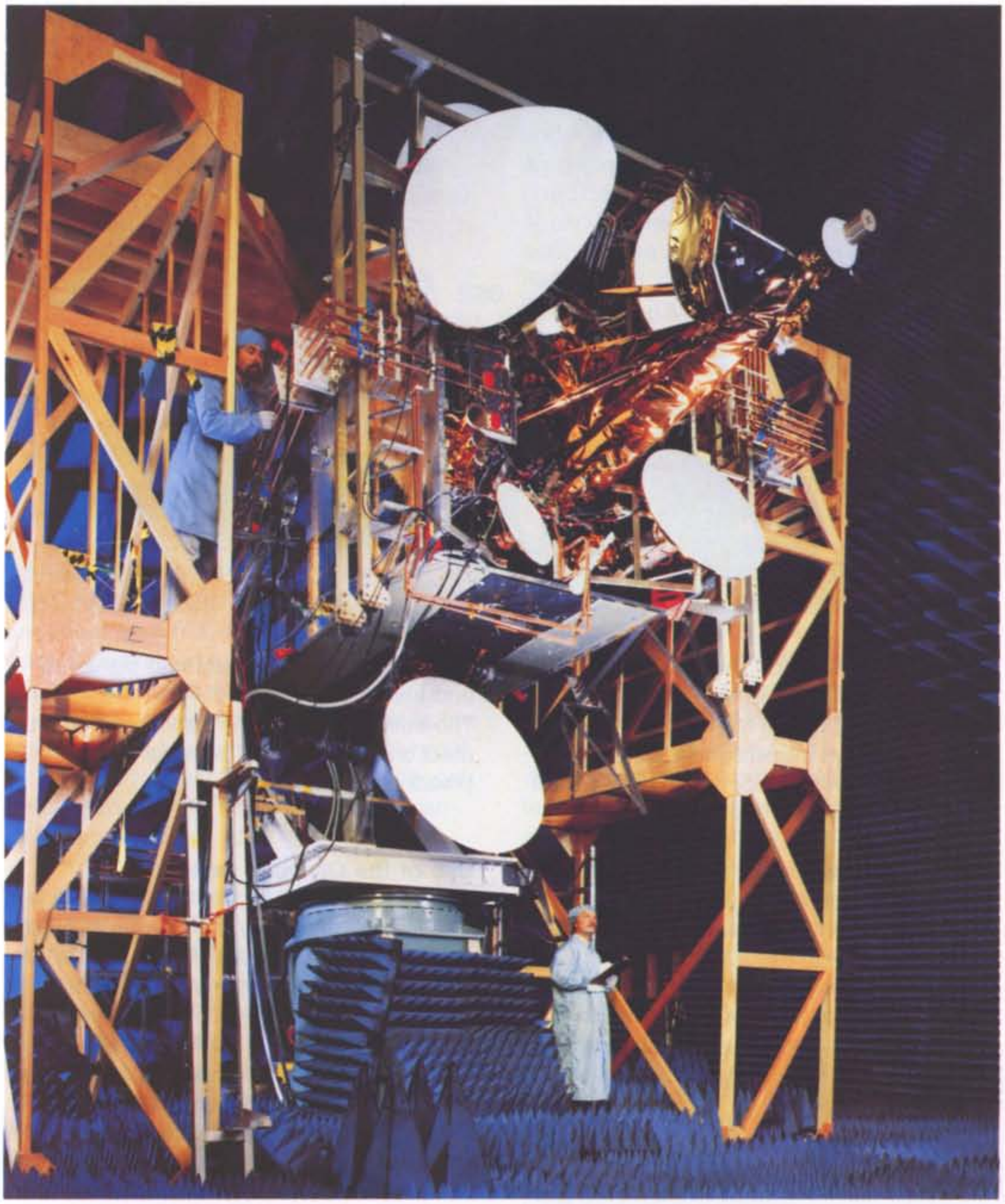

Figure 6. The Olympus satellite undergoing testing in the anechoic chamber at David Florida Laboratories in Ottawa, Canada

Figure 7. Test and checkout equipment being used for Olympus testing at David Florida Laboratories

Figure 8. The TDS-4 earth station
Transmit frequency band : 13—13.25 and 14—14.3 GHz
Receive frequency band : 12.5—12.75 GHz
Maximum EIRP : 73 dBW
Antenna diameter : 3.5 m
Transmit power : 2x250W
G/T : 25.5 dB (1/K)
Polarisation : Linear

learning organisations. The uplink station for the Italian channel, also being built by Selenia Spazio, will be located near Rome. A typical receive installation for Direct-Broadcast Satellite (DBS) reception will have an antenna diameter of 60 cm.

Earth stations are being built in Canada, the United Kingdom, Italy, Austria and The Netherlands for the various experiments to be performed with the 20/30 GHz Communications Payload. There are currently twelve stations of the 2 or 3 m-diameter transmit/receive class, plus numerous small stations for thin-route transmit/receive and receive-only applications. The Agency has itself procured three stations — TDS-6A, B and C (Fig.10) — which are land-, sea- and air-transportable, from Marconi (UK). They will be used initially for a business-communications experiment, but will also be employed later for the Eureca Inter-Orbit Communications Experiment. The latter will involve the relaying of data and signals to and from ESA's European Retrievable Carrier. The three TDS-6 ground stations will also be used on a time-shared basis for outside-broadcast experiments.

Use of the Olympus payloads

Approximately thirty scientific and technical establishments already plan to make use of the Olympus Propagation Payload. They are co-ordinated by the Olympus Propagation Experimenters Group (OPEX), chaired by Prof. G. Brussaard of the Technical University of Eindhoven (NL). The coordination work at ESTEC is in the hands of the Wave-Propagation Division. Particular ESA activities involve distribution of data collected, and analysis as well as publication of propagation-measuring station information. All the users are based in Europe, with the exception of one in Canada and one in the United States.

9

Figure 9. The TDS-5 earth station
Transmit frequency band : 17.3—18.1 GHz
Receive frequency band : 11.7—12.5 GHz
Maximum EIRP : 82 dBW
Antenna diameter: 4 m
Transmit power : 500 W
G/T : 24 dB (1/K)
Number of selectable channels : 40
Polarisation : Circular, RH and LH

10

Figure 10. The TDS-6 earth station antenna (photo courtesy of GEC Research, UK)
Transmit frequency band : 28—28.7 GHz
Receive frequency band : 18.85—19.55 GHz
Maximum EIRP : 77 dBW
Antenna diameter: 2.5 m
Transmit power : 2 x 350 W
G/T : 25.5 dB (1/K)
Polarisation : Linear

The work of OPEX is proceeding well. Four of the stations are already established to receive the beacon signals. Many others are currently being constructed, and it is anticipated that approximately twenty will be ready by the time Olympus starts operation. A Conference of all Olympus users was held in Vienna on 12—14 April 1989 at which several papers were presented by propagation experts who are members of OPEX.

There are twenty-seven separate organisations planning to use the Specialised-Services Payload on Olympus, thirteen of which are scheduled to use the satellite in its first nine months of operation. Applications that are international or European in nature are being coordinated with Eutelsat within the terms of the ESA/Eutelsat Agreement. Most of the users are drawn from PTT administrations, scientific establishments and technical universities which have the necessary facilities and resources to access the satellite. There is one Agency-initiated experiment, called 'Olympus for Africa', which will involve many additional small stations being located on the African Continent at a later date.

The Italian transponder of the Direct-Broadcast Payload is allocated to the RAI under the terms of an ESA/RAI Agreement, and they will schedule its use entirely. The European-beam transponder will be allocated to BBC Enterprises during the prime-time period of 17.00 h to 01.00 h GMT each day.

Much of the daytime usage of the European DBS channel will be allocated to transmissions from over 300 collaborating organisations who will demonstrate educational services. Thirty-eight of the fifty-two individual projects are led by universities and government agencies, and coordination of the transmissions into a suitable programme stream is currently being arranged.

There are approximately forty organisations planning to use the 30/20 GHz Communications Payload. Of these, thirteen have been scheduled provisionally to commence operations in the first year. The applications involve transmission tests, tele-education, satellite news gathering, video-conferencing and other related satellite-communication topics. The organisations involved include PTT administrations, private service providers, educational and scientific establishments.

As with the Specialised-Services Payload, international as opposed to national experiments within Europe are being coordinated in collaboration with Eutelsat under the terms of an ESA/Eutelsat Agreement for the Utilisation of Olympus' Fixed-Services Payload. There are two Agency-initiated experiments: the Direct Inter-establishment Communications Experiment (DICE), and the Cooperative Olympus Data Experiment (CODE). CODE in particular involves a further ten to twenty small-station users. There are also a number of users in Canada (co-ordinated by the Canadian Communications Research Centre), and one in the United States.

Clearly, the large number of Olympus users has made considerable overall coordination necessary, and this has been supplied by the Olympus Utilisation Board, a group chaired and manned by staff from ESA's Directorate of Telecommunications. The day-to-day running of the programme is the responsibility of the Olympus Payload Utilisation Secretariat (OPUS), which deals directly with users and potential users in terms of provision of information, applications, approvals and scheduling.

Further Reading

Other articles on the Olympus Programme that have appeared in earlier editions of the ESA Bulletin include:

Bulletin 50, May 1987
The Olympus Utilisation Programme, C.D. Hughes and P. Bartholomé.

Bulletin 54, May 1988
The Olympus Propagation Experiment OPEX — A Unique Example of European Cooperation, G. Brussaard.

Bulletin 56, November 1988
The ESA Olympus Satellite and Distance-Learning in Europe — An Opportunity for Educators, J. Chaplin.

Bulletin 57, February 1989
High-Definition Television Broadcasting via Satellite, G. Mica.

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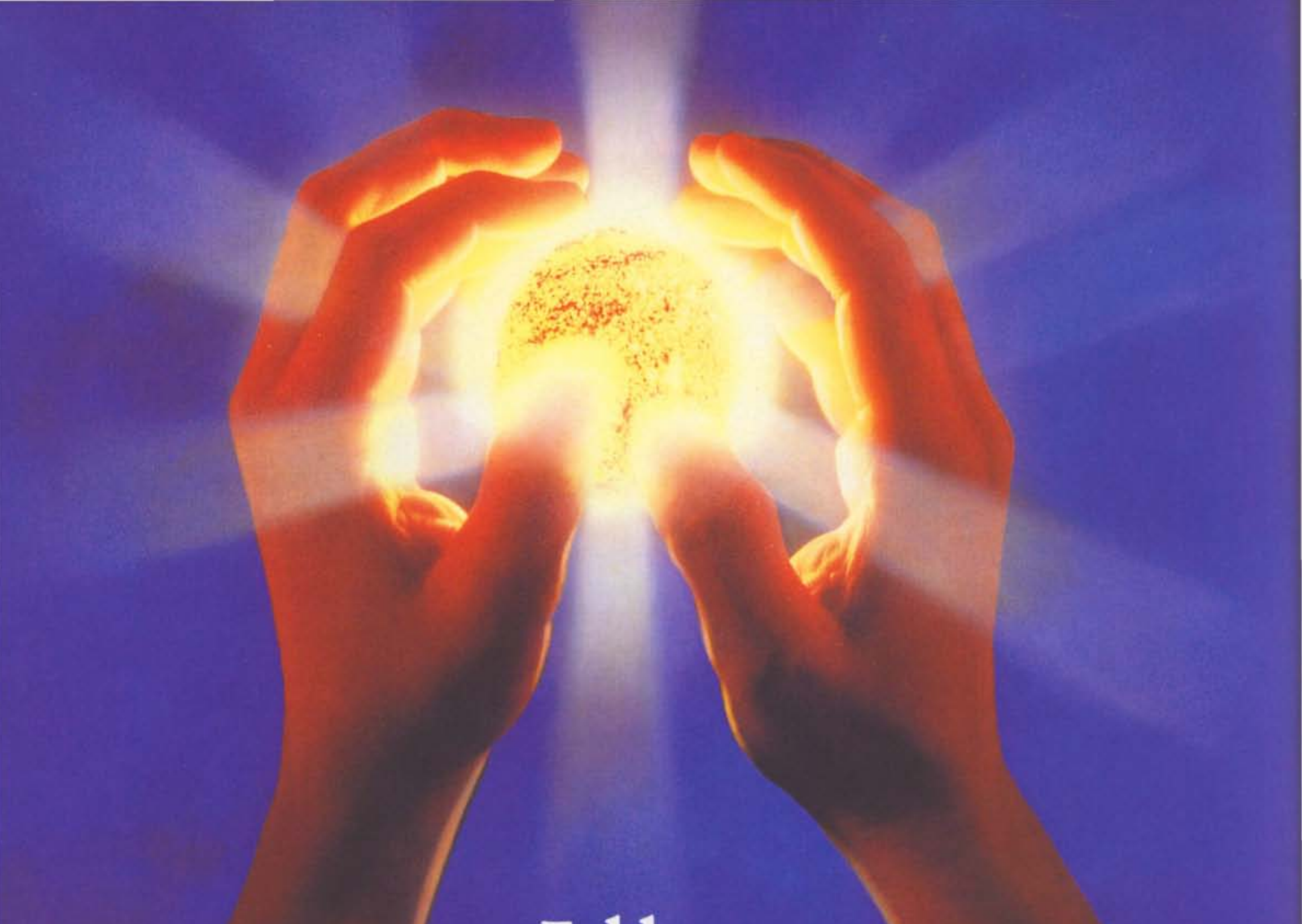

The demands made on individual
electronic systems and their com-
ponents increase with the degree
of complexity of satellites and
space transport systems. Cable
systems are no exception. During
ascent and while in orbit, they are
subjected to extraordinary stress,
such as the extreme mechanical
oad during lift-off, outgassing pro-
cesses while entering the vacuum
and continual bombardment by
ultraviolet and hard gamma radia-
ion during the entire operation
ime. Successful cable systems
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are called corona. Until now, the
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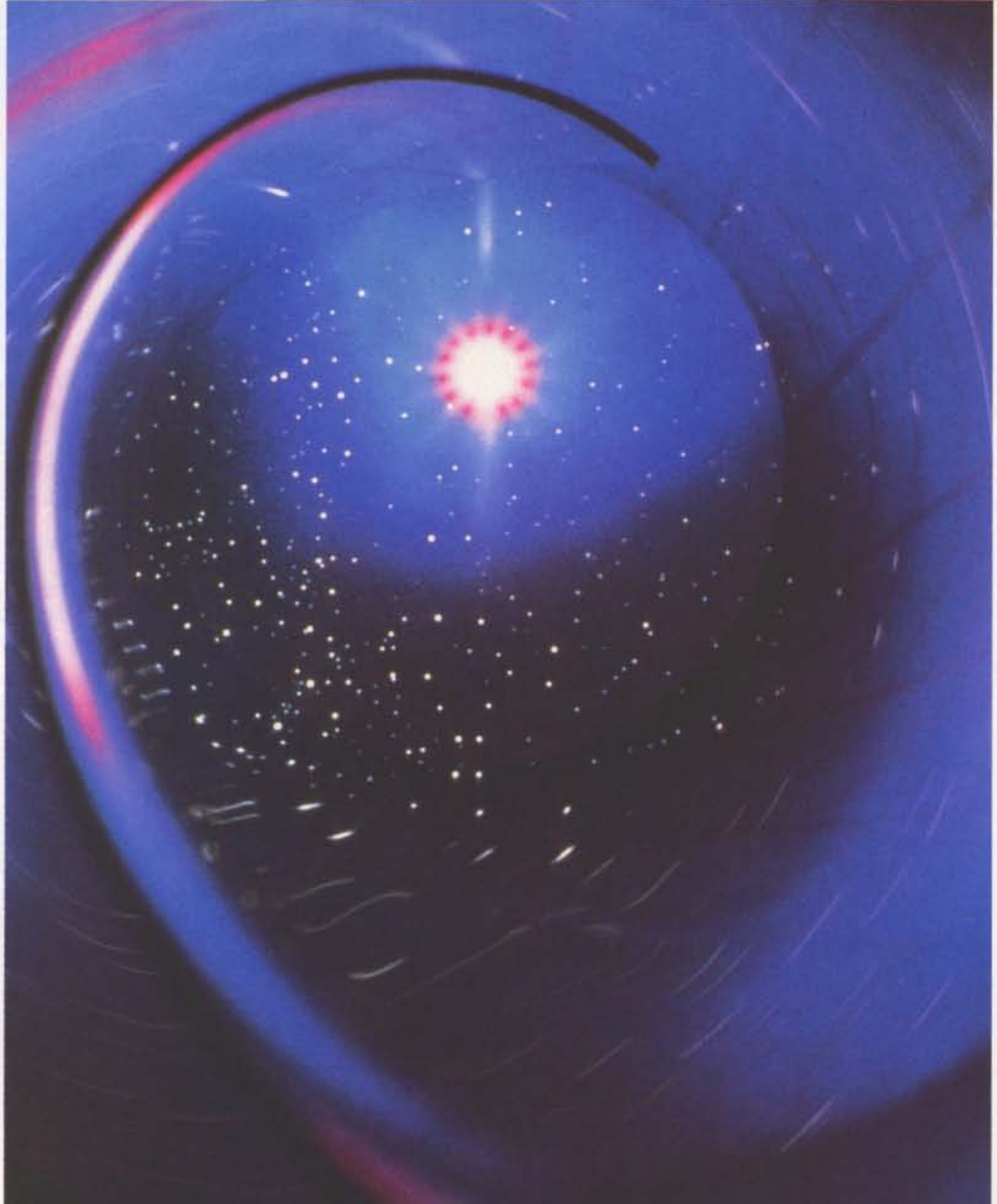

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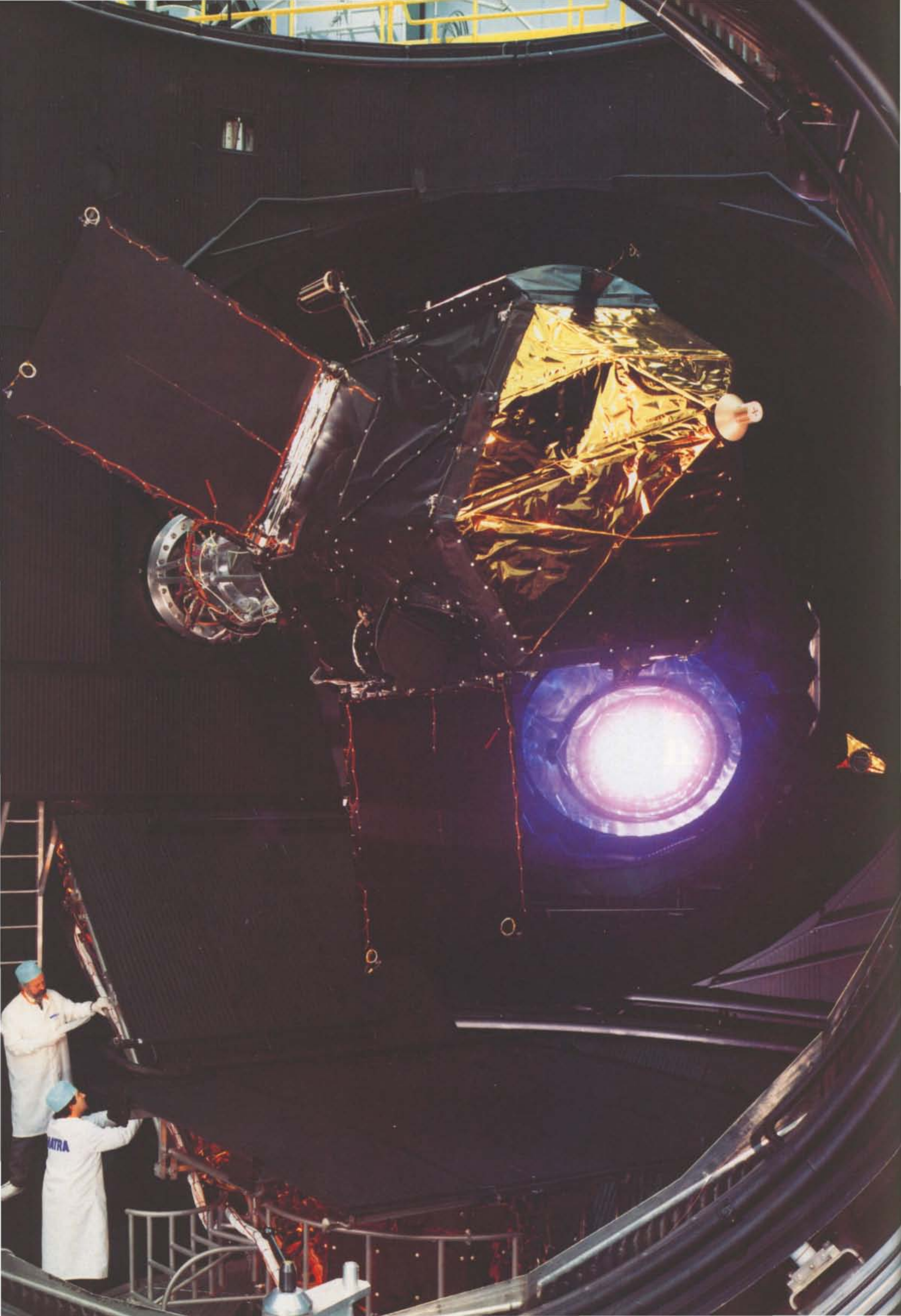
High Voltage Cable Constructions for Space Technology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The Hipparcos Project

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The accuracy achievable in measuring the positions of stars from the ground is limited by numerous observational difficulties. The most important of these involve the effects of an inhomogeneous and fluctuating Earth atmosphere, instrument flexure, and the inability to observe all parts of the celestial sphere simultaneously from any single observing location. There are, nevertheless, important astronomical and astrophysical reasons why more precise stellar positional measurements are urgently needed.

A dramatic and long-awaited improvement in the observational situation was heralded when, at the request of the scientific community, and following an internal feasibility study supported by its Member-State scientists, ESA decided to undertake the Hipparcos space mission. This spacecraft, scheduled for launch on an Ariane-4 in July 1989, is dedicated to measuring the precise positions of some 120 000 stars.

The final outcome of the mission will be a catalogue of star positions, parallaxes and proper motions, along with photometric and other data on the stars observed. This catalogue, of unprecedented precision, should be available to the scientific community in the course of 1995.

Historical context

While the Earth was assumed to be spherical by the Pythagorian School as early as the sixth century BC, and Aristotle in De Caelo (around 340 BC) presented various evidence to support this idea, it was not until about 240 BC that Eratosthenes made one of the first scientific estimates of the Earth's size. While the principle of the measurement of the distance between the Earth and the Moon had already been described by Aristarchus of Samos around 250 BC, it was about 120 BC before Hipparchus first calculated this distance by measuring the Moon's parallax.

A comparison of Hipparchus' star catalogue of 1080 stars with the work of his predecessors led to the discovery of the precession of the equinoxes and the eccentricity of the Sun's path. All of this was achieved by measurements with the naked eye, the resolving power of which is limited to about one minute of arc (although these early observations were rarely accurate to better than about 30 minutes of arc, due to the primitive instruments used).

As with other branches of science, astrometry made little advance during the millenium of the 'Middle Ages', in which western civilisation remained with the concept of a Universe with the Earth at its centre. But the awakening of man's scientific curiosity at the time of the Reformation led to revised interest in astrometry.

Copernicus propounded the heliocentric concept, and Tycho Brahe, using his brass azimuth quadrant and many other new instruments, carried out a long series of observations during the second half of the sixteenth century. These observations were to provide the basis for Kepler's laws of planetary motion.

By 1609 Galileo had invented the optical telescope, and this landmark was to be of particular significance for astrometry. The angular error in astrometric measurements fell to about 15 seconds of arc by 1700, and to about 8 seconds of arc by 1725. This made it possible to detect stellar aberration (small positional displacements due to the vectorial composition of the velocity of light to the Earth's orbital velocity) and nutation (an 18.6 year wobble in the Earth's spin axis produced by the gravitational influences of the Sun and the Moon).

Approximately eighteen hundred years after Hipparchus, Edmund Halley set about remeasuring the rate of precession by comparing contemporary observations with those that Hipparchus and others had made. While most of the stars displayed a general drift amounting to a precession of about 50 seconds of arc per year, Halley announced in 1718 that three stars, Aldebaran, Sirius and

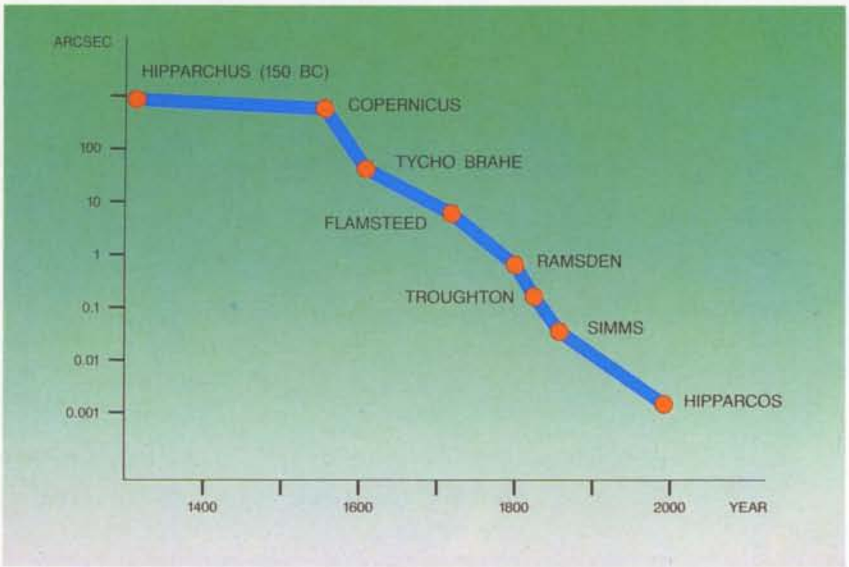


Figure 1. Improvement in the observational error in astrometric measurements of stellar positions as a function of time

Arcturus, were displaced from their expected positions by large fractions of a degree. Halley deduced that each of these stars had its own 'proper motion'.

The precision of astronomical observations improved again during the 18th century (Fig. 1), revealing the motions of many more stars, and in 1783 William Herschel found that he could partly explain these motions by assuming that the Sun itself was moving. This suggested that some stars might be relatively close to the Sun, and so astronomers intensified their efforts to detect 'trigonometric parallax', the apparent oscillation in a star's position arising from the Earth's annual motion around the Sun.

Friedrich Bessel was the first to publish a parallax value, following his studies of the motion of 61 Cygni. Thomas Henderson is credited with the first measurement of stellar parallax, that of the bright star Alpha Centauri, from observations made at the Cape of Good Hope in 1832-33, although he did not analyse the measurements for some years. The two components of this star, together with a faint companion called Proxima Centauri, form the nearest known group of stars to the Sun, at a distance of a little more than 4 light years (1 light year being 9.5 x 10^{12} km). Wilhelm Struve measured the parallax of Vega in 1837-38.

The invention of the photographic camera gave astrometry yet another new tool, and since the early part of this century astronomers have determined trigonometric parallaxes photographically at more than a dozen observatories. The technique is to measure the shift of the selected star relative to a few stars surrounding it on some 20 or more plates taken over a number of years. Several thousand such trigonometric parallaxes have now been measured; however, even now only a few hundred are known with an accuracy of better than about 20 %. The launch of the Hipparcos mission (Fig. 2) will revolutionise this long, difficult and very important task.

The scientific role of Hipparcos

Optical astrometry today may be summarised as having two main scientific objectives:

(a) that of providing a non-rotating stellar reference frame to which the motions of objects in the Solar System and stars in the Galaxy may be referred, and which can be used as a reference framework for relating optical observations to those in other regions of the electromagnetic spectrum;

Figure 2. Artist's impression of the Hipparcos satellite. The solar panels, pointing towards the Sun, the apogee boost motor, the antennas linking the satellite to the control centre on Earth, and the entrance apertures of the telescope are all visible

(b) that of providing, through the use of such a framework, basic observational data for the studies of stellar luminosities, the spatial distribution of stars within the Galaxy, and their motions.

The position of an object in space may be described by its direction with respect to some coordinate system (direction cosines), its heliocentric distance, and the rates of change of these quantities with time. Relative angular measurements made from astronomical observatories at two well-separated epochs yield, in principle, the direction cosines and their time dependence. Combined with the knowledge of the distance to the star, this angular movement, or 'proper motion', can be converted into a velocity projected onto the celestial sphere. A sequence of observations of a given object with respect to distant background stars, as the Earth travels in its annual orbit around the Sun, furthermore yields the distance to the object through the determination of its parallax (Fig. 3).

The space motion of an object in the radial direction, or radial velocity, is most conveniently determined by measuring its Doppler shift, and this quantity is normally omitted from the set of five remaining 'astrometric parameters': two positional coordinates, the rate of change of these coordinates with time (or the proper motion), and the parallax (inversely proportional to the object's distance).

Fundamental though these quantities are, the angles involved are extremely small (typically parallaxes and annual proper motions are measured in milliarcsec), and the measurements required to quantify them must be extremely precise. Conditions experienced from ground-based astronomical observatories, such as the perturbing atmosphere, lack of all-sky visibility, and gravitational and thermal flexure of telescopes, complicate the measurement and the separability of the positional and time-dependent parameters. They have also tended, in recent years, to result in a limit beyond which progress has proved technologically complex and observationally time-consuming.

Just as the scientific objectives of optical astrometry may conveniently be separated into discussions of the reference frame, and of the physical interpretation of the parallaxes and proper motions, so ground-based measurement techniques have evolved into two broad categories: large-angle and small-angle techniques. The current strategy adopted for reference frame construction, for example, is based on large-angle techniques, in which a fundamental frame based on meridian observations of a few thousand bright (*m* less than 8 mag) stars, is supplemented by meridian observations of additional reference stars reduced differentially with respect to the fundamental stars, and further interpolated by means of photographic surveys. Photographic parallax determinations, by contrast, are derived by small-angle (differential) measurement techniques.

Resulting positional catalogues generally fall into the category of small but precise catalogues, such as the FK5 Catalogue of a

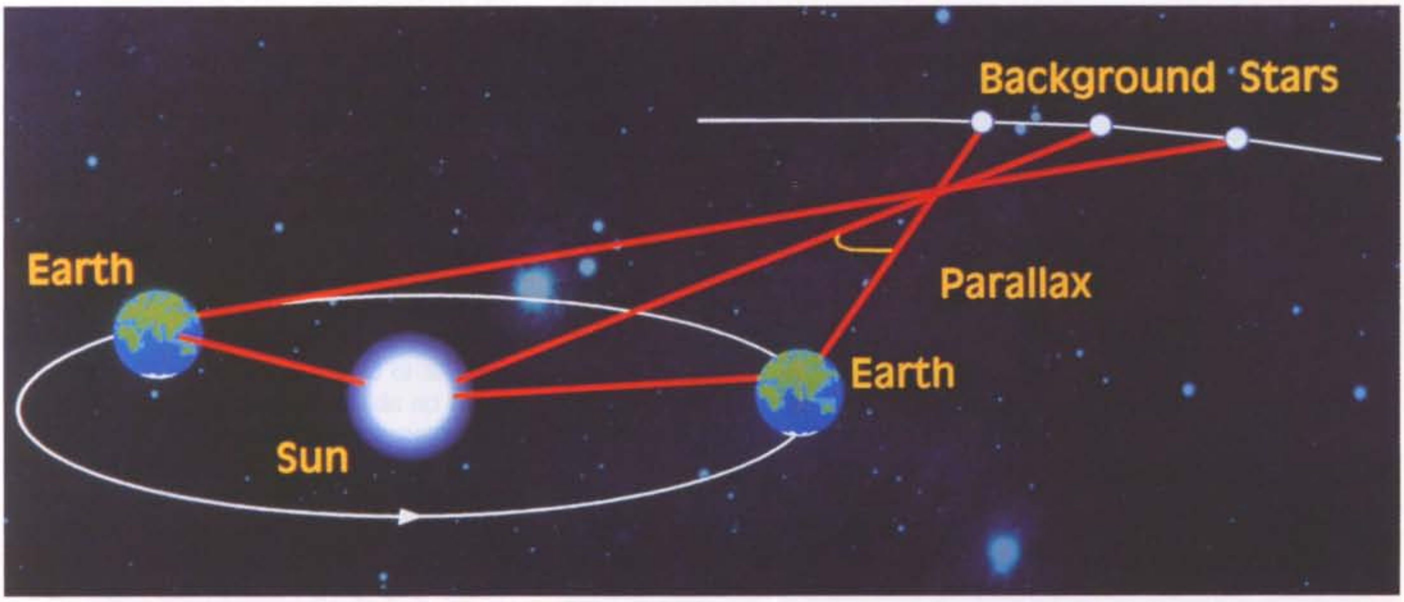


Figure 3. Parallax, and the principles of parallax measurements. As the Earth moves in its yearly orbit around the Sun, the movement of the observer results in an elliptical component of the apparent motion of the nearby stars, which can therefore be distinguished from the star's proper motion

few thousand stars with mean positional error at the catalogue central epoch (1949 in the case of FK5) of 0.019 arcsec, or large but less precise catalogues, an extreme example being the soon-to-be-completed Hubble Space Telescope (HST) Guide Star Catalogue of some 20 million objects with external coordinate errors in the range of 1–2 arcsec.

A complete separability of the goals and measurement techniques is, however, neither technically possible nor scientifically desirable: the accuracy of the reference frame deteriorates with time, due to the errors in the determinations of the individual space motions, and small-scale angular measurements typically give relative rather than absolute parallaxes. In consequence, a discussion of the errors on parallaxes or proper motions is complicated by the effects of external errors on the reference system to which such measurements are related. The important point to stress is that, while the latter techniques may also reach positional accuracies of a few milliarcsec, such measurements are generally local, while the Hipparcos measurements will span the whole sky.

What makes the Hipparcos mission unique, and the expected results so dramatic, is the all-sky visibility of the satellite, the absence of a perturbing atmosphere, and the instrumental stability brought about by the absence of gravitational instrument flexure, together with the provision of a stable thermal environment. Differential angular measurements are made over large angles, at many different orientations, and at many different epochs. The parallaxes will consequently be absolute, and regional or systematic errors in positions and annual proper motions are expected to be well below the milliarcsec level.

The main mission goals are summarised in Table 1.

The evolution of the Hipparcos project

Over the past one hundred years or so, observational uncertainties in astrometric measurements have been reduced by an order of magnitude due to instrument refinements. However, further rapid progress on the ground has been considered unlikely since the most significant uncertainties remaining are caused by the Earth's atmosphere. Averaging out the dominant effects of atmospheric turbulence has proved to be relatively efficient, but comparisons between results from different observatories still show systematic differences due to slowly varying refraction effects which cannot be studied accurately and cannot, therefore, be reduced with confidence. In the 1960s some astronomers considered that the best prospect for making major advances in this field was to go into space — beyond the atmosphere.

A preliminary proposal for a space astrometry mission was submitted by P. Lacroute to the Centre National de la Recherche Scientifique (CNRS) in France in March 1966. The proposal made was to build up a reference system using about 700 stars brighter than 7 mag, with relative positions known to better than about 0.01 arcsec.

In August 1967, a new version of the project was presented in Prague at the Congress of the International Astronomical Union. A revision of this proposal was then presented to the Centre National d'Etudes Spatiales (CNES) in France in November 1967. Some funds were subsequently made available by CNES for optical calculations, and for the trial manufacture of a 'beam-combining mirror' in 1969. It proved to be impossible, however, to construct such a mirror that would be able to resist the vibrations encountered during a launch.

In August 1970 a paper was presented at the International Astronomical Union's Congress in Brighton on the subject of astrometric measurements from space. New ideas were introduced, but featuring the same kind of characteristics, at the Astrometry Symposium in Perth in 1973. A description of the mission was presented at a meeting of the ESRO

Table 1 – Summary of expected results

Main Experiment	
Number of stars	120 000
Limiting magnitude	V = 12.4 mag
Completeness	7.3 – 9.0 mag*
Positional accuracy	0.002 arcsec (B = 9 mag)
Parallax accuracy	0.002 arcsec (B = 9 mag)
Proper-motion accuracy	0.002 arcsec per year (B = 9 mag)
Systematic errors	< 0.001 arcsec
Tycho Experiment	
Number of stars	> 400 000
Limiting magnitude	B = 10 – 11 mag
Positional accuracy	0.03 arcsec (B = 10 mag)
Photometric accuracy	0.05 mag in B and V
Observations per star	~ 100

* Depending on galactic latitude and spectral type.

Astronomy Working Group in Frascati in 1973. The Working Group selected thirteen projects that merited further consideration.

This was followed by a 'Space Astrometry' symposium organised by ESRO, soon to become ESA, in October 1974 in Frascati. The goal of this symposium was to assess the support for these ideas among astronomers.

A mission-definition study was subsequently carried out by a group of European astronomers with the support of ESA personnel. This study was able to define a mission with more emphasis on the astrophysical aspects of an astrometry satellite, because new technical ideas made it possible to observe a larger number of stars, and also faint ones, with a higher precision than previously, even with the use of a smaller telescope aperture.

The preferred mission was a dedicated astrometric satellite with a lifetime of three years during which the positions, parallaxes and annual proper motions of about 100 000 selected stars would be obtained to approximately 0.002 arcsec accuracy.

The study results were presented at an International Colloquium on Space Astrometry held at Copenhagen University in June 1976. Shortly afterwards, ESA approved a feasibility study of the project.

The mathematical problem of deriving the astrometric data from one-dimensional measurements of the sky by a scanning satellite was subsequently studied, and the problem was demonstrated to be solvable.

When the feasibility study started in February 1977, ESA had just decided that the Ariane launcher should be used for future missions. This opened the way for a heavier payload and a geostationary orbit. These new possibilities were exploited by the science team and the previous concept of a near-Earth spacecraft in polar Sun-synchronous orbit was abandoned. Consequently, active attitude stabilisation had to replace the older ideas of passive stabilisation by the gradient of the Earth's gravity field, since the gravitational stabilising force is too small at the geostationary distance from Earth.

The proposed active attitude control was based on the use of reaction wheels in the spacecraft, although the small disturbances (or 'attitude jitter') from the mechanical bearings might have jeopardised the astrometric mission aiming at angular measurements in the range of 2 milliarcsec. In fact, the studies were never able to supply reliable estimates of the attitude jitter before the attitude control by cold-gas jets was introduced by the satellite prime contractor in 1982. This control provides the same very smooth attitude motion between each jet firing as the passive stabilisation would have given. The smooth motion can be used to improve the precision for bright stars by 'dynamical smoothing'.

Between June 1978 and February 1980, a large promotional campaign was conducted

throughout Europe in favour of Hipparcos. An early and informal call for stars to be included in the observing programme, in an attempt to judge the scientific interest in the project, solicited about 170 research proposals, drawn up by 125 astronomers from 12 countries. Interest was generated in numerous scientific institutes and laboratories concerning the hardware and software aspects of the mission. As a result, the project received increasing attention from the members of ESA's Science Programme Committee.

The dialogue with the international scientific community was continued at specialised meetings: at the Congresses of the International Astronomical Union in Grenoble in 1976 and in Montreal in 1979, and at the Colloquium on European Satellite Astrometry in Padua, Italy in 1978. Coordination with ground-based astrophysical observations of the stars to be selected for Hipparcos was emphasised at these meetings, and so was coordination with the planned space astrometry from the Hubble Space Telescope.

Technical studies by ESA and outside contractors were continued and members of the ESA science team investigated the data-reduction aspects, leading up to the adoption of the project by ESA in March 1980. The detailed design study was completed in December 1983, and the hardware development phase began early in 1984.

Many of the astronomers and other scientists involved in the early assessment studies have continued their involvement with the mission, both through the ESA advisory teams, and through the setting up, in 1982, of the consortia who have assumed responsibility for the scientific aspects of this project.

A late enhancement to the project, which emerged during the detailed design study, was the addition of the two star-mapper channels that led to the Tycho experiment.

Satellite description

The payload, the primary characteristics of which are listed in Table 2, is centred around an optical all-reflective Schmidt telescope (Fig. 4). A novel feature of the telescope is the 'beam-combining' mirror, which brings the light from the two 0.9° x 0.9° fields of

Table 2 – Payload and satellite characteristics

Optics	
Telescope configuration	All-reflective Schmidt
Field of view	0.9° × 0.9°
Separation between fields	58°
Diameter of primary mirror	290 mm
Mirror surface accuracy	λ/60 rms
Primary Detection System	
Modulating grid	2688 slits
Slit period	1.2 arcsec (8.2 μm)
Detector	Image dissector tube
Photocathode	S20
Sensitive field of view	38 arcsec diameter
Spectral range	375 – 750 nm
Sampling frequency	1200 Hz
Star Mapper (Tycho) System	
Modulating grid	Four perpendicular to scan Four at ±45° inclination
Detectors	Photomultiplier tubes
Photocathode	Bi-alkali
Spectral range (B)	λ_{eff} = 430 nm, Δλ = 90 nm
Spectral range (V)	λ_{eff} = 530 nm, Δλ = 100 nm
Sampling period	600 Hz
Satellite Parameters	
Launch mass	1140 kg
Power requirements	295 W
Uplink data rate	2 kbit/s
Downlink data rate	24 kbit/s
Satellite orbit	Geostationary
Inclination to Sun	43°
Spin rate	168 arcsec/s

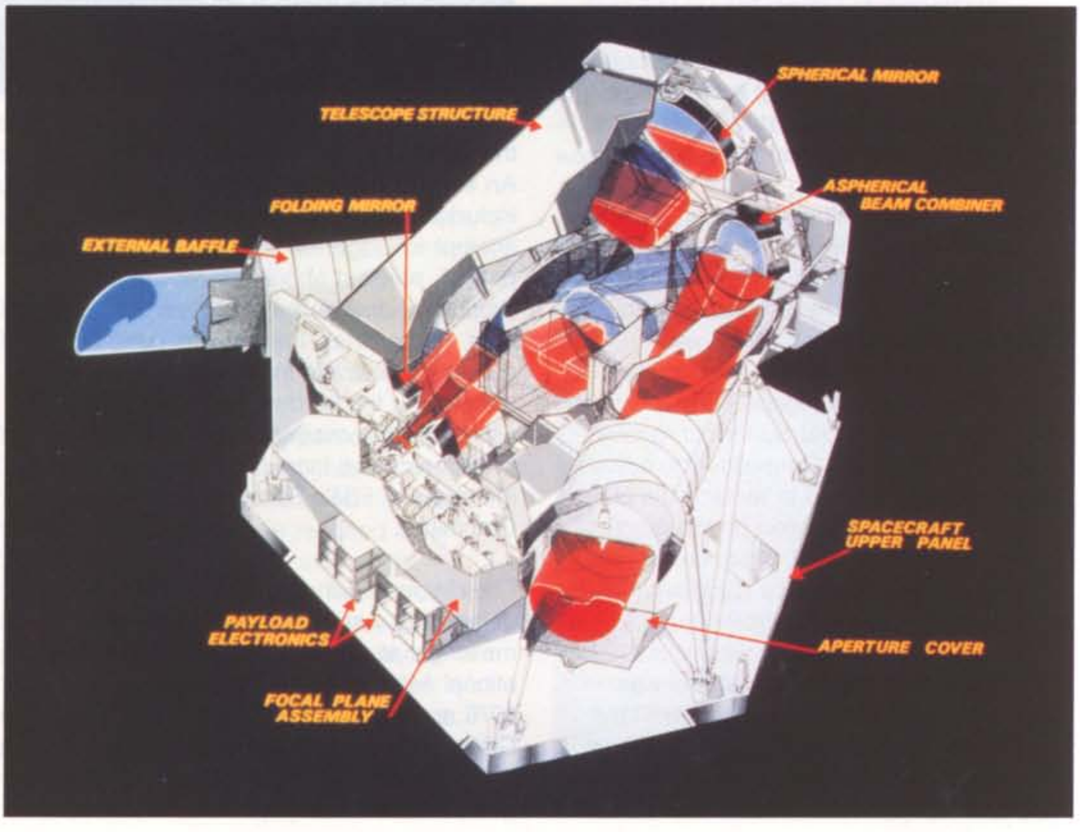


Figure 4. The key features of the Hipparcos payload. Light from the stars visible in two distinct fields of view (shown in red and blue in the figure) enters the telescope through the external baffles and is brought together by the beam combiner, which takes the light from the two fields of view and superimposes it on the spherical mirror. This light is then focussed onto a regular grid at the focal surface of the telescope, which modulates the light signal from the stars

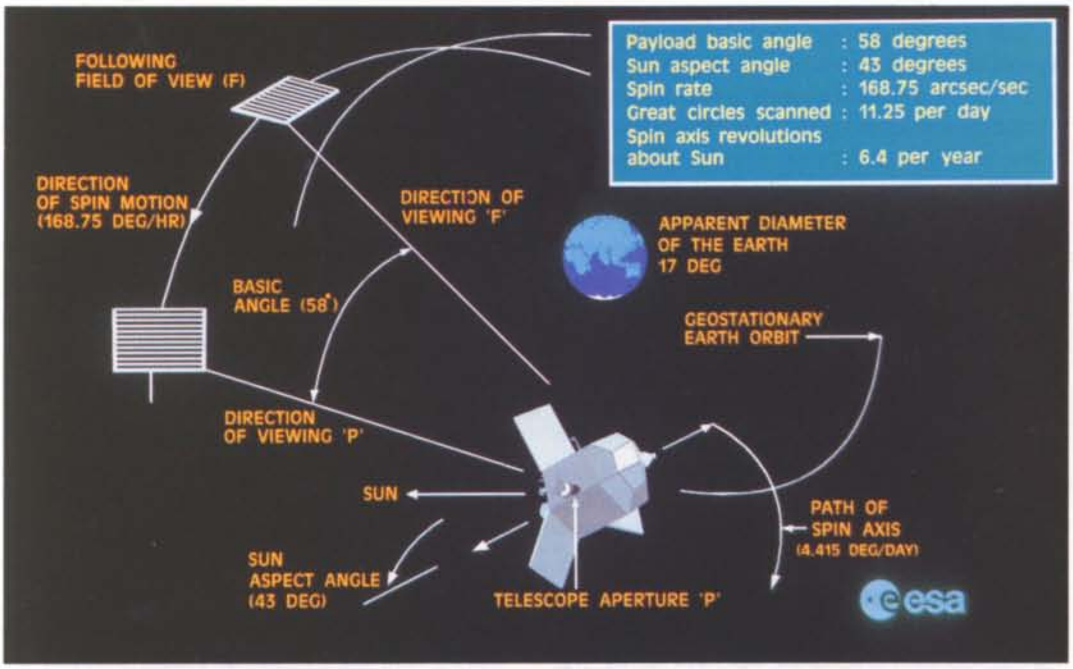


Figure 5. The scanning principle of the Hipparcos satellite. As the satellite sweeps out a great circle across the sky, stars continually enter and leave the telescope's fields of view

view, separated by about 58°, to a common focal surface, thereby allowing both large- and small-field measurements to be conducted simultaneously. The satellite will sweep out great circles over the celestial sphere (Fig. 5), and the star images from the two fields of view are modulated by a highly regular grid of 2688 opaque and transparent parallel slits located at the focal surface and covering an area of 2.5 x 2.5 cm^2. The construction of the aspheric asymmetric beam-combining mirror and of the highly accurate modulating grid (by electron beam lithography) were key technical challenges to be overcome during the payload's development.

The satellite is designed to spin slowly, completing a single rotation in just over 2 h. At the same time it can be controlled such that there is a slow change in the direction of the axis of rotation. This will allow the telescope to scan the complete celestial sphere several times during its 2.5-yr mission. As the telescope scans the sky, the star's light will be modulated by the slit system, and this modulated light will be sampled by an image dissector tube detector, at a frequency of 1200 Hz. At any one time, some four or five of the selected (or programme) stars will be present in the combined fields of view. The detector has a small sensitive area which covers a field about 38 arcsec in diameter (projected on the sky). The detector can only follow the path of one star at a time, but can be switched, under rapid computer control, to all the programme stars for short intervals of time during their passage across the field, which takes about 20 s.

The telescope will continually compare the relative positions of the programme stars, which will appear in successive fields of view due to the satellite's rotation. In this way, several comparisons with different stars can be made. As the scans will also overlap 'sideways' as the satellite's axis of rotation changes on each sweep of the sky, the stars will appear again, but this time compared with other stars. In this way, a dense net of measurements of the relative angular separations of all of the stars will be progressively built up.

In addition to the main instrument, the payload includes two star mappers (one redundant), the function of which is to provide data allowing both real-time satellite attitude determination (a task performed onboard the satellite), and a posteriori attitude reconstruction (a task carried out on the ground). The star mapper data is also to be used by the Tycho experiment to perform astrometric and two-colour photometric measurements on about 400 000 stars, down to about 10-11 mag.

Each star mapper consists of an aperiodic modulating grid located at the sides of the primary modulating grid, and two photo-multipliers measuring the light transmitted by the complete star-mapper grid in two different spectral bands (roughly corresponding to the Johnson blue and visual bands). The spectral separation (Table 2) is performed by means of a dichroic beam splitter. Each star mapper consists of two sets of four slits, each set being at a different inclination with respect to the scanning direction, so that the satellite's attitude can be derived from the detector signals as the star images move across the grid. The modulated light signal is converted into photon counts by the two photomultiplier tubes, which are sampled at a frequency of 600 Hz.

From the digitised photon counts from the main detector sent to the ground, along with relevant attitude information from the satellite's star mappers and other housekeeping data, the relative phases of the star images present within the combined field of view can be derived. The data processing will be carried out on the ground and will lead, after a full analysis of the data collected during the mission lifetime (nominally 2.5 yr), to the final catalogue of star positions, parallaxes and proper motions.

Figure 6 shows the Hipparcos satellite during integration and testing.

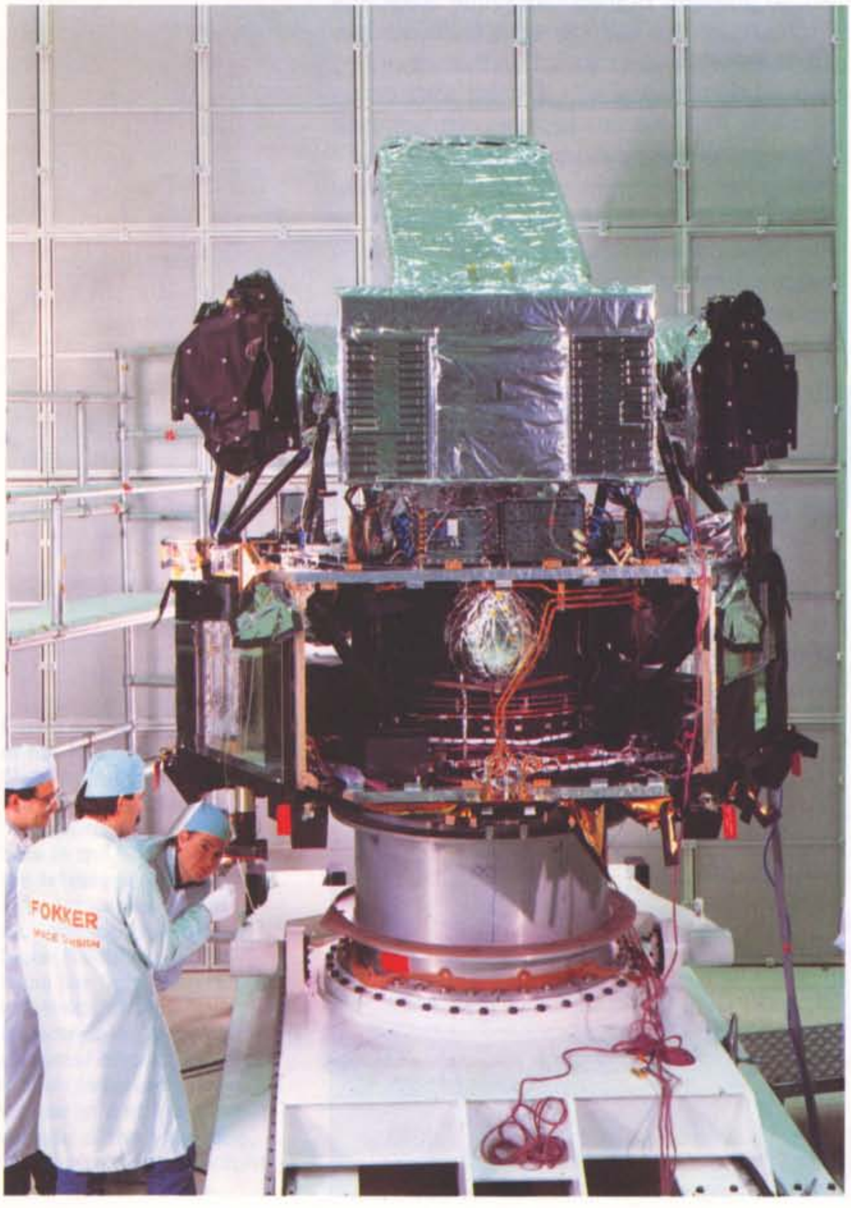


Figure 6. The Hipparcos satellite under test at ESTEC in Noordwijk (Nl)

Technical and scientific involvement in Hipparcos

ESA has taken overall responsibility for the satellite's design and hardware manufacture, which was contracted out to a European industrial consortium with Matra (F) as industrial prime contractor, and with Aeritalia (I) responsible for procurement of the spacecraft, as well as for the integration and testing of the complete satellite. Industrial responsibility at system level covered management, engineering and assembly, as well as integration and testing of the complete satellite. This responsibility was shared by eleven European companies, with some thirty-five European firms and a total of about 1800 individuals participating at all levels.

European scientific teams, who have worked closely with ESA since the project's approval in 1980, have undertaken the scientific tasks necessary for the successful completion of the project as a whole. This has included advising the Agency on detailed scientific considerations relating to the payload's design and development, and operational and calibration aspects both before and after launch. While the scientific-advisory-role approach that has been so essential to the successful design of the mission concept is one shared by all ESA scientific missions, the scientific participation in the Hipparcos project has been especially fundamental due to the setting up of four autonomous scientific consortia.

One aspect of this scientific involvement has been the preparation of the Hipparcos Input Catalogue by a consortium of institutes known as the Input Catalogue Consortium. This Consortium was selected by ESA on the basis of responses to an Announcement of Opportunity issued in 1981. The Consortium was subsequently entrusted with the task of defining, on the basis of scientific merit and satellite operational requirements, the unique list of stars that will be observed by the Hipparcos satellite. (Such a concise description of the Consortium's tasks does not do justice to the enormous effort and considerable scientific and administrative complexity which has been involved in the construction of the Input Catalogue).

The complete reduction of data from the satellite, from some 10^{12} bits of photon counts and ancillary data to a catalogue of astrometric parameters and magnitudes for the 120 000 programme stars, is a complex and substantial task. It is being undertaken independently by two scientific consortia, the

Northern Data Analysis Consortium (NDAC) and the Fundamental Astronomy by Space Techniques (FAST) Consortium. Both Consortia were also selected on the basis of responses to an Announcement of Opportunity issued by ESA in 1981. The selection of two parallel data-reduction teams was motivated by the size and complexity of the reductions, and has been adopted in an attempt to ensure the validity of the results. The end product will be a single, agreed-upon catalogue.

The star-mapper photon records contain extremely valuable photometric and astrometric information for hundreds of thousands of stars. The Tycho Data Analysis Consortium (TDAC) was set up to analyse the star-mapper data stream, and the processing of these largely serendipitous data will greatly enhance the scientific return from the mission.

The close collaboration between the Agency and the scientific teams has led to a satellite design that fully reflects the scientific requirements. The activities of all of the participating scientific institutes are funded by national agencies, universities, and private foundations. Nearly 200 scientists are involved in the work of the four scientific consortia.

The data reductions

The satellite will produce some 24 000 bits of data per second, mostly image dissector tube data and two-colour data from the star mapper. Approximately 10^{12} bits of data will therefore be generated during the satellite's lifetime of 2.5 yr, corresponding to the measurement of some 150 x 10^{6} grid coordinates. In the reduction process, some 10^{6} attitude unknowns and some 20 000 instrument unknowns (essentially the time-, position-, and colour-dependent coefficients representing the geometrical properties of the measurement system) are either to be eliminated or solved for.

The problem is essentially one of solving a very large and sparse set of normal equations with a large number of unknowns. Whilst being too substantial to be treated in any direct manner, the problem lends itself to linear decomposition by the formation of certain intermediate quantities — the star abscissae along the great circles swept out by the scanning motion of the satellite. While more rigorous solutions to the problem of the attitude and sphere reconstruction are still being studied, both data-reduction consortia have adopted a three-step approach as their baseline (see accompanying box for details).

Main Steps in the Hipparcos Data Reductions

Step 1:

The image dissector tube photon counts are extracted from the data stream, and fitted to a star intensity model of the general form

$$I = B + I_0 (1 + M_1 \cos(\omega t + \psi_1) + M_2 \cos(2\omega t + \psi_2))$$

where B is the background, I_0 the unmodulated star intensity, ω the satellite spin rate, M_1 and M_2 the first and second harmonic instrument modulation coefficients, and ψ_1 and ψ_2 the unknown signal phases. The phases are treated in data segments corresponding to a 'reference great circle', of about 12 h duration, which is selected with the celestial pole close to the mean position of the instrument's spin axis over this period. The star abscissae, the along-scan attitude parameters, and a set of instrument parameters describing the geometric transformation between the celestial sphere and the measurement system, are solved independently for each reference great circle by a least-squares process (Fig. 7).

Step 2:

The resulting star abscissae for a 'well-behaved' subset of some 40 000 of the programme stars are combined in a subsequent least-squares process, referred to as the sphere reconstitution, which brings together all the different reference great circles into a single global system. In this step, the abscissae are used as observations, and the astrometric parameters of the same stars, along with a single abscissa zero point for each reference great circle, as unknowns. The astrometric parameters are eliminated, and the remaining system of normal equations is solved for the abscissae zero points (Fig. 8).

Step 3:

Relative abscissae determined in Step 1 are converted into absolute abscissae, by adjustment to the origin of the reference great-circle systems determined in Step 2. Finally, the astrometric parameters of each star are determined by a least-squares combination of its abscissae on different reference great circles.

This three-step decomposition yields a tractable data reduction problem: Step 1 requires the solution of rather sparse normal equations with about 2000 unknowns, and these will be solved by direct-solution methods based on Cholesky factorisation of the normal equations. Some 2000 such reference great circles will be generated over the 2.5 yr mission. Step 2 produces a very dense system of normal equations with the 2000 abscissae zero points as unknowns. This will be solved by iterative methods.

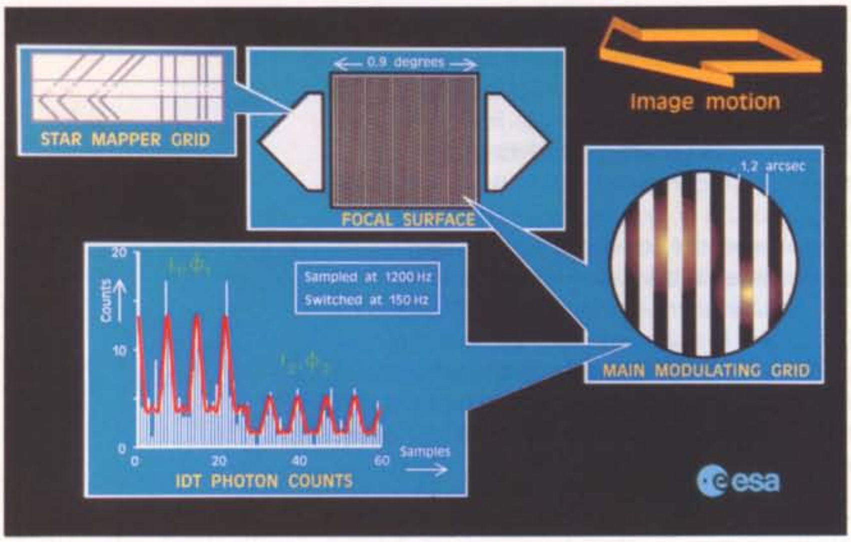


Figure 7. The principles underlying the phase determination of the modulated star signals, and hence the determination of the relative separations along the direction of scan of the stars simultaneously present within the telescope's two fields of view

Outside the three-step process are the related activities of calibration, photometry and double-star analysis. The accurate photometric measurements (to about 0.01 mag in the Hipparcos magnitude system at about 8 mag for each of the 100 or so grid crossings per star during the mission), and the detailed detection of double or multiple stars with separations larger than about 0.1-0.2 arcsec for magnitude differences less than about 3 mag, will be important byproducts of the astrometric measurements.

The attitude data are to be used both for the on-ground attitude reconstruction, and as input to the reductions leading to the construction of the Tycho Catalogue (Fig. 9). The Tycho Catalogue will be an additional catalogue of lower-precision astrometric data and two-colour photometric data for some 400 000 stars down to a limiting magnitude of about 11 mag, which will rely on a separate 'input catalogue' of star positions provided through a collaboration with the Hubble Space Telescope Guide Star Catalogue team.

One important satellite design concept is related to the choice and development of the attitude and orbit control system. Since the basic measurements are essentially quasi-simultaneous, a wide spectrum of attitude jitter was, in principle, acceptable. However, by a suitable choice of attitude control system (cold gas jets), the attitude motion has been made sufficiently smooth for stars not simultaneously present in the combined fields of view to still be tied 'directly' to each other through an extrapolation of the satellite attitude motion — a concept referred to as 'dynamical smoothing'. This leads to an effectively larger field of view, to an improvement in the great-circle rigidity, and hence to an improvement in the final star positions (in particular for the brighter stars which contribute directly to the rigidity of the reference frame).

Satellite operations

Mission operations will be conducted from the European Space Operations Centre (ESOC), in Germany. The ground station will periodically uplink segments of the observing programme, and this information will control both the observations and the scanning motion of the satellite. Data sent down from the satellite will be monitored, merged with auxiliary parameters such as satellite orbit information, and dispatched to the data-reduction consortia for subsequent processing.

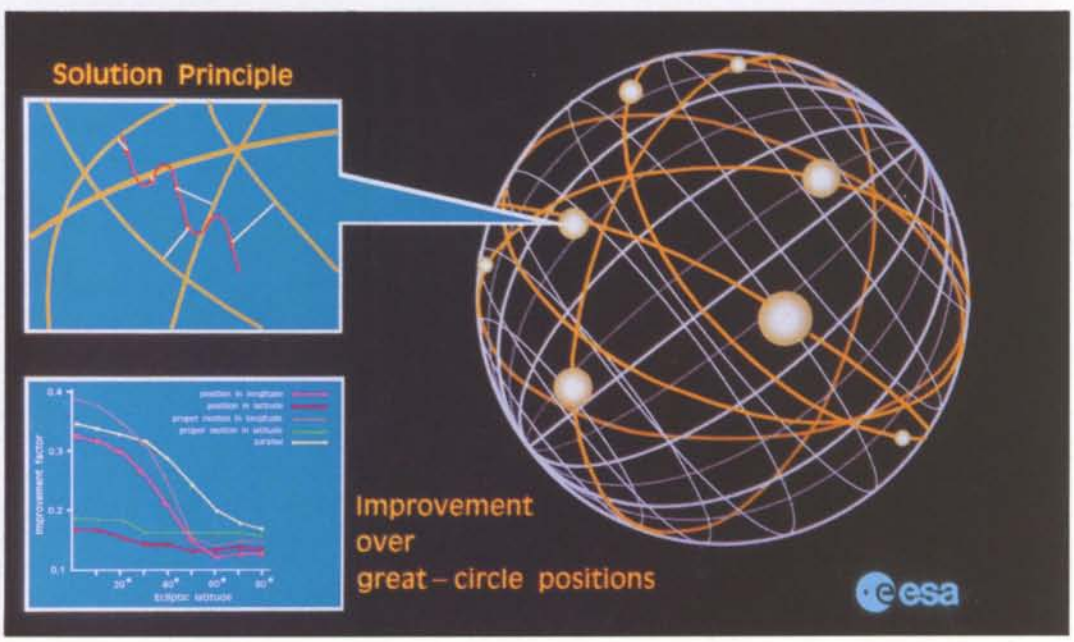


Figure 8. The final stage in the Hipparcos data processing is the sphere reconstitution. All the star measurements over the entire celestial sphere are taken together (right), and a small area of the sky is shown in greater detail in the figure at the top left. Different great circles yield measurements of the star positions at different epochs, projected onto these great circles

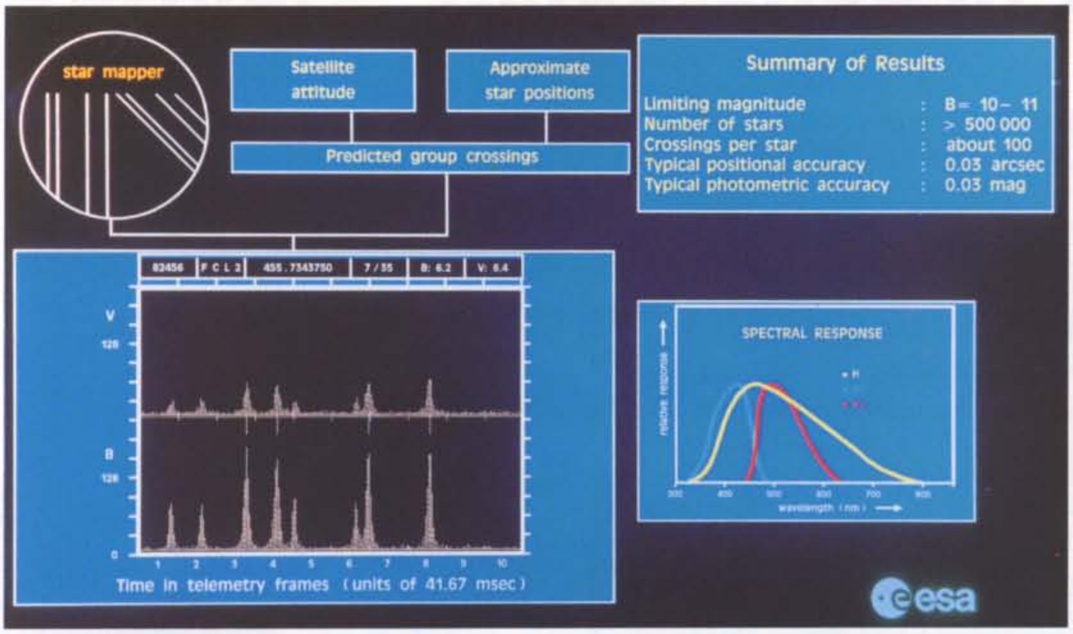


Figure 9. Stages in the processing of the Tycho data. The raw data related to a particular star are extracted from the data stream on the basis of the satellite's attitude (determined by the main reduction process) and the approximate star position, known before launch

After launch, Hipparcos will be manoeuvred from its transfer orbit into its final geostationary orbit by means of its apogee boost motor (Fig. 10). Once on station, the satellite will be despun, its spin axis will be oriented towards the Sun, and the 'scanning law' progressively acquired by means of star-pattern recognition using the star mapper. About 30 days are foreseen for payload commissioning, during which time preliminary estimates of the geometric and photometric properties of the payload, its stability as a function of time, and quantities such as the modulation coefficients, detector response profile, and star-mapper calibration parameters will be determined. Routine operations will commence at the end of commissioning.

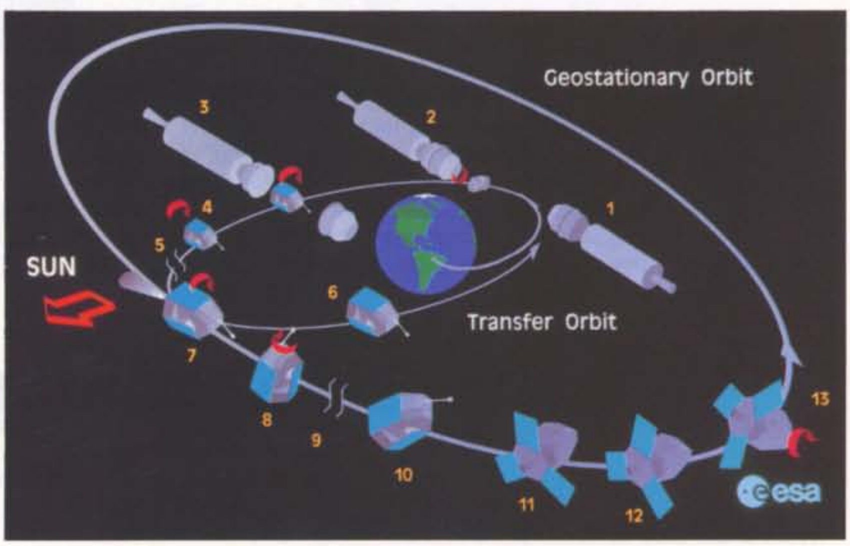
Payload monitoring activities will be carried out at the ESOC ground station throughout the mission, and the comprehensive data treatment carried out by the data-reduction consortia will identify significant instrument changes (once the mission is under way it is expected that the data treatment will lag behind data production by some 2–3 weeks). A 'first-look' facility, implemented by the FAST Consortium, will process a set of about 12 h of data per week — its function being to validate, as swiftly as possible, the data coming from ESOC, and to provide the results of initial data-calibration quantities to both the FAST main processing chain and to the Operations Centre.

Conclusion

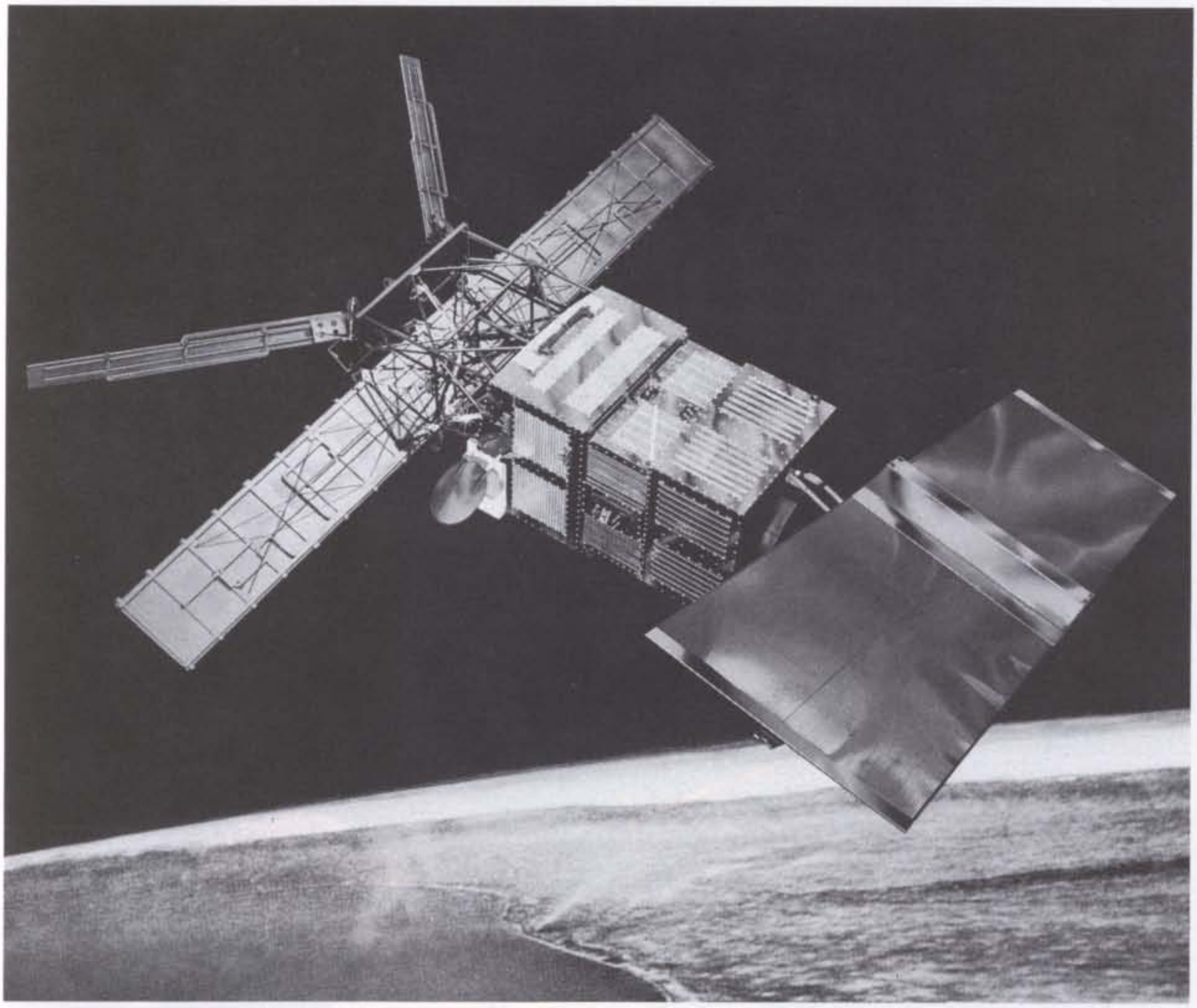
The final results of the Hipparcos mission, in the form of a single star catalogue, will be published and made available to the scientific community in about 1995.

Just as astrometric measurements made over the past two millenia have led to pictures of stellar motion and stellar evolution in our Galaxy, leading to an increasing awareness and comprehension of man's place in the dynamic exploding Universe around us, so the Hipparcos mission will allow many more pieces of the 'cosmic jigsaw' to be set in their place.

Figure 10. The early stages of the Sun acquisition, deployment of the solar panels, and initialisation of the scanning of the celestial sphere by the Hipparcos satellite



Dornier – Milestones in Space.



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Dornier, for instance was prime contractor for the satellite projects AEROS A/B, ISEE-B, Ulysses/ISPM, and the complex space systems FOC and IPS.

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The Hubble Space Telescope

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The NASA/ESA Hubble Space Telescope (HST), which is scheduled to be launched in December 1989, is one of the most ambitious and demanding projects in space astronomy ever undertaken. Yet, in concept, it is one of the simplest: to place a two-metre-class astronomical telescope and its associated instrumentation into low Earth orbit and maintain and operate it over an extended period as an international multipurpose astronomical observatory — in much the same way that large ground-based telescopes are used by astronomers on clear nights at observatories all over the World today. However, operating above the Earth's atmosphere, HST will provide astronomers with a far clearer and much more detailed view of the Universe throughout the ultraviolet, visible and near-infrared parts of the spectrum. Observations obtained with HST are therefore expected to have a profound impact on nearly all fields of modern astronomy.

A limit to 'seeing'

Like all astronomical telescopes, the Hubble Space Telescope consists basically of a reflecting telescope, which collects and focusses light from celestial objects, followed by several different scientific instruments that can be used to analyse the light gathered. With a primary mirror diameter of 2.4 m, HST is by no means a huge telescope by modern standards; both the 5 m Hale Telescope on Mount Palomar (USA) and the 6 m telescope of the Crimean Observatory (USSR) have mirrors more than twice as large. Moreover, several huge 8–10 m class telescopes are currently under construction at various sites around the World.

Nonetheless, HST — operating above the Earth's atmosphere — is expected to outperform these Earth-bound giant telescopes by a comfortable margin. The main reason for this has to do with the adverse effects on images of celestial objects obtained from the ground caused by scattering during light's passage through the turbulent layers of the Earth's atmosphere. Irrespective of the size of the telescope, this unavoidable blurring — or 'seeing' as it is termed by astronomers — effectively limits the resolution that can be obtained in ground-based astronomical images to about one second of arc (1 arcsec). The level of detail that can be seen in images taken with the best telescopes from the ground is roughly equivalent to reading the headlines of a newspaper from a distance of one kilometre.

Figure 1. Artist's impression of the Hubble Space Telescope (HST) in orbit

Because of the adverse effects of the intervening atmosphere, carrying out astronomical observations from the ground has been likened (somewhat exaggeratedly) to 'bird-watching from the bottom of a lake'. In space, on the other hand, light propagates freely — stars do not twinkle in space, for instance — and the limiting performance of any telescope is determined solely by the inherent quality of the optics and the accuracy with which it can be kept pointed during an exposure. The images taken with the Hubble Space Telescope are expected to show about ten times more detail than similar images taken from the ground. This increase in performance is roughly equivalent to reading not only the headlines, but also the fine print of a newspaper one kilometre away.

It is primarily in this dramatic tenfold improvement in image quality that the motivation and promise of HST lies. HST will enable astronomers not only to study already known astronomical objects at a much higher level of discernible detail, but also to detect and study hitherto unknown objects some thirty times fainter — or five times more distant — than observable from the ground. In this way HST will expand the volume of space accessible to astronomical observation by a factor of more than 100.

A further important advantage of a telescope operating in space is that light radiated by astronomical objects in a large region of the electromagnetic spectrum will enter the telescope and be focussed. In contrast, because of absorption in the Earth's atmosphere, only a small fraction of the total emitted spectrum reaches a telescope situated on the ground. Hence HST will be capable of viewing celestial objects not only in visible light, but also in the ultraviolet and infrared. The ultraviolet spectral region (wavelengths between 90 and 330 nm) is of particular importance to astronomers since it contains most of the so-called 'atomic transitions' of the most common elements. All chemical elements have their own characteristic signature in terms of being able to absorb and emit light, and it is by identifying these signatures in the spectra of celestial objects that their chemical composition, temperature and physical properties can be determined.

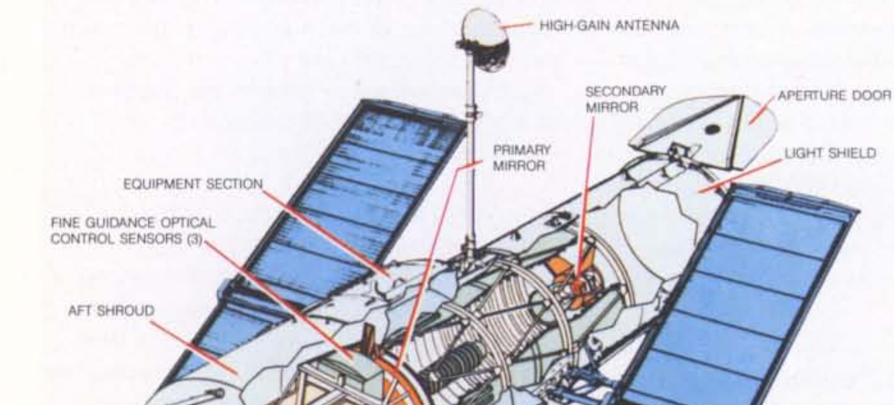


Figure 2. Cutaway view of HST, showing both the telescope and its scientific instruments

A joint NASA/ESA project

The potential advantages of carrying out astronomical observations from space, beyond the Earth's atmosphere, were pointed out by the German rocket pioneer H. Oberth back in 1923. The first serious recommendations that a large astronomical space telescope be built were received 40 years later by NASA, in the early sixties. Following a series of feasibility studies, the present joint NASA/ESA programme was finally approved and initiated in 1977.

The ESA contribution to the HST project consists of three elements:

(i) The Faint Object Camera (or FOC), one of the prime focal-plane instruments on board Space Telescope.

(ii) The solar arrays, which provide power to the spacecraft.

(iii) Scientific and technical personnel to staff the Space-Telescope Science Institute in Baltimore, Maryland, and the European Coordinating Facility for Space Telescope, at the European Southern Observatory in Garching, West Germany.

In return for this contribution, European astronomers from ESA Member States will be guaranteed a minimum of 15% of the available observing time with HST.

The spacecraft: designing for a long life

The fully assembled Hubble Space Telescope is 14 m long, has a diameter of 4 m, and weighs more than 11 t. It will be launched by the Space Shuttle into a 590 km high, 28.5° inclination low Earth orbit. The most recent NASA launch manifest targets HST for launch on 11 December 1989 on board the Space Shuttle 'Discovery'.

A key aspect of the Space Telescope observatory is its planned 15-year lifetime, with the possibility for maintenance and upgrading in orbit. All scientific instruments and many of the critical spacecraft subsystems are designed so that they can be repaired or replaced by a space-suited astronaut in orbit. The Space Shuttle is expected to visit HST approximately once every three years. It will therefore be possible to gradually refurbish or replace the various scientific instruments as they fail or become obsolete during the observatory's lifetime.

To achieve these objectives with maintenance missions not more than once every three years requires a number of special features. Firstly, HST will be placed in a relatively high orbit at 590 km. This is twice the altitude flown by most of the Shuttle missions, and will ensure that the orbital decay caused by residual atmospheric drag is not a limiting factor. Additionally, the HST attitude control system uses no consumables such as gas or propellant, relying instead on so-called 'reaction wheels' (excess accumulated angular momentum will be off-loaded using magnetic torquers reacting with the Earth's magnetic field). The maintenance requirements are therefore based on the need to replace those items that fail, wear out or become obsolete. This has resulted in a modular approach in HST's design.

One of the more critical subsystems of the spacecraft, where the design requirements for a long lifetime are especially important, can be found among ESA's contributions to

Figure 3. The assembled Faint Object Camera (FOC). The yellow handles are to assist the astronauts in handling the instrument in orbit

the HST mission — namely the solar arrays that power the HST spacecraft by converting sunlight into electricity. The performance of these arrays will degrade with time due to the accumulated effects of radiation bombardment, and the repeated heating and cooling as the orbiting HST passes from sunlight to shadow, causing fatigue in the electrical interconnections. This will limit the useful life of the solar arrays to approximately five years and they have therefore been designed to be easily replaceable in orbit.

A typical HST maintenance mission will involve a Space Shuttle mission carrying all the spare subsystems needed, including two new solar arrays, on a special carrier in its cargo bay. The Flight Support System maintenance platform first used on the Solar Maximum Repair Mission in 1984 will also be carried. The Space Shuttle will rendezvous with the Hubble Space Telescope and the Shuttle's crew will capture it using the Remote Manipulator System and mount it on the maintenance platform. The solar arrays will be retracted and the HST observatory will enter a dormant mode. Two crew members will then exit through the Shuttle aft airlock and start the maintenance activities.

Usually several units will have to be replaced, and a new set of batteries will probably also be installed routinely, at each maintenance visit. During maintenance of the solar arrays, one of the old arrays will first be removed by releasing a clamp at its base and moving that wing to a temporary storage bracket. The first of the new wings will then be removed from the carrier and fitted to HST. This process will then be repeated for the second wing. The new solar arrays will then be deployed either partially or fully prior to the Shuttle reboosting back to the nominal 590 km altitude where the HST observatory will be redeployed and reactivated.

The payload: an astronomer's toolbox

The Space Telescope proper is a 2.4 m-diameter reflecting telescope; it has an effective focal length of 57 m, which is achieved by folding the light path in a so-called 'Ritchey-Chrétien Cassegrain configuration'. The two mirrors of the

Figure 4. One of the ESA-supplied HST solar arrays undergoing testing. HST has two such arrays, which together provide 4.5 kW of power to the spacecraft

Figure 5. The 2.4-m diameter primary mirror blank of the HST. Its reflecting surface is figured to an accuracy of better than five millionths of a centimetre (courtesy of Perkin-Elmer)

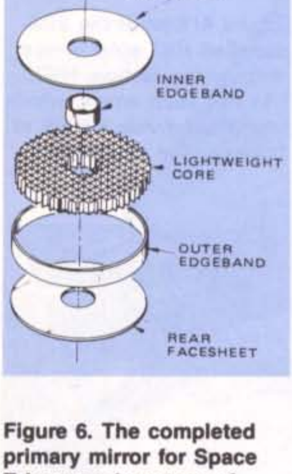


Figure 6. The completed primary mirror for Space Telescope (courtesy of Perkin-Elmer)

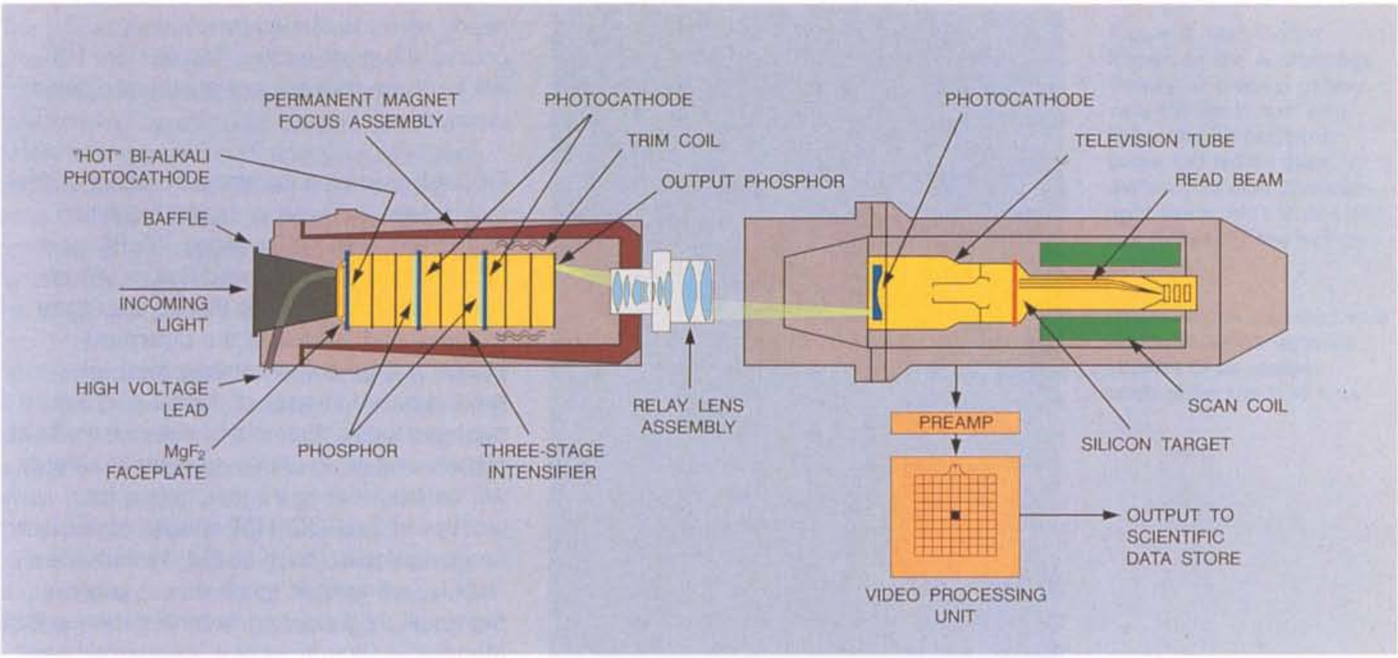
telescope are coated with aluminium and magnesium fluoride and reflect light with wavelengths between about 115 nm and 1 mm. The figures of the telescope surfaces have been polished to an extremely high accuracy of better than five millionths of a centimetre. Combined with an expected pointing stability of 0.007 arcsec, this should permit HST to resolve two objects in the sky separated by as little as 0.1 arcsec.

Light entering the telescope can be analysed by one or more of five scientific instruments and three fine-guidance sensors, which are used to keep HST accurately pointed during an observation. The first generation of scientific instruments to be flown aboard HST will consist of two direct-imaging cameras, two spectrographs and a photometer. This complement of instruments essentially spans the full range of tools used by astronomers.

The two cameras onboard HST are extremely sensitive, television-camera-type systems that take pictures of the sky through the Space Telescope. The Wide Field/Planetary Camera (WF/PC) is capable of operating in two modes: a 'Wide Field' mode with a 2.7x2.7 arcmin field of view, and a higher magnification 'Planetary' mode with a 1.2x1.2 arcmin field of view. The WF/PC is also equipped with a large bank of filters, prisms, gratings and polarisers.

The light detectors of the WF/PC are eight so-called 'Charge-Coupled Device' (CCD) semiconductor chips. These CCD detectors consist of an array of 800x800 individual, 15x15 micron, solid-state silicon detectors. Each element of the CCD chip effectively converts incoming light quanta into single electrons, which are held trapped for the duration of the exposure. When the exposure is complete, the total accumulated charge in each of the individual CCD elements is 'read out', amplified electronically, and telemetered to the astronomers on the ground.

The Faint Object Camera, which has been designed and built by ESA and European industry, is in many respects complementary to the WF/PC. It is capable of operating in four basic modes: direct imaging at magnifications of 2, 4 and 12 times, as well as in a so-called 'long-slit' spectrographic mode. Whereas the WF/PC provides a slightly undersampled image of a 'wide' region of the sky, the FOC is designed to fully exploit the unique imaging capability of the Hubble Space Telescope and provide



images of the highest possible resolution and limiting sensitivity. However, the fields of view in the three nominal imaging modes are very small: 22x22, 11x11, and 4x4 arcsec, respectively. Moreover, whereas the WF/PC operates best at longer wavelengths, the FOC is most sensitive in the blue and ultraviolet spectral regions. The FOC is also equipped with a large number of filters, prisms and polarisers, in addition to two coronographic 'fingers'. The latter can be used to block out light from bright stars and permit better study of their immediate surroundings.

The FOC uses two separate imaging 'photon-counting' light detectors consisting of three-stage intensifier tubes coupled to television cameras. The operating principle of these detectors is illustrated in Figure 7.

A second important tool for the astronomer is the spectrograph. Spectrographs separate light into its various colours by means of prisms and diffraction gratings, thereby enabling a detailed analysis to be made of the light emitted by celestial bodies. In addition to several spectrographic modes included in the FOC and the WF/PC, the HST also carries two specially designed, dedicated spectrographs.

The Faint Object Spectrograph (FOS) and Goddard High-Resolution Spectrograph (GHRS) both use one-dimensional 'Digicon' devices as their basic detectors. Like those of the FOC, these detectors are also capable of detecting and counting individual quanta of light. A key figure of merit for any spectrograph is its 'resolving power', i.e. the ability to separate light into its various components. The FOS is capable of operating in both a low-resolution and an intermediate-resolution mode. It also has spectro-polarimetric capabilities. The spectral response range of the FOS is 115–850 nm. The GHRS, on the other hand, operates in three very-high-resolution modes. It is the only true ultraviolet instrument on board Space Telescope in that its spectral response is limited to the 115–320 nm region.

Another tool for the astronomer to be found aboard HST is the High-Speed Photometer (HSP). Photometers are used to measure the intensity of light accurately. The HSP is the simplest of the first-generation Space-Telescope instruments. It contains no moving parts and consists of four photon-counting image-dissector tubes, a photomultiplier and more than fifty focal-plane filter/aperture combinations. The various filters span the 115–700 nm range. The HSP can also measure the polarisation of light, and it is capable of detecting rapid fluctuations in the light from celestial sources by measuring the arrival time of individual photons to an accuracy of better than 20 microseconds.

The capabilities of the 'sixth' scientific instrument on board HST, namely the three Fine-Guidance Sensors (FGSs), are also worth mentioning. These instruments are located at the outermost edge of the HST's focal plane and consist of highly sophisticated interferometric devices. During an observation, the FGSs will 'lock on' to pre-selected guide stars in the vicinity of the target and assist in keeping the telescope pointed steadily at the target to an accuracy

Figure 7. Schematic showing the operating principle of the Faint Object Camera. Individual light quanta striking the front-end photo-cathode of the intensifier release single photoelectrons which are amplified through a cascade process. The electron cloud released is electromagnetically focussed and accelerated to impact on the phosphor-coated output window of the intensifier tube. In this way, each detected photon produces an intense flash of light in the output phosphor. The output window of the intensifier tube is continuously viewed by a scanning television camera, the signal from which is fed to a microprocessor. This microprocessor, in turn, is programmed to determine the exact location and size of each flash. If the event in question fulfils the various validation criteria set by the discrimination logic, then the microprocessor gives the command to increment by one the register in an electronic memory corresponding to the event location. Using this technique, an image is gradually built up in the memory during an exposure that may last for many hours. The contents of this memory are then telemetered to the ground, once the exposure is complete.

of 0.007 arcsec. Since only two FGS interferometers are needed to point the spacecraft at any given time, the third FGS is free to measure the relative positions of other stars within its field of view. It is hoped that a positional accuracy of 0.002 arcsec can be achieved in this way.

This accuracy is similar to what will be achieved by the Hipparcos mission, but the HST will study astrometrically a much more limited number of stars in a far less systematic manner than will Hipparcos. In particular, HST astrometry will result in measurements over only a small field at any given time, and will never yield a general reference frame like Hipparcos.

Several of the next generation of instruments for installation in HST are already either in the process of being built or on the drawing board. In addition to the WF/PC 'clone' that is presently being assembled for possible installation in HST in 1993, two other 'second-generation' instruments for Space Telescope have been selected by NASA. These are a near-infrared camera/ spectrograph — the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) — and a second-generation ultraviolet-through-visible spectro-graph — the Space-Telescope Imaging Spectrograph (STIS). The near-infrared instrument is expected to be installed on board HST around 1995, and installation of the STIS is foreseen for 1998.

Scientific results: great expectations

The Hubble Space Telescope is a truly multidisciplinary observatory. The scientific opportunities presented by its complement of instruments are therefore extremely broad in scope. Observations carried out from HST are expected to have a profound impact on nearly all fields of modern astronomy. Of course, the most exciting results from HST will be those that are entirely unanticipated discoveries.

Figure 8 illustrates the dramatic effect of the factor-of-ten increase in spatial resolution anticipated from HST images. WF/PC and FOC images of Jupiter and Saturn will be comparable in quality to the Voyager flyby pictures, and images of the outermost planets will be comparable to the best ground-based images of Jupiter and Saturn available today. Attempts to detect extra-solar planets and proto-planetary nebulae directly will be made using the coronographic facilities of the FOC. HST images of relatively nearby galaxies, such as the Andromeda Nebula, will appear much as our galaxy's two small neighbouring satellite galaxies, the Magellanic Clouds, appear to ground-based observers today, thereby permitting detailed studies of their stellar populations for the first time.

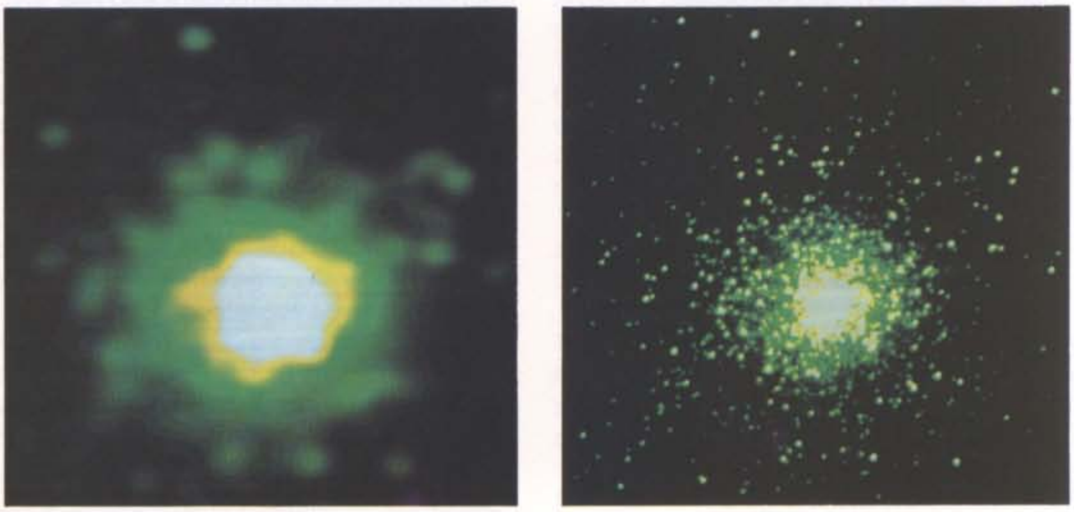


Figure 8. This illustration demonstrates the dramatic tenfold increase in image quality attainable with HST. The leftmost picture shows how a hypothetical, very distant globular star cluster appears to a ground-based telescope. The righthand picture shows how the same cluster will appear when viewed with HST.

In fact, the picture on the right is an image of the globular cluster M15, located in the constellation Pegasus, obtained with an engineering model of the Faint Object Camera used on the 1.8-m telescope of the Asiago Observatory. The image was then computer-processed to produce the image on the left.

Globular clusters such as M15 are among the oldest objects in the Galaxy and will be extensively studied with HST

By obtaining much higher quality spectra of much fainter objects in the ultraviolet, the FOS and GHRS spectrographs will allow astronomers to expand greatly upon and follow up the impressive series of discoveries already made by the extremely successful NASA/SERC*/ESA International Ultraviolet Explorer (IUE) satellite. FOS and GHRS ultraviolet observations of stars within our own Galaxy will undoubtedly lead to major advances in our understanding of stellar atmospheres, winds, mass loss and chromospheres. The GHRS will also be used extensively to study the tenuous gas present in the vast voids of interstellar and intergalactic space.

* UK Science and Engineering Research Council

The High-Speed Photometer will, among other things, be used to search for the extremely rapid flickering expected in the light emitted by compact objects such as binary star systems containing neutron stars and black-hole candidates. It will almost certainly also be used to study the newly-born, extremely rapidly spinning pulsar recently discovered in Supernova 1987A in the Large Magellanic Cloud.

Another exciting task for HST, and one that will involve observations taken with essentially all of its instruments, is that of unravelling the goings-on in galaxies showing violent activity within their central nuclei and in the more extreme, but very poorly understood, quasars. One popular theory holds that the enormous energy outputs seen in these objects stem from the release of gravitational energy by matter in the form of stars and gas being drawn into massive black holes lurking in the centres of the active galaxies. With its tenfold increase in resolving power, HST will permit these ideas to be checked, as it will provide direct images of regions closer to the hypothetical black hole. It will also be possible to study the host galaxies assumed to surround the extremely bright and remote quasars, by using the occulting fingers of the FOC. Yet other predictions of the accreting-black-hole theory will be checked against observation by obtaining detailed spectra of quasars in the ultraviolet using the FOS, GHRS and FOC spectrographs.

Gauging the Universe: the quest for Hubble's Constant

Another crucial, but much more long-term task for HST — its importance being reflected in the choice of the name — is to dramatically improve our knowledge of the overall size and age of the Universe. In 1929, Edwin P. Hubble discovered that the Universe is expanding in a uniform manner, such that galaxies move away from us at a speed that is proportional to their distance away (see box). The constant ratio of recession velocity to distance describing this expansion is today called the 'Hubble Constant'. The Hubble Constant — referred to as H_0 (pronounced 'aitch nought') by astronomers — is hence a measure of both the overall size of the Universe and of the time that has elapsed since its birth in the 'Big Bang'. H_0 is therefore one of the fundamental parameters of modern cosmology.

Unfortunately, however, the Hubble Constant is very difficult to measure and its value is currently only known to within a factor of two at best. In fact, some current measurements of H_0 lead to a paradoxically low age for the Universe of about 10 billion years — which is less than the estimated ages of the oldest known stars!

One component of the Hubble Constant, the recession velocities of remote galaxies, is relatively easily determined via measurements of the Doppler shifting of galaxy spectra. The other component, their distances, can only be deduced by indirect means. The cosmic distance scale is determined by astronomers in a very laborious step-by-step fashion that gradually

Figure 9. M31, better known as the Andromeda Galaxy, is a spiral galaxy very similar to our own Milky Way. It contains some 100 billion stars. At a distance of only 2 million light years, M31 is one of the closest of the nearby galaxies.

Observations obtained with HST will permit detailed studies of its stellar content for the first time

Figure 10. Portion of the Large Magellanic Cloud showing Supernova 1987A, whose evolution will be extensively monitored with HST in the coming decades

moves out to span greater and greater distances. The first two rungs of this so-called 'Cosmic Distance Ladder' start very close to home, with the size of the Solar System determined by radar ranging, and the distances to nearby stars determined by a geometrical parallax technique. To climb the next rungs, however, astronomers must rely on various classes of progressively brighter stars, and ultimately entire galaxies, that can be recognised at greater and greater distances and used as 'standard candles'. This technique relies on the fact that the

Figure 11. A remote cluster of galaxies found in the constellation of Coma, approximately 400 million light years from Earth. They are moving away from us at a speed of 24 million kilometres per hour.

Observations of these and similar galaxies obtained with HST will permit their distances to be determined much more accurately

amount of light received from a celestial object drops off inversely with the square of its distance. Hence, by accurately measuring the apparent brightness of a remote galaxy and assuming its intrinsic brightness, its distance can be estimated.

The Cosmic Distance Ladder built up so far by astronomers is admittedly somewhat rickety. However, there is hope that it will be considerably strengthened and overhauled in the coming years. Whereas the Hipparcos mission will dramatically stabilise the foundation, the Hubble Space Telescope — with its ability to see a given type of object five times further away — will greatly strengthen the upper parts of the ladder by permitting use of the most reliable standard candles to much greater distances, thereby leaping over several of the more questionable rungs of the current ladder. Once the value of Hubble's Constant has been accurately determined, astronomers will use HST to address an even more difficult task, namely that of determining whether the Universe is infinite or closed in space.

Operations: an automated observatory

The overall scientific utilisation of the Space Telescope will be managed by the Space Telescope Science Institute (STScI), housed on the campus of the Johns Hopkins University in Baltimore, Maryland (USA). STScI staff will be responsible for the day-to-day scheduling of HST observations and will act as the primary point of contact between astronomers using HST and the HST project staff. Fifteen ESA staff members are working in different branches of the STScI and form an integral part of the Institution.

European astronomers will also be supported by the ESA/ESO European Coordinating Facility for Space Telescope (ST-ECF) located within the European Southern Observatory (ESO) near Munich, West Germany. The main functions of the ST-ECF are to provide Europe with a convenient local source of up-to-date knowledge of the workings and status of the scientific instruments on board HST, software for the analysis of HST data, and access to the HST data archives.

The data telemetered from HST will flow via NASA's Tracking and Data-Relay Satellite System (TDRSS) to the NASA Goddard Operations Center, and finally to the STScI for scientific analysis and archival. HST will not be operated like several previous astronomical satellite observatories, that is with observing time being allocated to astronomers in blocks or shifts. Instead, a detailed monthly observing plan will be worked out approximately six months in advance, and the exposures of the various programmes planned for this period will be taken in a pre-scheduled, optimised sequence in order to maximise the overall operating efficiency of the low-Earth orbiting observatory.

Since it will not always be in contact with the Earth, HST is designed to carry out its sequence of astronomical exposures in a fully autonomous manner. This includes slewing and locking onto new targets and telemetering the accumulated data during contacts with the TDRSS. It is hoped that a steady-state observing efficiency of 25–35% will be achieved once sufficient experience in operating the very complex spacecraft has been accumulated.

If all goes well, the Hubble Space Telescope will be declared officially operational some six months after launch, after the initial engineering checkout and in-orbit calibration/performance evaluation phases have been completed. From this point on, HST will become accessible to 'General Observers' from the worldwide astronomical community, via a peer-reviewed proposal-submission process, and the amount of observing time taken up by 'Guaranteed-Time Observers' (i.e. the instrument teams) will gradually diminish. ESA Member-State astronomers wishing to use HST will respond directly to the Announcements of Opportunity issued by the STScI. European observers will be able to apply for time on all five scientific instruments, and they will have no special claims to time on the FOC.

Astronomers will also have access to HST data via the Data Archive and Distribution System. The basic concept for this system is similar to that used for the highly productive IUE and Exosat projects — all raw and calibrated HST data, upon reception at the STScI, will be placed in the archives, and will become generally available once the original observer's proprietary period of access (normally one year) has elapsed. A copy of the HST data archives will be kept at the European Coordinating Facility (ST-ECF), where ESA Member-State astronomers will have full access to it.

The first Announcement of Opportunity for 'General Observing Time' with the Hubble Space Telescope was issued by the STScI in late 1985. A total of 563 proposals involving proposers from 29 different counties were received in response to this first call. Of these, 111 are led by Principal Investigators from the Agency's Member States. The 563 proposals together involve more than 600 investigators from ESA Member States. All of the proposals will be reviewed in the spring of 1989 and successful applicants will be notified during the summer.

The present first complement of HST observing proposals spans virtually all fields of modern astronomy, from the planetary sciences to cosmology. More than six times the available HST observing time has been requested. This enthusiastic response attests to both the great versatility of the Hubble Space Telescope as an astronomical observatory and the great expectations that the scientific community has for this ambitious project.

Who was Edwin P. Hubble?

One of the great pioneers of modern astronomy, the American astronomer Edwin Powell Hubble (1889–1953) started out by getting a law degree and serving in World War I. However, after practising law for one year, he decided to: 'chuck law for astronomy and I knew that, even if I were second rate or third rate, it was astronomy that mattered'.

He completed a PhD thesis on the 'Photographic Investigation of Faint Nebulae' at the University of Chicago, and then continued his work at Mount Wilson Observatory, studying the faint patches of luminous 'fog' or nebulae in the night sky.

Using the largest telescope of its day, a 2.5 m reflector, he studied Andromeda and a number of other nebulae and proved that they were other star systems (galaxies) similar to our own Milky Way.

He devised the classification scheme for galaxies that is still in use today, and obtained extensive evidence that the laws of physics outside the Galaxy are the same as on Earth — in his own words: 'verifying the principle of the uniformity of nature'.

In 1929, Hubble analysed the speeds of recession of a number of galaxies and showed that the speed at which a galaxy moves away from us is proportional to its distance (Hubble's Law). This discovery of the expanding Universe marked the birth of the 'Big Bang Theory', and is one of the greatest triumphs of 20 th century astronomy.

In fact, Hubble's remarkable discovery could have been predicted some ten years earlier by none other than Albert Einstein. In 1917, Einstein applied his newly developed General Theory of Relativity to the problem of the Universe as a whole. Einstein was very disturbed to discover that his theory predicted that the Universe could not be static, but had to either expand or contract. Einstein found this prediction so unbelievable that he went back and modified his original theory in order to avoid this problem. Upon learning of Hubble's discoveries, Einstein later referred to this as 'the biggest blunder of his life'.

Edwin P. Hubble (1889-1953)

Hardware status and things to come

The Hubble Space Telescope is currently stored in a large clean room in Sunnyvale, California. All five scientific instruments have been installed and a minimal amount of reworking and retesting of certain spacecraft subsystems is being carried out. A number of tests involving the Operations Control Center at NASA's Goddard Space Flight Center and the Space Telescope Science Institute are being prepared to validate the HST ground-system software.

The ESA-provided Faint Object Camera was delivered to NASA in 1983 for interface testing. It was first installed in the Space Telescope in 1985. It has since been removed a number of times to allow reworking of both the FOC and HST. It was last re-installed in the HST in August 1988.

The other hardware contributed by ESA, the solar arrays, was first delivered to NASA in 1986. The launch delay caused by the Space Shuttle 'Challenger' accident was used to return the arrays to Europe in order to upgrade their power output and to apply atomic-oxygen protection to lengthen their lifetime during the impending solar maximum. The arrays have now been reassembled and are about to be redelivered to NASA. Their power output has been increased from 4 to 4.5 kW by replacing the original solar cells with a newer, more efficient type. This additional power will permit greater operational flexibility and allow more than one of HST's scientific instruments to be operated at the same time.

The Hubble Space Telescope is expected to be flown to Kennedy Space Center on a C5A transport aircraft this August, and to be launched on Space Shuttle 'Discovery' on 11 December 1989.

The second set of solar arrays required for the maintenance mission are now being built and will be ready early in 1991. The Solar Array Carrier has completed its critical design review. The first HST maintenance mission is presently planned for 1995, but a contingency maintenance mission could be flown as early as 1991.

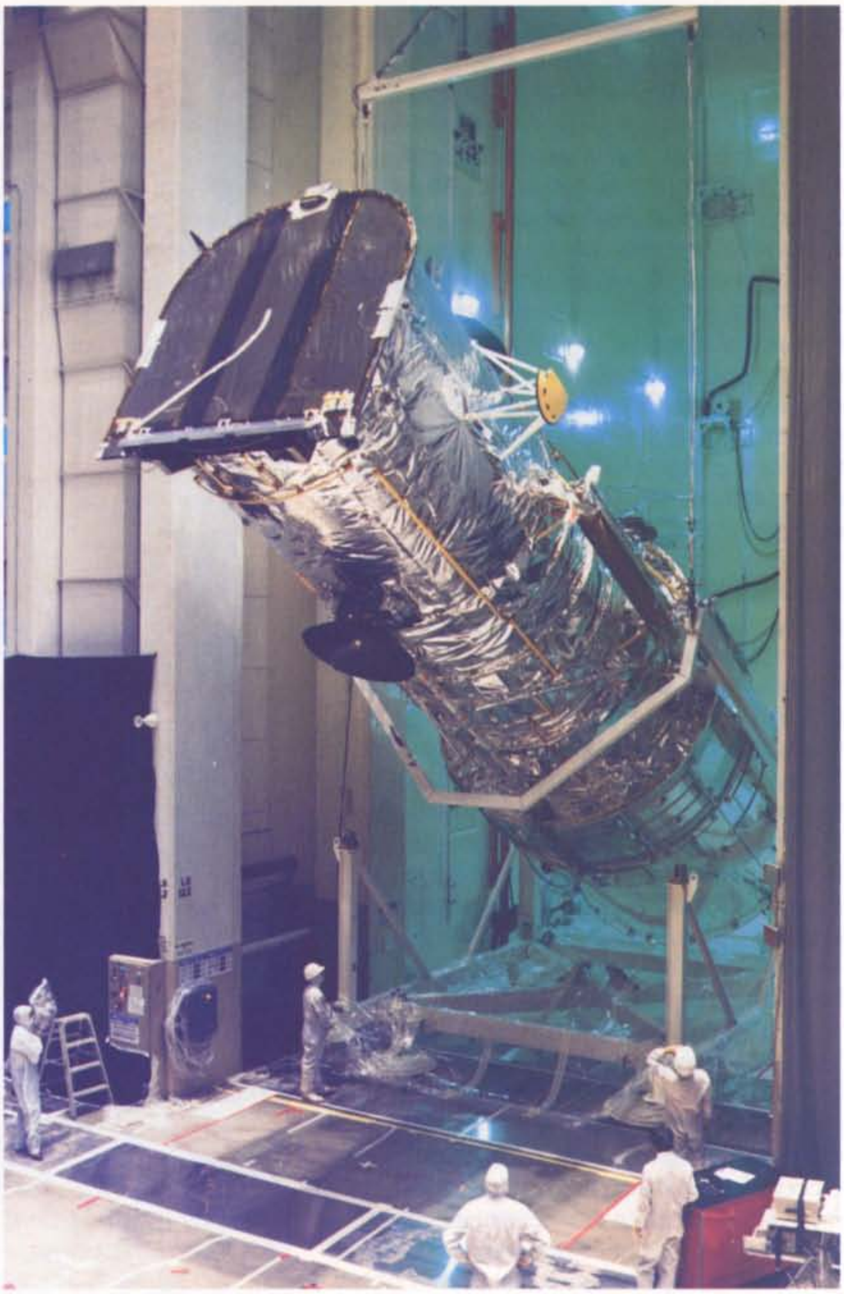


Figure 12. The assembled HST spacecraft undergoing final testing in California (LMSC, Sunnyvale)

Industrial contributions

The Faint Object Camera design and development was coordinated by the ESA HST Project Team at ESTEC, with industrial contracts with British Aerospace (UK) for the Photon Detector Assemblies and Dornier System (D) and co-contractor Matra (F) for the Camera Module. The Solar Arrays were procured from British Aerospace (UK), with AEG (D) as subcontractor for the Solar Blankets.

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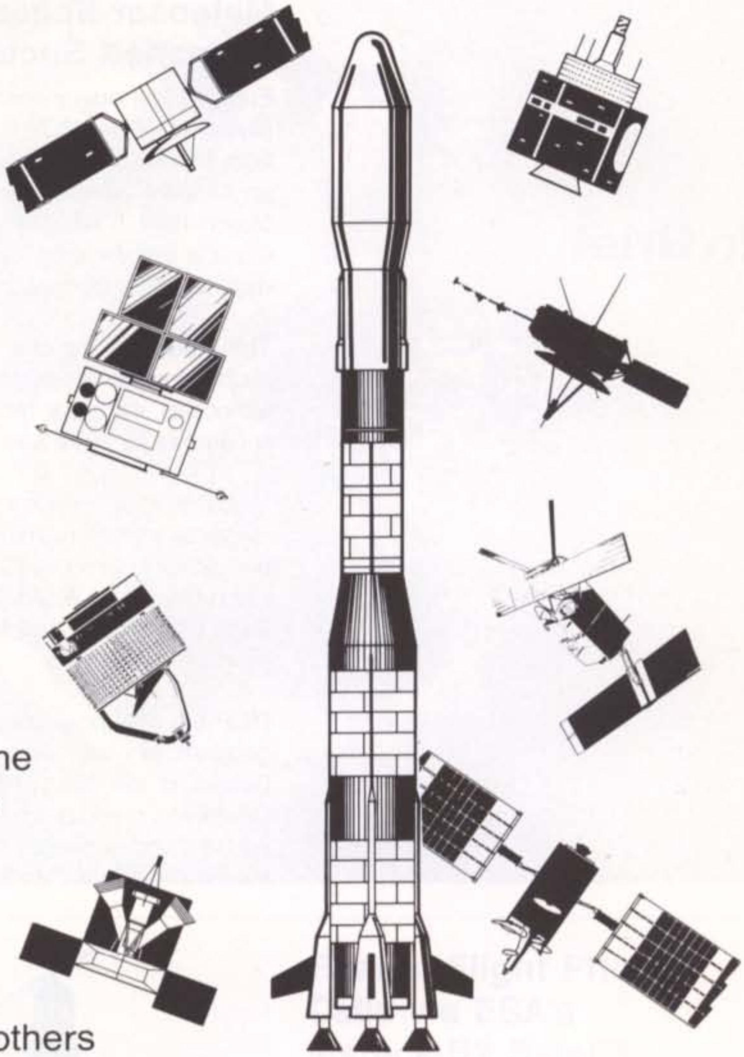

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In Brief

First Operational Meteosat Spacecraft Launched Successfully

Europe's first operational meteorological satellite (MOP-1) was launched from Kourou, French Guiana, on board an Ariane-4 vehicle (flight V29) on 6 March 1989. It was placed first into an elliptical transfer orbit, and then two days later into geostationary orbit.

This marks the first of a series of three such launches of operational Meteosats, the other two being scheduled for 1990 and 1993.

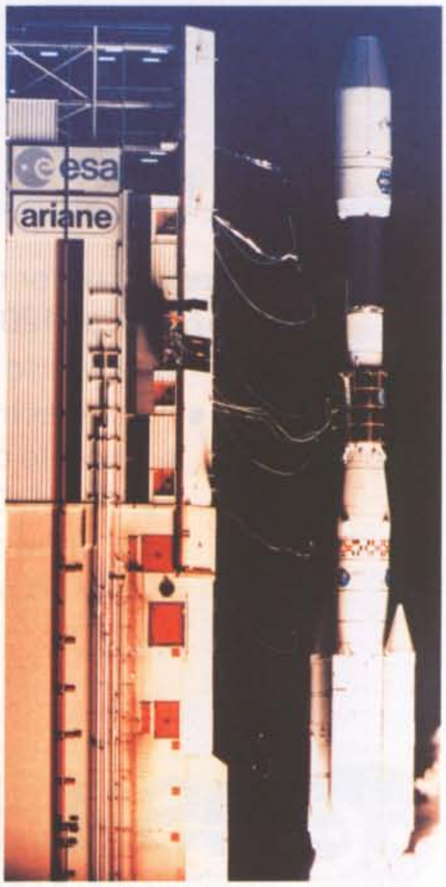
'This is part of Europe's contribution in response to the crucial need to monitor our global environment,' according to Philip Goldsmith, ESA's Director of Earth Observation and Microgravity Programmes.

MOP-1 is now positioned in a geostationary orbit over the Gulf of Guinea, at the point where the Greenwich meridian crosses the equator, and is generating images of the Earth's disc at half-hourly intervals.

The satellite is operated from the Meteosat Operations Control Centre at ESA's European Space Operations Centre (ESOC), in Darmstadt, W. Germany. After processing at the Meteosat facility in Darmstadt, the image data (sectorised images) are retransmitted, via the satellite, to the smaller ground stations within its field of view. This makes it possible for weather forecasters to have immediate and accurate information to hand.

MOP-1 follows three pre-operational Meteosats, which were launched in November 1977, June 1981 and June 1988, respectively. These satellites, funded and developed by ESA, have been part of the network of satellites used by meteorologists world-wide. Meteosat satellite images are seen every day by more than three hundred million European viewers during television weather forecasts.

To capitalise on the initial success of the Meteosat satellites, the European Meteorological Satellite Organisation, Eumetsat, was set up to fund and administrate the operational programme in January 1987. ESA has continued to develop and operate the satellites.

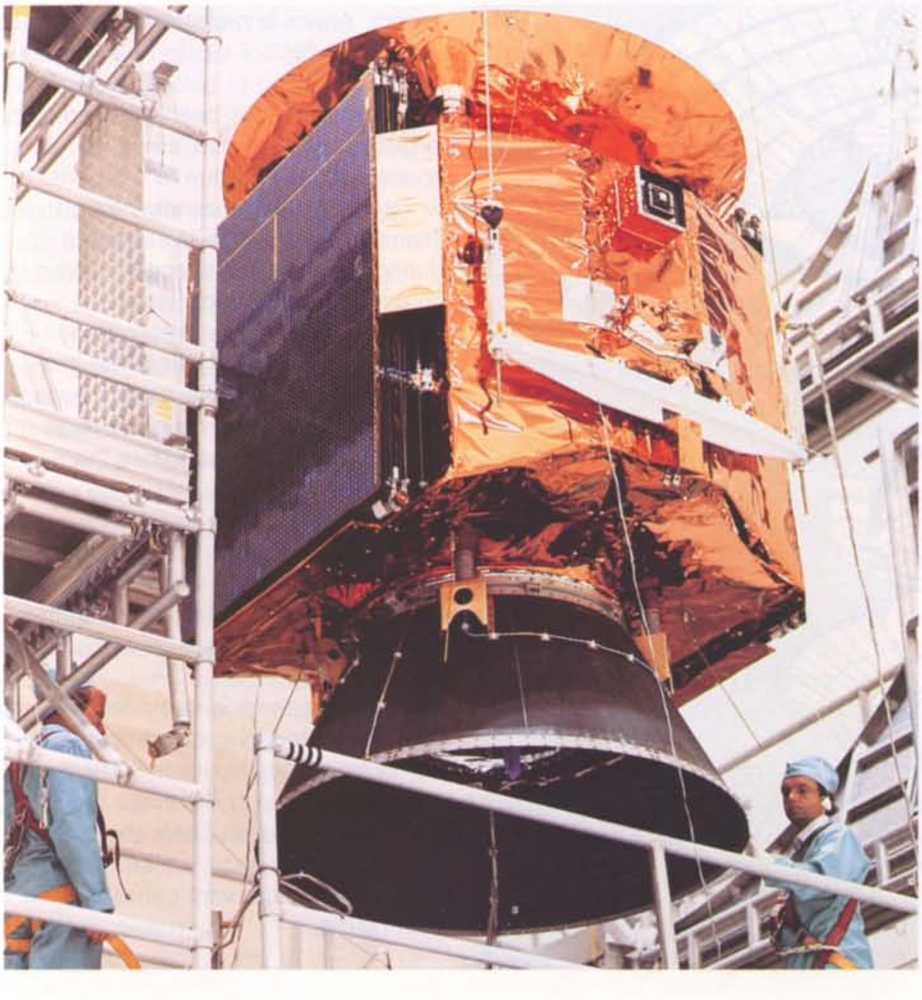


First Image from Meteosat MOP-1

After its successful Ariane-4 launch on 6 March 1989 (see previous page), Meteosat MOP-1 has now arrived at its operating location in geostationary orbit (at 0°).

On 19 April, the radiometer was switched on and the first image, shown here, was acquired.

Further testing will now be conducted until the end of May, when the spacecraft will be turned over to the international organisation Eumetsat, which is funding the Meteosat Operational Programme. The satellite will continue to be operated by ESOC in Darmstadt (W. Germany), and will henceforth be known as Meteosat-4.



First In-Flight Phone Calls via ESA's Marecs-B2 Satellite

The first commercial public satellite telephone calls from an aircraft were completed on 14 February 1989 via ESA's Marecs-B2 satellite, operated by Inmarsat.

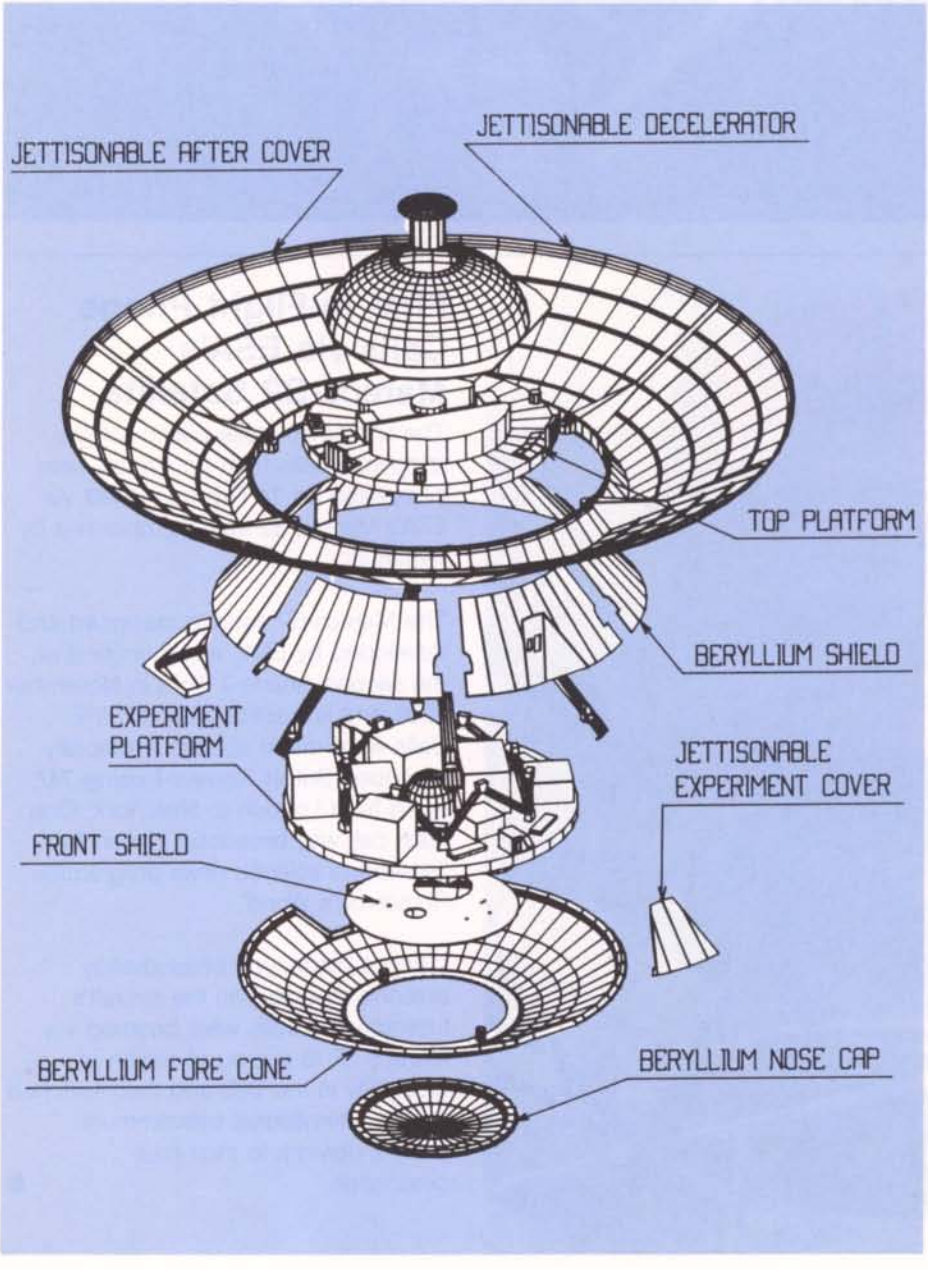
The Marecs-B2 satellite, designed and developed by ESA, was launched on the second Ariane-3 flight in November 1984 and is positioned at 177.5°E. Calls were made aboard a specially equipped British Airways Boeing 747, flying from London to New York. One such call was broadcast live on BBC Television's science news programme 'Tomorrow's World'.

Using a blade-type phased-array antenna mounted on the aircraft's fuselage, the calls were beamed via Marecs-B2 to a ground station at Goonhilly in the UK, and then switched via the international telecommunications network to their final destination.

ESA Selects Huygens Probe In Cassini Project

ESA's Science Programme Committee has selected Huygens, the probe studied by Marconi Space Systems, as the Agency's contribution to the cooperative international Cassini project to investigate the Saturn environment and analyse the atmosphere of Titan, Saturn's largest moon.

The Cassini mission is a combined effort by ESA and NASA and represents ESA's second venture into deep space, after Giotto's successful encounter with Halley's Comet in March 1986. NASA will be responsible for Cassini, the Saturn orbiter.



Cassini, which is named in honour of the French-Italian astronomer Giovanni Cassini, who discovered several of Saturn's moons and ring features, is scheduled for launch in April 1996 and will act as mothership, carrying ESA's Huygens probe, named after the Dutch astronomer Christian Huygens, who discovered Titan and the Saturn ring system. Arrival is projected to be December 2002.

Once Huygens has been released and targetted to Titan, the Cassini spacecraft will continue to orbit Saturn, whilst the probe descends through Titan's atmosphere to its surface. It is during this two-hour descent that the important, and possibly historical, measurements of the atmosphere's composition will take place. The low-velocity impact with the moon's surface (5 m/s) may be soft enough to allow analysis of the surface before the probe dies.

Analytical data acquired during the descent and landing will be transmitted back to Earth from the probe via the Cassini Saturn orbiter.

Titan's atmosphere is composed of methane, nitrogen and hydrocarbons, but lacks molecular oxygen. These elements are much like those that probably existed on Earth shortly after its birth and, as such, should provide an insight into the very genesis of our own planet.

High-Level Meeting Between ESA and the CEC

ESA's Director General, Prof. Reimar Lüst, met recently with Mr. Jacques Delors, President of the Commission of the European Communities (CEC), and other members of the Commission, to explore the possibilities emerging from the close integration of the space effort with the mechanics of the building of Europe.

Since ESA adopted its Long-Term Programme in late 1987, substantially opening up the prospects for Europe, the two organisations have stressed the need for Europe to take account of the industrial, commercial and technological aspects of the development and use of space technologies which have resulted from ESA's efforts and successes, in order to jointly defend and promote Europe's space interests on the international stage.

Both ESA and the CEC expressed their satisfaction with the outcome of the cooperative projects already undertaken, and look forward to developing more comprehensive, systematic and global forms of cooperation directed at combining the general skills of the EEC with the specific skills of ESA.

Discussions centred mainly on three major areas of space-technology applications: Earth observation, telecommunications, and microgravity. In addition, it was agreed there is a need for cooperation in addressing the industrial aspects of space exploitation and Europe's ability to launch a systematic and coordinated effort in meeting growing international competition, especially at the commercial level.

Earth observation
Agreement was reached on a joint initiative involving an environmental research and monitoring project at the synoptic scale permitted by space technologies, covering operational applications and Europe's contribution to international cooperation for the global study of our planet.

Telecommunications
The EEC will give priority to the integration of the 'satellite component' into their telecomunications policy (statutory and regulatory aspects). Specific cooperation in other areas will cover: the use of ESA's Olympus satellite for demonstration experiments involving the EEC's technological development programmes and their policies; studies on possible synergy between the Community's RACE programmes and ESA's PSDE programmes; mobile communications; and an examination of the role of satellites in organising assistance in the event of accidents or natural disasters.

Microgravity
An initial cooperative project will take the form of a joint analysis of prospects in the field of microgravity, of the elements necessary for a genuine long-term European strategy for the utilisation of the infrastructure developed by ESA, and the Community's role in the strategy.

The Meeting concluded with an agreement that the CEC and ESA would join forces in preparing a European initiative to promote environmental research and monitoring through the exploitation of the opportunities offered in this area by space technology.

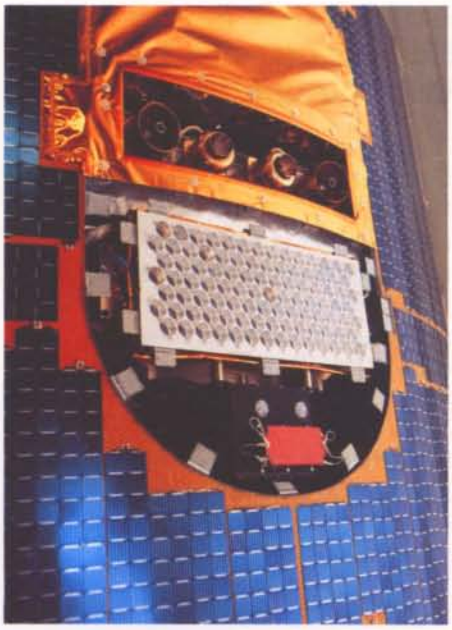
LASSO Experiment Working Well

The LASSO (Laser Synchronisation from Stationary Orbit) experiment has successfully begun to demonstrate the feasibility of achieving an accuracy of one billionth of a second in a new operational method of time-standard synchronisation over intercontinental distances.

This laser experiment, carried on ESA's Meteosat-P2 satellite, involves laser ground stations firing light pulses at instruments onboard the spacecraft (a passive retro-reflector array and an optical pulse detector linked to a time annotation system). This is the first time any process has been capable of measuring the range from ground to spacecraft with an accuracy of 5 to 10 centimetres.

Differences between time standards can be derived from the travel times of laser pulses emitted by the ground station and returned by the satellite, and from the onboard time annotation of these pulses.

Later stages of the experiment should make it possible to achieve time synchronisation between many stations in Europe and America to an accuracy of one billionth of a second.



The LASSO retro-reflector on Meteosat-P2

The LASSO experiment is controlled from the Telespazio ground station at Fucino in Italy, working in collaboration with the Meteosat Operations Control Centre at ESA's European Space Operations Centre (ESOC) in Darmstadt, W. Germany.

EUROSTEP Assists Education with Satellite Communications

A major outcome of last month's Olympus Utilisation Conference in Vienna, from 10 to 15 April, was the establishment of EUROSTEP, a European association of telecommunication satellite users in training and education programmes. The elected president is Prof. L.N. Mavridis from the University of Thessaloniki (Gr).

More than 50 projects are already planned using an ESA Olympus direct-broadcast satellite channel to demonstrate and develop distance-learning services for Europeans in their homes and offices.

Twenty countries and more than 300 institutes are already involved in EUROSTEP, which will be responsible for the overall coordination and management of the association.

EUROSTEP is currently negotiating a detailed agreement with ESA, which will allow EUROSTEP to use Olympus for nine hours of broadcasting daily to most of Europe.

A wide mix of experimental programmes is planned, including professional education, schools broadcasts, language learning, and instructional arts programmes. Further proposals are being actively sought.

Further information can be obtained from:

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EUROSTEP Headquarters
Leiden (NL)
Tel. (31)71-277268
or
J. Chaplin
ESA Communications Satellites Dept.
ESTEC, Noordwijk (NL)
Tel. (31)1719-83146

Olympus-1 Readied For Launch

The Agency's Olympus-1 communications satellite, built by a consortium of aerospace companies led by British Aerospace (Prime Contractor), has arrived in Kourou, French Guiana, where it will be prepared for its Ariane launch in June 1989.

When in orbit, Olympus-1 will be the World's most powerful civil communications satellite and will serve as a technology demonstrator for a future class of larger and more powerful communications satellites.

Prior to shipment, Olympus-1 successfully completed a series of rigorous environmental and mechanical tests at the David Florida Laboratories and the National Aeronautical Establishment, in Ottawa, Canada.

The main body of the Olympus-1 spacecraft is 2.9 m wide and 5.5 m high. In orbit, the satellite's deployed solar arrays will extend 25.6 m from tip to tip, which is approximately half the width of a football pitch.
Future Olympus satellites could have solar arrays up to 56 m across, providing up to 7.7 kW of electrical power — enough to power 40 channels of direct-broadcast television or up to 250 000 simultaneous telephone calls.

Olympus-1 carries four separate communications payloads, which will assist in the development of new communications services within Europe. The experimental applications will include tele-educational services, data transmission, video conferencing, high-power direct-broadcast television, and atmospheric attenuation measurements at high frequencies.

A detailed description and history of the Olympus Programme can be found on page ** of this issue.

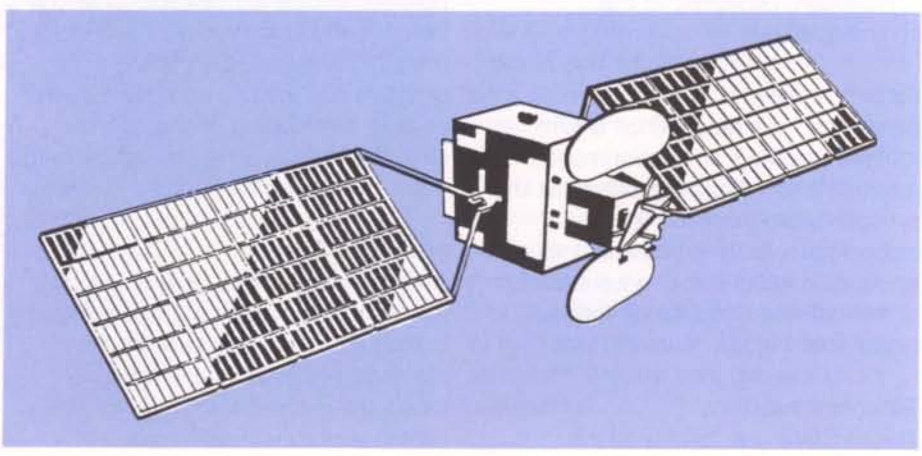
Tele-X Satellite Launched by Ariane

The Scandinavian Tele-X communications satellite was launched into a geostationary transfer orbit (GTO) by an Ariane-2 from Kourou in French Guiana on 2 April 1989. This was the 30th launch of an Ariane vehicle.

The satellite's orbit has since been circularised by means of the three foreseen apogee-boost-motor firings, the solar panels have been fully deployed, as too has the transmit antenna reflector.

Tele-X reached its final operating position of 5°E on 14 April. All satellite subsystems are functioning nominally and the general condition of the spacecraft is very satisfactory.

Produced by Aerospatiale/Eurosatellite and Saab Space, as Prime Contractors to the Swedish Space Corporation — the latter representing the system's owners, Nordiska Satellitaktiebolaget — Tele-X is a television direct-broadcasting and data-transmission satellite. It is equipped with three high-power channels (230 W) for the TV mission in the 17/12 GHz band, and two channels in the 14/12 GHz band for data transmission.



......and 25 Years Ago!

From the pages of the ESA Bulletin's progenitor:

15 April 1964

EUROPEAN SPACE RESEARCH ORGANISATION

(ESRO - CERS)

36, rue La Perouse - Paris 16 - BAL.24-02

N E W S IN B R I E F

ENTRY INTO FORCE OF THE CONVENTION creating the EUROPEAN SPACE RESEARCH ORGANISATION on 20 March 1964.

The first session of the Council took place on 23 - 24 March 1964 and was attended by delegates from: BELGIUM, DENMARK, FRANCE, GERMANY, NETHERLANDS, SPAIN, SWEDEN, SWITZERLAND and the UNITED KINGDOM. ITALY, which had signed the Convention but not yet ratified it, took part in the work of the Council under the terms of a special agreement. AUSTRIA was represented by an observer.

Sir Harrie MASSEY (United Kingdom) was elected Chairman; Dr. HOCKER (Fed.Rep.Germany) and Professor van de HULST (Netherlands) were elected Vice-Chairmen. Professor P. AUGER (France) was designated DIRECTOR GENERAL.

Next Session: 15-16 June, 1964, in Paris

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Successful LAUNCHING of ARIEL II, the second in a series of three British satellites designed to carry out investigations in and above the ionosphere. The British National Committee on Space Research chose the three experiments, aimed at measuring the intensity of galactic radio noise, the vertical distribution of ozone in the Earth's atmosphere, and the minometeroids encountered. Launching by a Scout rocket, Wallops Island, 27 March. (communiqué NASA).

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AGREEMENT FRANCE/PORTUGAL of 8 April for the purpose of establishing a missile observation station in the Azores.

page 2.

LAUNCHING of 2 CENTAURE ROCKETS in February 1964, at Hammaguir, for the team of Dr. Lüst, Director of the Max Planck Institut für Extra-terrestriche Forschung (Munich), with a view to carrying out optical measurements on the ionisation of the upper atmosphere. (Communiqué CNES).

x

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FRENCH GUIANA (4^{o} lat. N): the study of a launching site is in progress.

x

x x

ITALY, end March: Sub-orbital test flight of a space vehicle launched from a floating platform off Kenya; this launching took place as part of the SAN MARCO project (American launcher).

x

x x

CONSTRUCTION IN AUSTRALIA (near Canberra) of a station for tracking and satellite data recovery under the terms of the AGREEMENT AUSTRALIA/UNITED STATES of 26 February 1960. (Communiqué NASA).

x

x x

LAUNCHING BY PAKISTAN OF THE FIRST METEOROLOGICAL ROCKET under the terms of a bilateral agreement between NASA and the Pakistan Space and Upper Atmosphere Research Committee. (Communiqué NASA).

x

x x

THE CANADIAN UNIVERSITY McGILL plans the launching in 1964, from the British West Indies, of 200 high altitude research rockets, MARTLET type, by a 16 inch Naval gun. (CNES review).

x

x x

THE LEGAL SUB-COMMITTEE of the UNITED NATIONS' SPACE COMMITTEE (28 Member States, of which 5 ESRO countries), held a 3 weeks' meeting in March on the RESPONSIBILITY FOR DAMAGES that might be caused by the launching of objects in space (United States, Hungary and Belgium presented draft agreements) and on ASSISTANCE TO COSMONAUTS (American and Russian proposals). Work will resume in August or September.

page 3

THE NEGOTIATIONS BETWEEN EUROPE AND UNITED STATES concerning TELECOMMUNICATIONS BY SATELLITES (London 6-8 April) were conducted on the basis of the document prepared by the European countries, members of the C.E.T.S. A meeting of experts will be held in Montreal in the near future to discuss the issues still unsettled.

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THE SUMMER SCHOOL of Space Technology organized by ESRO will be held in Oxford from 10 August to 3 September 1964. It will be open to qualified engineers and physicists. 20 Fellowships are provided.

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COLUMBIA UNIVERSITY has offered to receive representatives of ESRO at its Summer School on space technology and physics.

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American experts will give a series of lectures on the TECHNOLOGY OF METEOROLOGICAL SATELLITES, due to take place from 16-20 June and 23-27 June 1964 in Oslo and London respectively.

x
x x

CONTRACTS PLACED BY ESRO

- Problems associated with the stabilisation of medium satellites:
  Ministry of Aviation (U.K.).
- Preliminary design of a large astronomical satellite:
  Deutsche Versuchsanstalt für Luft und Raumsfahrt (Germany);
  Centre National d'Etudes Spatiales (France);
  Ministry of Aviation (U.K.).
- Preliminary design of ESRO II satellite:
  ACEC (Belgium);
  Eidgenössische Technische Hochschule (Switzerland).
- Study of the launching parameters of space probes:
  Instituto Nacional de Tecnica Aeronautica (Spain).
- Planning of the Kiruna range:
  A.I.B. (Sweden).

page 4

FORTHCOMING MEETINGS:

- 21 April, London. Technical Committee of the EUROPEAN CONFERENCE ON SATELLITE COMMUNICATIONS.
- 21 April, 19, Av. Kléber, Paris. Conference on the Orbiting Astronomical Observatory (OAO) by engineers of Grunman Int. Inc.
- 23 April, Paris. ESRO, Launching Programme Sub-Committee, (projects for ESRO I and ESRO II satellites; launching ranges etc.).
- 24 April, Paris, ESRO, Symposium on the Large Astronomical Satellite.
- 27-29 April, OECD. Committee of Scientific and Technical Personnel. (5th Meeting of Directors and Representatives of National Groups).
- 5 May, Paris. ELDO/CECLES, First meeting of the Council.
- 8-20 May, Florence. COSPAR, and Symposium on Space Sciences (12-16 May).
- 22 May - 12 June, Geneva. Scientific and Technical Sub-Committee of the United Nations' Committee on Outer Space.
- 23-27 May, Vienna. SCIENTIFIC AND PARLIAMENTARY CONFERENCE.
- 25-26 May, Paris. ESRO, temporary Scientific and Technical Committee.
- 19-21 June, Rome. European Space Symposium.
- 24-26 June, OCDE. Committee for Scientific Research.
- 7-11 September, Geneva. UNITED NATIONS' COMMITTEE on the Peaceful Uses of Outer Space.
- September, Warsaw, Annual Congress of the International Astronautical Federation.

OBITUARY:

Professor Julius BARTELS, vice-president of the German Commission for Space Research died on 6 March. He attended the last meeting of the COPERS Scientific and Technical Working Group held in Delft on 18 and 19 February 1964.

EUROPEAN SPACE RESEARCH ORGANISATION

CERS - ESRO 36, rue La Pérouse, Tel: 225 24-02 30 June 1964

NEWS IN BRIEF

I. ESRO NEWS*

FIRST LAUNCHINGS: The payloads for the first ESRO experiments have been mounted at ESTEC on two Skylark Rockets. They consist of baryum and ammonium releases at an altitude of approximately 200 km for the study of diffusion and photo-ionisation phenomena. One of the main reasons for the choice of these experiments is to prepare for more important space experiments, which would produce an artificial comet. If all goes according to plan, these rockets are to be launched at sunset or sunrise during the period 2 - 16 July, from Salto-di-Quirra, Sardinia. This period, which immediately precedes and follows the new moon, was chosen in order to minimise interference caused by moonlight.

STAFF MEMBERS WHO HAVE JOINED: Since May 15, 5 new engineers at ESTEC :

In the Projects Directorate Mr. OPALKA (F.R.G.) and Mr. EARNSHAW (U.K.) for sounding rockets; in the Instrumentation Division, Mr. FINNAMORE (U.K.) and Mr. LE PELTIER (France); to Civil Engineering Planning for Tracking Stations Mr. ROBISHAW (U.K.).

PARTICIPATION IN CONGRESSES AND CONFERENCES

- Professor Auger inaugurated a series of lectures on the Engineer and Space at Lausanne University (8 May) and spoke on space radiations at the Royal Society of Arts, London (13 May).
- COSPAR Assembly and Space Science Symposium (8-20 May, Florence): Sir Harrie Massey (member of the Executive Committee of COSPAR), Professor Auger, Dr. Lüst, Mr. Beattie, Dr. Dattner, Dr. Grossmann-Doerth, Professor di Benedetto.
- Second Scientific and Parliamentary Conference (23-27 May, Vienna): Mrs. Labeyrie-Menahem.
- European Conference on Satellite Communications:
  - at the sub-committee appointed to examine the possibilities for co-operation with other European Organisations (8 June, Paris) Mr. Bertrand and Dr. Dattner;
  - at the Plenary (Rome, 25 June): Prof. Auger and Dr. Dattner.

* Reports on meetings, and news of the Establishments will be combined in News in Brief, N° 5.

page 2

- In addition, a Conference was held in London on 9 June under the chairmanship of Sir Harrie Massey, with the participation of Dr. Ortner, to outline to United Kingdom physicists the possibilities of the ESRO programme.

PUBLICATIONS

- Report of the Working Group on the Large Astronomical Satellite (220 pp.).
- "Introduction to Sun-Earth Relations" - About 50 lectures delivered at the First ESRO Summer Course (Alpbach 1963) are to be published by the Reidel Co., Dortrecht, Netherlands.
- The british publication NATURE published, in its 30 May 1964 issue, an article on ESRO by Dr. Lines and Dr. Lüst.

II. OTHER NEWS

AGREEMENTS CONCERNING SPACE RESEARCH

FRANCO-INDIAN AGREEMENT (15 May 1964) for the construction under licence, in India, of sounding rockets "Bélier" and "Centaure", the assistance of the CNES for equipping a launching base in India, and exchanges of scientists and students.

o

FRANCO-SPANISH AGREEMENT (4 June, 1964) for the installation of a satellite control station in the island of Grand Canary. It is specified therein that the station will be able to participate in the activities of ESRO and other international or governmental organisations.

o

AGREEMENT between NASA and the MAX PLANCK INSTITUT für Kernphysik, in Heidelberg, on the collection of micrometeorites and their laboratory analysis* (Pressereferat der Bundesminister für wissenschaftliche Forschung, 30.4.64).

o

NASA and the SWEDISH SPACE COMMITTEE have agreed to extend for another year co-operative sounding rocket studies of the upper atmosphere and noctilucent clouds* (Cqé. NASA 5.6.64).

o

AUSTRALIA - NASA AGREEMENT for the installation of a tracking station near Canberra, in the Orroral Valley (Cqé. NASA, 12.3.64).

o

* Further information on this agreement can be obtained on application to the Secretariat.

page 3

In addition the Secretariat has received the text of earlier agreements*:

- Exchange of notes between the United States and the United Kingdom on Co-operation in Space Research (1961).
- Memorandum of understanding between the Norwegian Space Research Committee, The Ionospheric Research Laboratory of the Royal Technical Institute of Denmark and the United States National Aeronautics and Space Administration to sponsor scientific sounding rocket studies of the D-region of the ionosphere (1963).

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UNITED STATES-SOVIET CO-OPERATION

At the recent session of the Scientific and Technical Sub-Committee of the U.N. Committee on the Peaceful Uses of Outer Space, Mr. Blagonravov (U.S.S.R.) and Dr. Hugh Dryden (U.S.) announced a UNITED STATES-U.S.S.R. AGREEMENT:

1) on the co-ordinated launching of METEOROLOGICAL SATELLITES. (This agreement provides for the creation of a Washington-Moscow telecommunications link for the exchange of meteorological data supplied by satellites);

2) on scientific co-operation in the fields of SPACE MEDECINE and BIOLOGY.

Furthermore, NEGOTIATIONS are proceeding for the joint utilisation of telecommunications satellites.

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AGREEMENT between the EURATOM COMMISSION and the UNITED STATES ATOMIC ENERGY COMMISSION (USAEC) on the implementation of a comprehensive co-operation programme covering the development of rapid reactors. USAEC is also to supply EURATOM with plutonium and enriched uranium.

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MISCELLANEOUS

ELDO: the first experimental launching of the Blue Streak rocket took place on 5th June at Woomera.

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28th May: experimental launching of the APOLLO capsule by means of a SATURNE rocket (Cqé. NASA).

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* Further information on this agreement can be obtained on application to the Secretariat.

page 4

First two-way telephone call between the United States and Japan via communication satellites Relay I and Relay II (Cqé. NASA, 21 May).

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Creation of an IBERO-AMERICAN SPACE LAW INSTITUTE at Madrid (Argentina, Brazil, Costa Rica, Columbia, Equador, Guatemala, Mexico, Nicaragua, Panama, Peru, Uruguay) ("La Semaine espagnole" 25.5.64).

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1964 SPACE BUDGET of the FEDERAL REPUBLIC OF GERMANY: DM 158 millions (61 millions more than in 1963) including DM 51 millions of contributions to European space organisations.

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The first technological launchings of VERONIQUE 61 sounding rockets took place at Hammaguir (Algeria) on 8 and 13 June. The rocket culminated at 260 km (Cqé. CNES).

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PROBLEM-SOLVING A T O X SIMULATION

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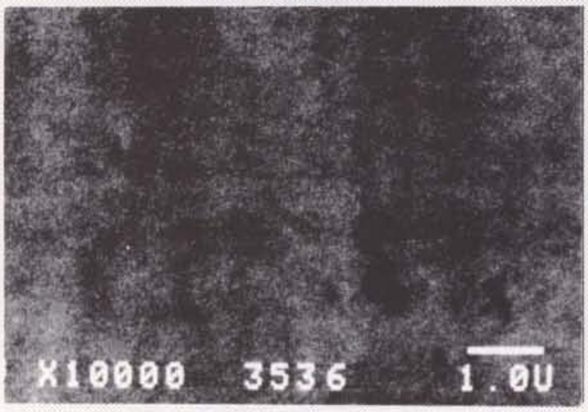
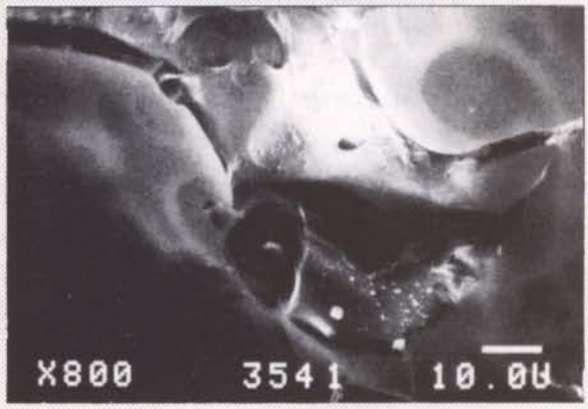


MYLAR film, Al Metallized, BEFORE being exposed to the flux of ATOX



MYLAR film subjected to DEGRADATION by the ATOX, due to FAILURE of the "PROTECTIVE" metallic layer

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