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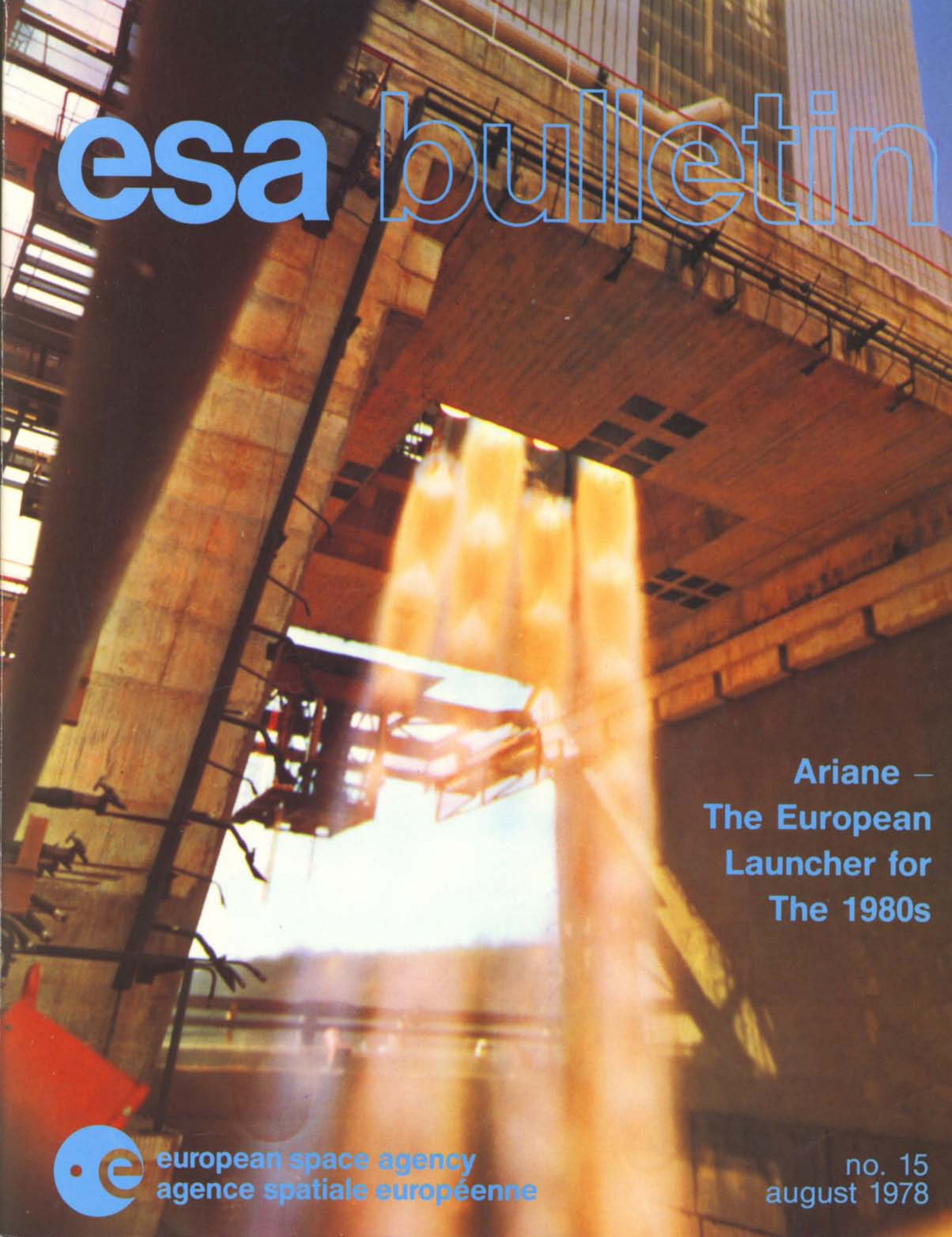

Ariane – The European Launcher for The 1980s

european space agency
agence spatiale européenne

no. 15
august 1978

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

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

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

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

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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

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

ESRIN, Frascati, Italy.

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

Director General: Mr. R. Gibson.

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

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

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

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

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

Le SIEGE de l'ESA est à Paris.

Les principaux Etablissements de l'ESA sont:

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

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

ESRIN, Frascati, Italie.

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Directeur général: M. R. Gibson.

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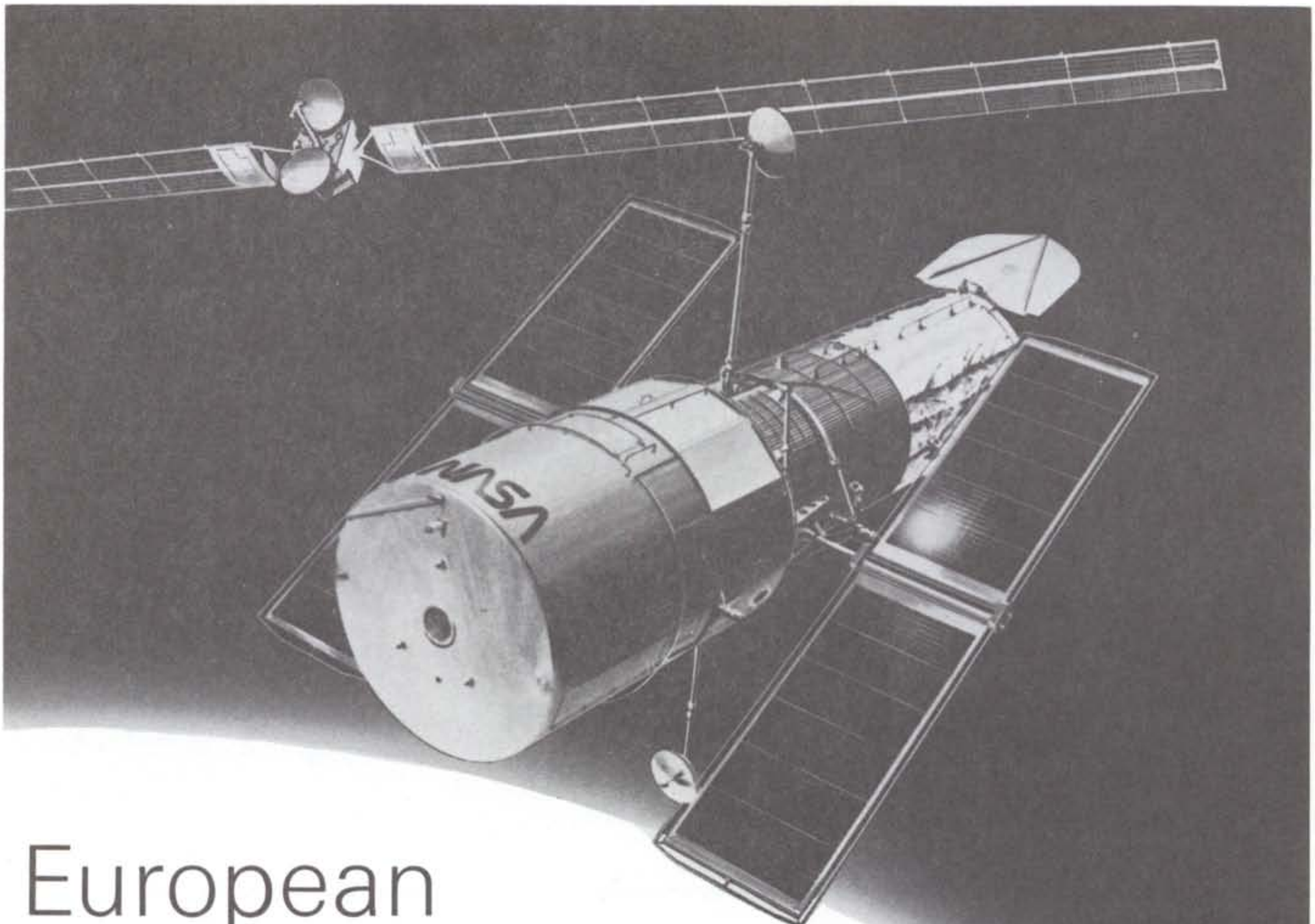
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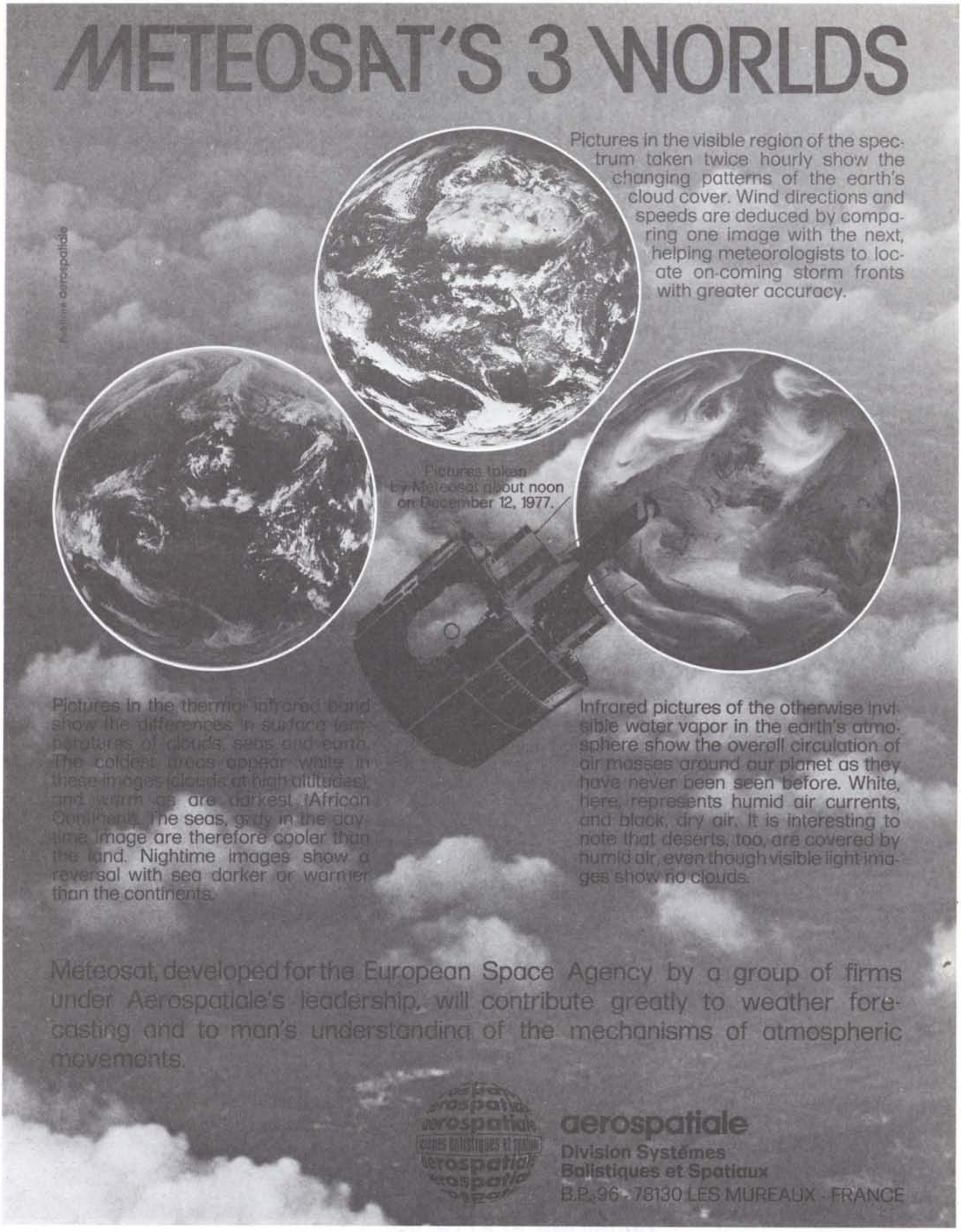

METEOSAT'S 3 WORLDS
Pictures in the visible region of the spectrum taken twice hourly show the changing patterns of the earth's cloud cover. Wind directions and speeds are deduced by comparing one image with the next, helping meteorologists to locate on-coming storm fronts with greater accuracy.
Pictures taken by Meteosat about noon on December 12, 1977.
Pictures in the thermal infrared band show the differences in surface temperatures of clouds, seas and earth. The coldest areas appear white in these images (clouds at high altitudes), and warm areas are darkest (African Continent). The seas, grey in the daytime image are therefore cooler than the land. Nightime images show a reversal with sea darker or warmer than the continents.
Infrared pictures of the otherwise invisible water vapor in the earth's atmosphere show the overall circulation of air masses around our planet as they have never been seen before. White, here, represents humid air currents, and black, dry air. It is interesting to note that deserts, too, are covered by humid air, even though visible light images show no clouds.
Meteosat, developed for the European Space Agency by a group of firms under Aerospatiale's leadership, will contribute greatly to weather forecasting and to man's understanding of the mechanisms of atmospheric movements.
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Introduction

R. Orye, Ariane Department/Département Ariane, ESA, Paris

The Ariane programme, which consists of a development phase followed by an operational (utilisation) phase, is one of the most important programmes ever undertaken by the European Space Agency. It originated from a proposal by the French Government in December 1972, and a subsequent decision in July 1973 by ESRO's Council, that the development phase would be carried out as an Agency programme. To this end, legal arrangements were concluded between ESRO and the participants in the programme (all the Member States of the Agency, except for Ireland and the United Kingdom, the latter participating in the programme under a bilateral agreement with France), and also between ESRO and CNES, which was to manage the programme for ESA.

The aim of the Ariane programme is to provide Europe with an independent launch capability as from late 1980 onwards. Surveys show that the World market for satellites in the period 1981–1990 could be substantial and that Europe is in a position to acquire a significant number of launches, particularly in the applications-satellite field. It would already seem that European missions alone will guarantee two launches per year, a figure that could be raised to four or five by vigorous sales promotion at European level.

After five years of development work and less than a year before the first test flight, scheduled for June 1979, the programme is proceeding according to plan. The period between now and this first flight will be devoted mainly to 'finishing touches' and qualification of the launcher stages and equipment bay, as well as the commissioning of the Ariane launch base, at Kourou in French Guiana. The other three test flights are scheduled for December 1979, May 1980 and October 1980. They will complete the qualification of Ariane, which will then be available for operational launches from late 1980 onwards.

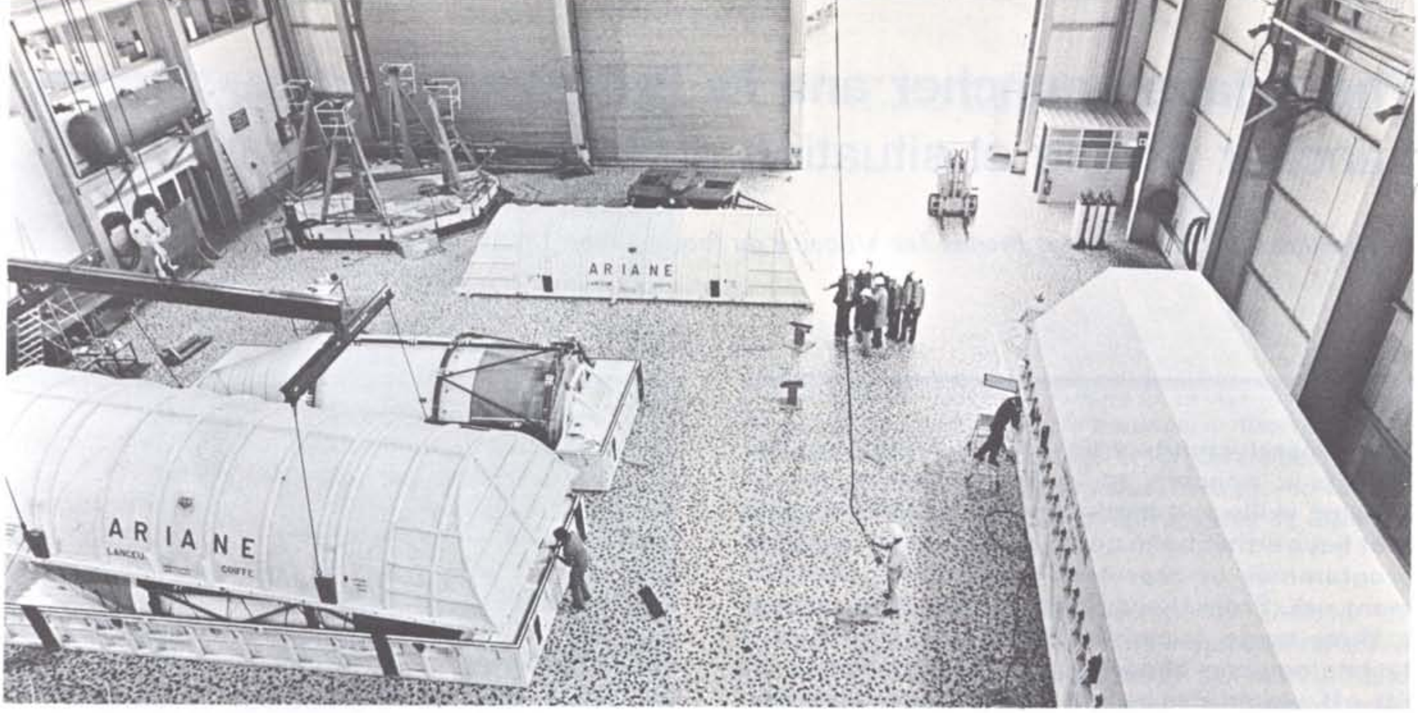
The decision by the ESA Council to begin manufacture of a series of five launchers, to be available from late 1980, constitutes another important milestone. The size of this first series is justified by the number of approved programmes making use of Ariane launches: namely, the scientific satellite Exosat (launch foreseen for second quarter 1981), the Marecs-B satellite (second quarter 1981), the ECS-1 satellite (fourth quarter 1981), all of which are ESA programmes, and the French earth-

Le programme Ariane, qui comprend une phase de développement du lanceur suivie d'une phase d'utilisation opérationnelle, est l'un des plus importants programmes jamais entrepris par l'Agence Spatiale Européenne. Ce programme prend son origine dans une proposition faite par le Gouvernement français en décembre 1972; en juillet 1973, le Conseil du CERS – devenu depuis lors l'ESA – décidait que la phase de développement serait exécutée comme programme de l'Agence. A cet effet, des arrangements juridiques étaient conclus, d'une part entre le CERS et les participants au programme (tous les Etats membres de l'Agence, à l'exception de l'Irlande et du Royaume-Uni, ce dernier Etat participant au programme par le biais d'un accord bilatéral avec la France), et d'autre part entre le CERS et le CNES, gérant le programme pour le compte de l'ESA.

L'objectif du programme Ariane est de doter l'Europe d'une capacité autonome de lancement à partir de la fin de 1980. Une prospection continue du marché mondial des satellites de la période 1981/1990 en montre l'importance et fait ressortir qu'un nombre important de lancements peut être capté par l'Europe, surtout dans le domaine des applications. Un rythme de deux lancements par an semble dès à présent garanti pour les seules missions européennes; ce rythme peut être porté à quatre ou cinq moyennant une activité de promotion vigoureuse au niveau européen.

Après cinq années de développement, et pratiquement un an avant le premier essai en vol prévu pour juin 1979, le développement se déroule suivant le calendrier prévu. La période qui nous sépare de ce premier essai sera principalement consacrée à la mise au point finale et à la qualification des étages et de la case à équipement du lanceur, ainsi qu'à la mise en service de la Base de lancement située à Kourou en Guyane française. Les trois autres essais en vol sont prévus pour décembre 1979, mai 1980 et octobre 1980. Une fois acquise la qualification du lanceur, Ariane sera disponible pour des lancements opérationnels à partir de la fin 1980.

Une autre étape importante vient d'être franchie avec la décision du Conseil de l'Agence de lancer la fabrication d'une série de cinq Ariane, qui doivent être disponibles à partir de 1980. Le volume de cette première série se justifie par le nombre de programmes approuvés faisant appel à



Transport of the Ariane propellant mock-up from the Launch Integration Site (SIL), Les Mureaux, France, on route for the Launch Base in French Guiana/Transport de la maquette ergols d'Ariane du Site d'intégration lanceur (SIL), Les Mureaux, France vers la Base de Lancement en Guyane française.

observation satellite SPOT, scheduled for launch in late 1983. Other European missions, such as the second unit of the ECS programme and the heavy satellite, H-Sat, will very probably also rely on Ariane launchers.

In addition, ESA has undertaken a campaign aimed at markets outside Europe. For example, after very thorough studies conducted in conjunction with the INTELSAT Organisation, ESA has tendered for the launch by Ariane of units 5, 6 and 7 of Intelsat-V, competing against the NASA tender for launch services using the Space Shuttle. These tenders are now being evaluated, and a decision is due to be made this autumn. The importance of this decision, not only for Ariane but for European aerospace industry as a whole, is self-evident.

If demand from the users justifies, steps will be taken in conjunction with industry to either extend manufacture of the first series or undertake a second one.

By way of conclusion, I should like to take this opportunity to thank all those who have contributed, and I am sure will continue to do so, to the success of the programme – the Delegations to the Ariane Launcher Programme Board and in particular its Chairman, Mr van Eesbeek, the many European industrialists, the staff of CNES, which manages the programme, and the ESA staff, all of whom have worked unstintingly on this programme.

des lancements par Ariane: le satellite scientifique Exosat (lancement prévu: 2ème trimestre 1981), le satellite Marecs-B (2ème trimestre 1981), le satellite ECS-1 (4ème trimestre 1981), tous programmes de l'Agence, ainsi que le satellite français d'observation de la Terre SPOT (fin 1983). D'autres missions européennes, telles que la deuxième unité du programme ECS et le satellite lourd H-Sat, feront très vraisemblablement appel à Ariane.

Finalement, l'Agence a entrepris un effort visant les marchés extérieurs à l'Europe. C'est ainsi par exemple que, suite à des études très poussées entreprises avec l'Organisation INTELSAT, l'ESA a fait une offre pour le lancement des unités 5, 6 et 7 d'Intelsat-V par Ariane, en compétition avec l'offre de la NASA pour des services de lancement au moyen de la Navette spatiale. Ces offres sont en cours d'évaluation, et une décision devrait intervenir au cours de l'automne de cette année. L'importance de cette décision pour Ariane, mais aussi pour l'industrie aérospatiale européenne, n'échappera à personne.

En cas de besoin, les mesures industrielles seront prises, soit par l'accroissement de la première série, soit par le lancement d'une deuxième série, pour faire face aux demandes des utilisateurs.

Qu'il me soit permis à cette occasion de remercier tous ceux qui ont contribué et, j'en suis sûr, continueront de contribuer au succès du programme: les délégations au Conseil directeur Ariane et plus particulièrement son Président, M. van Eesbeek, les nombreux industriels européens et, enfin, le personnel du CNES, gestionnaire du programme, et le personnel de l'Agence qui, tous, se dépensent sans compter pour ce programme. □

The Ariane Launcher and its Progress
Lanceur Ariane et situation du programme

R. Vignelles & P. Rasse, Ariane Project Team/Equipe du Projet Ariane, CNES, Evry, France

The general architecture of the Ariane vehicle reflects a concern to make maximum use of existing skills and hardware and of technologies that have either been qualified previously in other programmes or represent a minimum development risk. From the various possible alternatives, a three-stage launcher based on conventional technology was chosen which, though heavier at lift-off, would also be less costly to develop and to produce than one involving major technical innovations. Optimisation of the propellant masses of each stage and the general dimensions of the vehicle led to different diameters being adopted for the first stage and for the two upper stages. However, adoption of a bulb-shaped fairing provides sufficient usable volume to house large satellites. The only advanced propulsion technology employed is that of the third stage, where use of liquid hydrogen and liquid oxygen has allowed the requisite performance to be obtained without unduly increasing vehicle dimensions.

L'architecture générale du lanceur Ariane résulte du souci d'utiliser au mieux les compétences et matériels existants, ainsi que les technologies, soit antérieurement qualifiées au titre d'autres programmes soit présentant un minimum d'aléas de développement. Parmi les diverses options possibles, on a retenu celle d'un lanceur triétage de technologie classique, plus lourd au décollage, mais aussi moins coûteux en développement comme en production qu'un lanceur présentant des innovations techniques majeures. L'optimisation des masses d'ergols de chaque étage et des dimensions générales du lanceur ont conduit à retenir un diamètre différent pour le premier étage et pour les deux étages supérieurs. Cependant, l'adoption d'une coiffe bulbe offre un volume utile suffisant pour loger les grands satellites. La seule technique avancée, adoptée en matière de propulsion, est celle du troisième étage à hydrogène et oxygène liquides qui doit permettre d'obtenir les performances voulues sans augmenter excessivement les dimensions du lanceur.

DESCRIPTION OF THE LAUNCHER

Ariane is a three-stage launcher with a total height of 47.4 m and weighing 208 t at lift-off, 90% of the mass being constituted by propellant. The structures and the payload account for about 9% and 1% of the total weight, respectively.

FIRST STAGE (L 140)

The first stage weighs 13.2 t empty and has a height of 18.4 m and a diameter of 3.8 m. It is equipped with four Viking-V engines, developing a thrust of 2445 kN (about 245 t) at lift-off and 2745 kN in vacuo (specific impulse 281.3 s).

The 147.5 t of propellants (UDMH and N_2O_4) – of which 815 kg remain unburnt after 145 s of flight – are contained in two identical tanks of 15 CDV - 6 steel connected by a cylindrical skirt.

DESCRIPTION DU LANCEUR

Ariane est une fusée à trois étages de 47,4 m de hauteur totale, pesant 208 t au décollage avec 90% de la masse représentée par les propergols. Les structures et la charge utile représentent respectivement environ 9% et 1% de la masse totale.

PREMIER ETAGE (L 140)

Le premier étage pèse 13,2 t à vide et mesure 18,4 m de hauteur pour 3,8 m de diamètre. Il est équipé de quatre moteurs Viking-V qui développent une poussée de 2445 kN (~245 t) au décollage et 2745 kN dans le vide (impulsion spécifique 281,3 s).

Les 147,5 t d'ergols (UDMH et N_2O_4) – dont il reste 815 kg d'imbrûlés après 145 s de vol – sont contenus dans deux réservoirs identiques en acier 15 CDV-6 reliés par une jupe cylindrique.

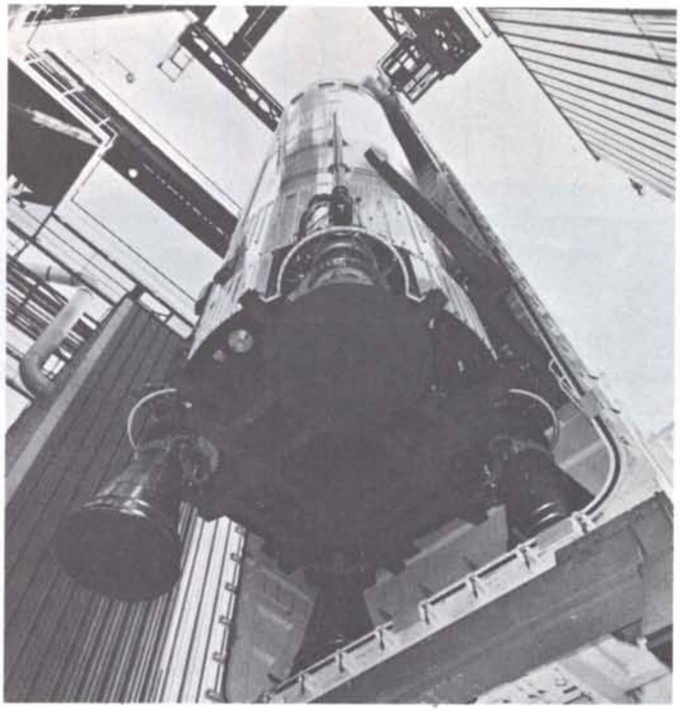


Figure 1 – The first stage on the test stand at Vernon (France)/ Le premier étage sur le banc d'essai à Vernon (France).

The whole of the lower part of the stage, which comprises the four engines, the thrust frame, the water tank, propulsion-system accessories, the cowlings and the fins for aerodynamic stabilisation during atmospheric flight, constitutes the propulsion bay of the L 140 stage.

The four turbopump engines and 54 bar combustion chambers are mounted symmetrically on the thrust frame and can be swivelled in pairs about two orthogonal axes to provide three-axis control. The propellant feed is provided by a turbopump with a flow of 270 kg/s at a pressure of 70 bar. Propellant intake is effected through a radial injector. The refractory steel chamber has a single wall cooled by propellant film injected along the wall and is fitted with a bell-shaped nozzle with a graphite throat. To avoid pump cavitation, the tanks are pressurised to about 5 bar by the gases produced by the generator associated with each engine. This generator uses the same propellants as the main engine, but the gases are cooled by water injection. They power the turbine of the turbopump unit of each Viking engine as well as the hot-gas motor of each of the four actuators that command the swivelling of the engines.

SECOND STAGE (L 33)

The second stage weighs 3.22 t empty (without the interstage and the jettisonable acceleration rockets) and has a height of 11.6 m and a diameter of 2.6 m. It is equipped with a Viking-IV engine which develops 717 kN of thrust in vacuo (specific impulse 294 s). The engine is

L'ensemble de la partie inférieure de l'étage qui regroupe les quatre moteurs, le bâti de poussée, le réservoir d'eau, les accessoires de propulsion, les carénages et les empennages de stabilisation aérodynamique du lanceur pendant le vol atmosphérique, constitue la baie de propulsion du L 140.

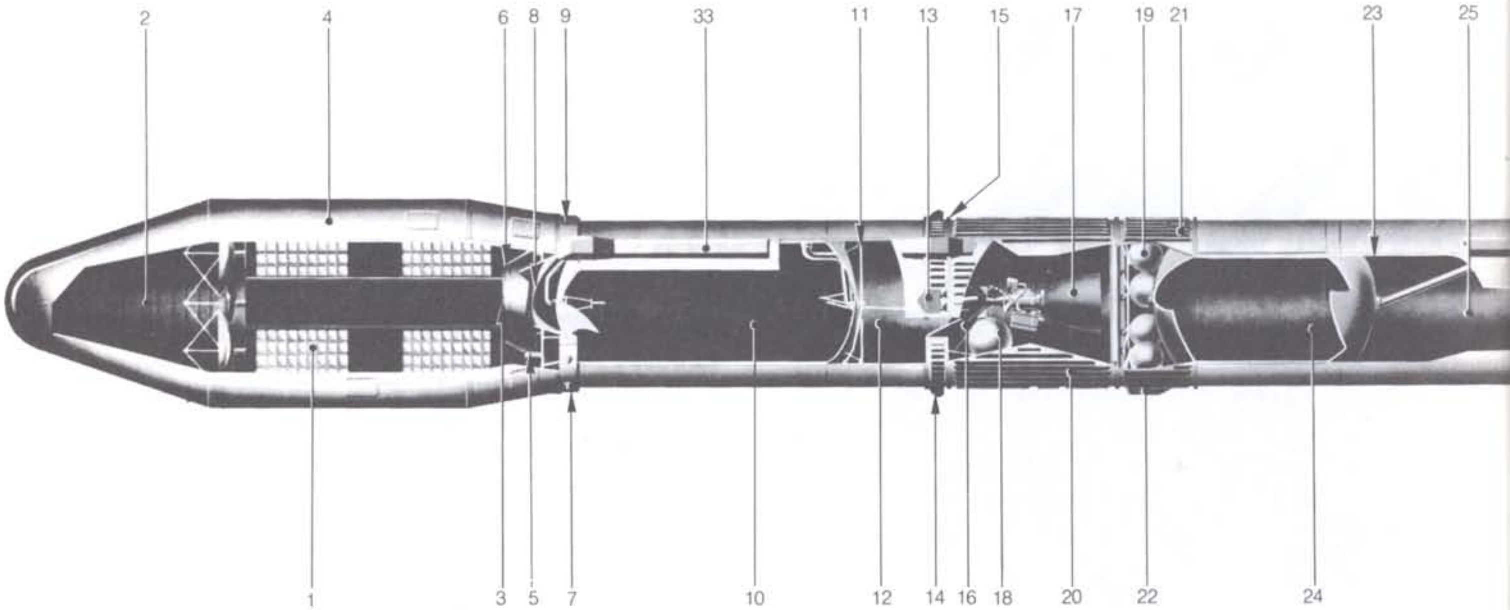
Les quatre moteurs à turbopompe et chambre de combustion à 54 bar sont fixés symétriquement sur le bâti de poussée et articulés par paires selon deux axes orthogonaux pour assurer le pilotage sur les trois axes. L'alimentation en propergols est assurée par une turbopompe débitant 270 kg/s sous 70 bar de pression. L'admission des ergols se fait à travers un injecteur radial. La chambre en acier réfractaire est à simple paroi, refroidie par film de combustible injecté le long de la paroi, avec un divergent en forme coquetier muni d'un col de graphite. Pour éviter la cavitation des pompes, les réservoirs sont pressurisés à environ 5 bar par les gaz du générateur associé à chaque moteur. Ce générateur utilise les mêmes ergols que le moteur principal mais les gaz sont refroidis par injection d'eau. Ils entraînent la turbine du groupe turbopompe de chaque moteur ainsi que le moteur à gaz de chacun des quatre vérins permettant de contrôler le braquage des moteurs.

DEUXIEME ETAGE (L 33)

Le deuxième étage pèse 3,22 t à vide (sans l'interétage et les fusées largables d'accélération) et mesure 11,6 m de haut pour 2,6 m de diamètre. Il est équipé d'un moteur Viking-IV qui développe une poussée de 717 kN dans le vide (impulsion spécifique 294 s). Le moteur est lié au bâti de poussée tronconique par un cardan à deux degrés de liberté pour le pilotage en tangage et lacet, le pilotage en roulis étant assuré par des tuyères auxiliaires alimentées en gaz chauds prélevés sur le générateur de gaz de l'étage. Les deux réservoirs – en alliage d'aluminium A-Z5G à fond intermédiaire commun – sont pressurisés à l'hélium gazeux (3,5 bar) et contiennent 34,2 t d'ergols (UDMH et N_2O_4) dont il reste 137 kg d'imbrûlés après 138 s de vol.

TROISIEME ETAGE (H8)

Le troisième étage qui pèse 1,157 t à vide et mesure 9,08 m de hauteur pour 2,6 m de diamètre, est le premier étage cryogénique réalisé en Europe. Equipé d'un moteur



1. Typical payload
2. Fairing separation plane
3. Third-stage/Payload separation plane
4. Fairing
5. Equipment-bay subsystems
6. Payload adaptor
7. Vehicle equipment bay (VEB)
8. Sealing membrane
9. Antennas
10. Liquid-hydrogen tank
11. Anti-sloshing
12. Liquid-oxygen tank
13. Acceleration rockets (4)
14. Roll and attitude command system (RACS)
15. 2/3 separation plane
16. Third-stage thrust frame
17. Third-stage engine HM-7
18. Helium pressurisation tank
19. Helium pressurisation tanks
20. Interstage 2/3
21. Second-stage front skirt
22. Retro rockets (3)
23. Anti-sloshing
24. N_2O_4 tank
25. UDMH tank
26. Acceleration rockets (6)
27. Second-stage thrust frame
28. 1/2 separation plane
29. Second-stage toric water tank
30. Interstage 1/2
31. Second-stage engine – 1 Viking-IV
32. Retro rockets (8)
33. External cable duct
34. N_2O_4 tank
35. N_2O_4 pipes
36. Intertank skirt
37. UDMH tank
38. First-stage thrust frame
39. First-stage toric water tank
40. Fins
41. Fairings
42. First-stage engines – 4 Viking-V

Figure 2 – The Ariane launch vehicle (cut-away view)/

attached to the tapered thrust frame by a gimbal with two degrees of freedom for pitch and yaw control, roll control being effected by auxiliary jets fed with hot gas tapped from the stage gas generator. The two propellant tanks are of A-Z5G aluminium alloy, have a common bulkhead, and are pressurised with gaseous helium (3.5 bar); they contain 34.2 t of propellants (UDMH and N_2O_4) of which 137 kg remain unburnt after 138 s of flight.

THIRD STAGE (H8)

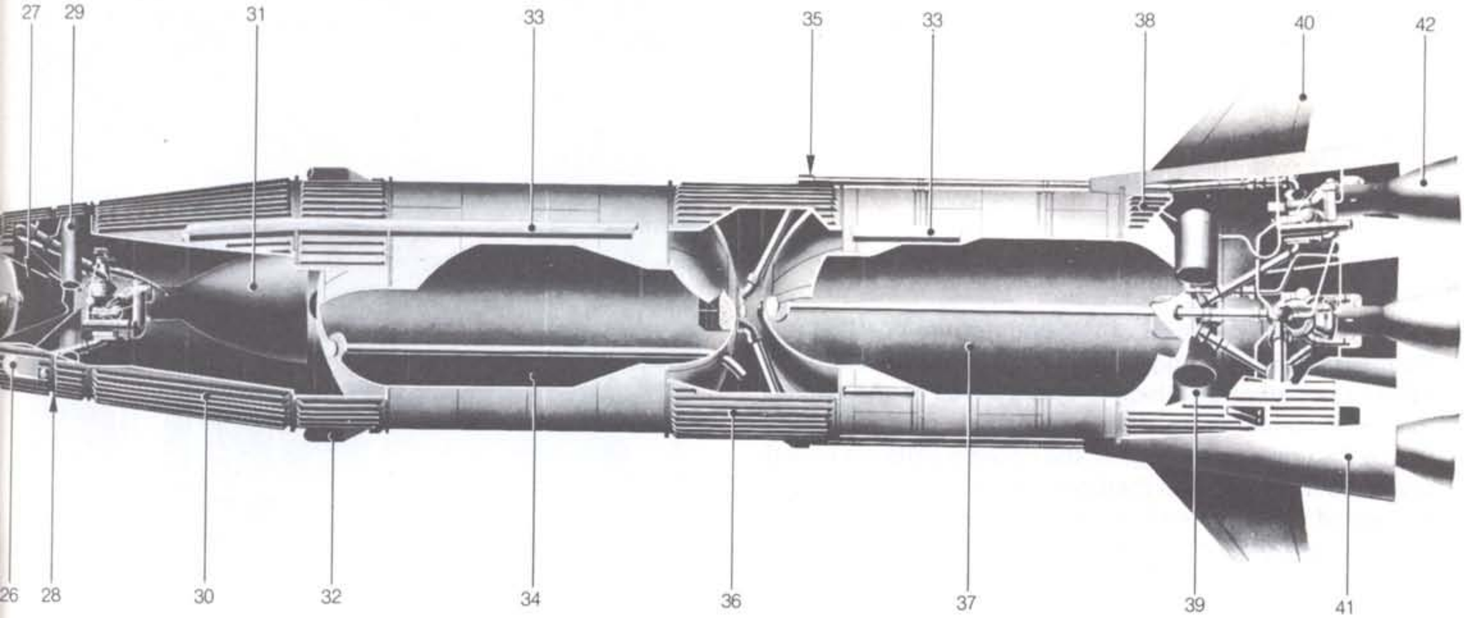
The third stage is the first cryogenic stage developed in Europe. It weighs 1.157 t empty and is 9.08 m high and 2.6 m in diameter. It is equipped with an HM-7 engine, which develops a thrust of 60 kN (specific impulse 441 s).

The two tanks, which contain 8.23 t of propellants (liquid

HM-7, il développe une poussée de 60 kN (impulsion spécifique 441 s).

Les deux réservoirs, qui contiennent 8,23 t d'ergols (hydrogène et oxygène liquides) dont il reste 67 kg d'imbrûlés après 570 s de vol, sont en alliage d'aluminium A-Z5G, choisi pour sa bonne tenue à la température de l'hydrogène liquide (−20 K), avec un fond commun intermédiaire (à double paroi sous vide). Ils sont revêtus d'une protection thermique externe en Klégecell pour éviter l'échauffement des ergols. Les réservoirs d'hydrogène et d'oxygène sont pressurisés en vol respectivement à l'hydrogène gazeux et à l'hélium.

La turbine du moteur alimentée par les gaz d'un générateur entraîne à 12 000 tr/mn la pompe à oxygène et à 60 000 tr/mn la pompe à hydrogène. La chambre de



1. Charge utile
2. Plan de séparation coiffe
3. Plan de séparation 3ème étage/charge utile
4. Coiffe
5. Equipements case
6. Adaptateur charge utile
7. Case à équipements
8. Membrane d'étanchéité
9. Antennes
10. Réservoir d'hydrogène liquide
11. Anti-ballottant
12. Réservoir d'oxygène liquide
13. Fusées d'accélération (4)
14. Systèmes de contrôle attitude et roulis (SCAR)
15. Plan de séparation 2/3
16. Bâti moteur du 3ème étage
17. Moteur du 3ème étage HM7
18. Sphère d'hélium de pressurisation
19. Sphères d'hélium de pressurisation
20. Jupe inter-étages 2/3
21. Jupe avant du 2ème étage
22. Fusées de freinage (3)
23. Anti-ballottant
24. Réservoir N_2O_4
25. Réservoir UDMH
26. Fusées d'accélération (6)
27. Bâti moteur du 2ème étage
28. Plan de séparation 1/2
29. Tore d'eau du 2ème étage
30. Jupe inter-étages 1/2
31. Moteur du 2ème étage – 1 Viking IV
32. Fusées de freinage (8)
33. Gouttière électrique
34. Réservoir N_2O_4
35. Canalisations d'arrivée N_2O_4 (4)
36. Jupe inter-réservoirs
37. Réservoir UDMH
38. Bâti moteur du 1er étage
39. Tore d'eau du 1er étage
40. Empennages
41. Carénages
42. Moteurs du 1er étage – 4 Viking V

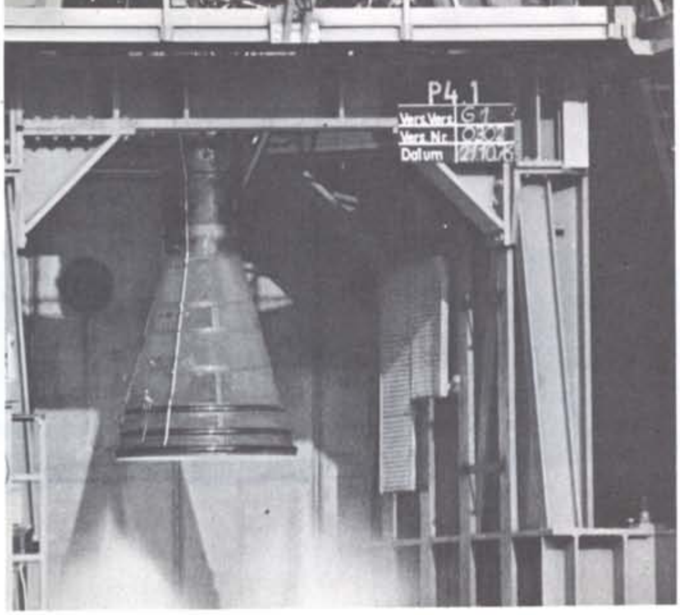
Le lanceur Ariane (vue écorchée).

hydrogen and liquid oxygen), of which 67 kg are unburnt after 570 s of flight, are made of A-Z5G aluminium alloy, chosen for its good behaviour at the temperature of liquid hydrogen (−20 K), and have a common bulkhead (two walls separated by a vacuum). They are clad with an external thermal protective layer of Klégecell to prevent the heating of propellants. The hydrogen and oxygen tanks are pressurised in flight by gaseous hydrogen and helium, respectively.

The engine turbine, which is fed by the gases from a generator, drives the oxygen pump at 12 000 rpm and the hydrogen pump at 60 000 rpm. The combustion chamber is of the regenerative-cycle type. The walls are cooled by the circulation of fuel through a network of slots adjacent to the chamber before its admission to the axial injector, which consists of 90 elements arranged in concentric

combustion est à cycle régénératif. Les parois sont refroidies par le passage de carburant circulant dans un réseau de canaux contigus à la chambre avant son admission dans l'injecteur axial constitué de 90 éléments concentriques. La réalisation du corps de la chambre de combustion fait appel à une technologie originale (de MBB) dont le brevet est également utilisé aux Etats-Unis pour la réalisation de la chambre de combustion du moteur principal de la Navette spatiale: les canaux de refroidissement sont fraisés dans une ébauche de cuivre et sont ensuite recouverts par un dépôt électrolytique de nickel. La chambre est prolongée par un divergent en forme de coquetier composé de tubes en Inconel enroulés en spirale dont le refroidissement est assuré par une circulation d'hydrogène qui se vaporise dans les canaux. Le moteur est lié au bâti de poussée tronconique par l'intermédiaire d'un cardan permettant le pilotage en

Figure 3 – Test firing of the second stage's Viking engine at Hardthausen (Germany)/Tir du moteur Viking du deuxième étage à Hardthausen (Allemagne).



circles. The construction of the body of the combustion chamber relies on original technology (developed by MBB) the patent of which is also applied in the United States in constructing the combustion chamber of the Space Shuttle's main engine: the cooling slots are milled in a copper casting and then covered with an electrolytic deposit of nickel. The chamber opens into a bell-shaped nozzle consisting of spiralled tubes of Inconel cooled by the circulation of hydrogen which vaporises in the slots. The engine is attached to a tapered thrust frame, gimbal-mounted for pitch and yaw control, roll control being provided by auxiliary nozzles which eject gaseous hydrogen.

Stage separation is achieved by linear shaped pyrotechnic charges located in the aft skirts of the second and third stages. The stages are moved apart by retro-rockets mounted on the lower stage and acceleration rockets attached to the upper stage.

EQUIPMENT BAY

The equipment bay weighs 319 kg and is 2.66 m in diameter and 1.15 m high. It is mounted on the third stage and houses the vehicle's electronic equipment, supports the payload and provides the attachment points for the fairing. In it are centralised all the launcher functions (sequencing, guidance, flight control, tracking, destruction and telemetry). Only the actuating and executive systems are distributed among the stages.

The guidance and control system, based on a digital computer and an inertial platform, detects the vehicle's attitude and measures its acceleration. From this information and the instructions contained in the guidance program, the computer provides navigation and guidance. It generates and transmits attitude-correction commands to the stages of the launcher. An analogue flight-control unit mixes the required attitude deviations (provided by the computer) with the information supplied by the rate gyros. After filtering the structural and liquid-sloshing critical modes, the autopilot sends commands to the hydraulic actuators that swivel the engines, as well as commands for the opening of the roll-control jets of the second stage and the attitude-control jets of the third stage. At the end of flight, when the velocity corresponding to the desired orbit is attained, the computer orders

tangage et lacet. Des tuyères auxiliaires éjectant de l'hydrogène gazeux assurent le pilotage en roulis.

Les séparations des étages sont effectuées par cordeaux découpeurs pyrotechniques situés sur la jupe arrière des deuxième et troisième étages. Les étages sont écartés l'un de l'autre par des rétrofusées placées sur l'étage inférieur et par des fusées d'accélération disposées sur l'étage supérieur.

CASE D'EQUIPEMENTS

La case d'équipements pèse 319 kg et mesure 2,66 m de diamètre pour 1,15 m de hauteur. Placée au dessus du troisième étage, elle renferme les équipements électroniques du lanceur, supporte la charge utile et sert de point d'attache à la coiffe. Dans la case sont centralisées toutes les fonctions du lanceur (séquentiel, guidage, pilotage, localisation, destruction, télémesure). Seuls les organes de puissance et d'exécution sont répartis dans les étages.

La chaîne de guidage et de pilotage, organisée autour d'un calculateur numérique et d'une centrale inertielle, assure la détection d'attitude et la mesure des accélérations du lanceur. A partir de ces informations et des instructions contenues dans le programme de guidage, le calculateur effectue la navigation et le guidage. Il élabore et transmet les ordres de corrections d'attitude aux étages du lanceur. Un bloc de pilotage analogique mélange les écarts d'attitude à effectuer (issus du calculateur) avec les informations fournies par les gyromètres. Après filtrage des modes critiques de structure et de ballottement des liquides, le bloc de pilotage envoie les ordres de braquage aux vérins hydrauliques orientant les moteurs, et les ordres d'ouverture des tuyères de roulis du deuxième étage et de celles de contrôle d'attitude du troisième étage. En fin de vol, lorsque la vitesse correspondant à l'orbite désirée est atteinte, le calculateur ordonne l'arrêt propulsion cut-off. The precision thus obtained is of the order of 5 m/s for a velocity of more than 10 000 m/s.

FAIRING

The fairing weighs 826 kg and is 3.2 m in diameter and 8.65 m high (external dimensions). It protects the payload during the ascent through the atmosphere and is jettisoned during the flight of the second stage, at an altitude of about 110 km. It consists of two half-shells of aluminium with a boat-tail section of laminated material which is radio transparent. Its useful volume of 35 m^3 allows large geostationary satellites of the Intelsat-V or H-Sat type to be carried, or two medium size satellites mounted one above the other in the 'Ariane dual launch system' (Sylda).

de la propulsion. La précision ainsi obtenue est de l'ordre de 5 m/s sur une vitesse de plus de 10 000 m/s.

COIFFE

La coiffe pèse 826 kg et mesure 3,2 m de diamètre pour 8,65 m de hauteur (dimensions extérieures). Protégeant la charge utile pendant la traversée de l'atmosphère, elle est larguée pendant le vol du deuxième étage, à environ 110 km d'altitude. Elle est constituée de deux demi-coquilles en aluminium avec un rétreint en stratifié transparent aux émissions radio-électriques. Son volume utile de 35 m^3 permet de lancer de grands satellites géostationnaires du type Intelsat-V, H-Sat, ou deux satellites de taille moyenne superposés dans le système de lancement double Ariane (Sylda).

PROGRESS IN THE PROGRAMME

In rather less than a year (in June 1979) the first Ariane flight test will take place at the Guiana Space Centre. Now that the ground testing of the various launcher sub-systems is coming to an end and the stage and system tests are in full swing, it is perhaps appropriate to review the programme as a whole.

SYSTEM STUDIES

The general studies for the launcher (trajectory, performance, aerodynamics, flight control, stresses, dynamics, guidance, flight mechanics, thermal and acoustic) have been conducted in several iterations as hardware definition and tests have progressed. They are now largely completed, and work in this area is concentrated on adjustments and preparations for the first flight (LO1) and its exploitation.

These studies, carried out by Aérospatiale (programme system integrator), checked by CNES and, in critical cases, confirmed by independent studies carried out by ONERA, have been the subject of intense critical examination and verification. Ground testing and flight simulation have allowed the coherence of subsystem

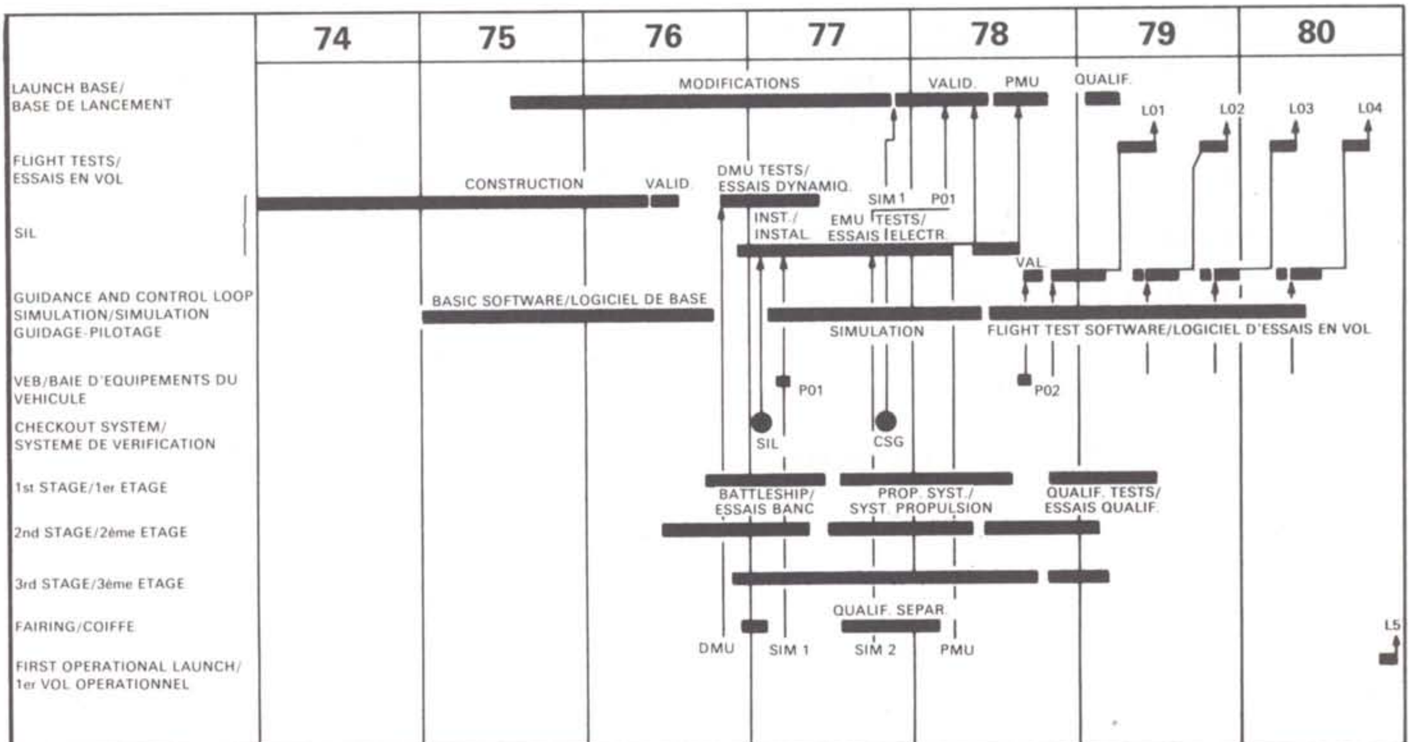
SITUATION DU PROGRAMME

C'est dans moins d'un an (en juin 1979) qu'aura lieu le premier essai en vol du lanceur Ariane à partir du Centre Spatial Guyanais. Au moment où les essais au sol des différents sous-systèmes du lanceur s'achèvent et où les essais d'étages et de système sont bien engagés, il est utile d'effectuer une analyse d'ensemble du programme.

ETUDES SYSTEME

Les études générales du lanceur (trajectoires, performances, aérodynamique, pilotage, efforts généraux, études dynamiques, guidage, mécanique du vol, thermique, acoustique) ont été effectuées en plusieurs itérations au fur et à mesure que la définition des matériels et les essais ont progressé. Elles sont maintenant terminées dans l'ensemble; les travaux dans ce domaine sont concentrés sur les réglages et la préparation du vol L01 et son exploitation.

Ces études effectuées par l'Aérospatiale, Architecte industriel du programme, contrôlées par le CNES et, dans les cas critiques, validées par des études contradictoires menées par l'ONERA, ont subi un niveau d'examen critique et de vérification très poussé. A l'aide des essais



EMU : ELECTRICAL MOCK-UP/MAQUETTE ELECTRIQUE
DMU : DYNAMIC MOCK-UP/MAQUETTE DYNAMIQUE
PMU : PROPELLANT MOCK-UP (SCALE ONE MOCK-UP IN FLIGHT CONFIGURATION, FOR VALIDATION OF ALL FILLING AND PRESSURISATION PROCEDURES ON THE LAUNCH SITE)/ MAQUETTE ERGOL (MAQUETTE A L'ECHELLE 1 EN CONFIGURATION DE VOL, VALIDATION DE TOUTES LES PROCEDURES DE REMPLISSAGE ET DE PRESSURISATION SUR LE SITE DE LANCEMENT).
SIL : INTEGRATION BUILDING/SITE D'INTEGRATION DU LANCEUR (LES MUREAUX – FRANCE)
VEB : VEHICLE EQUIPMENT BAY/ BAIE D'EQUIPEMENTS DU VEHICULE
CSG : CENTRE SPATIAL GUYANAIS

Figure 4 – General planning scheme for the Ariane programme/Planning général du programme Ariane.

specifications and the various margins and dispersions to be checked.

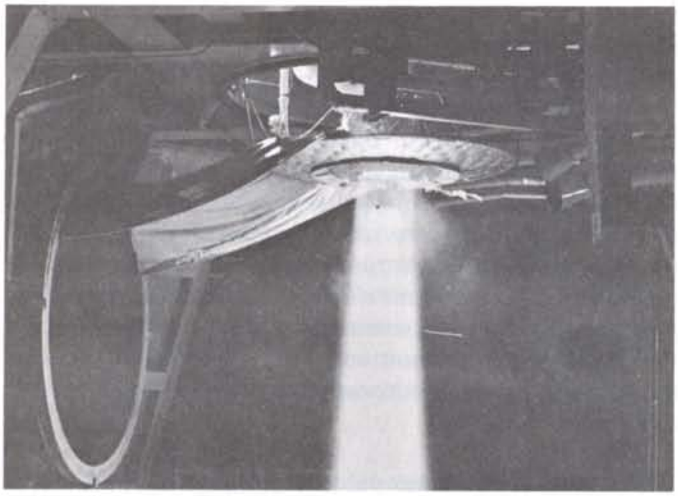
It is noteworthy that the general performance currently guaranteed to Ariane users is a satellite mass of 1700 kg in transfer orbit (200/36 000 km), appreciably more than the 1500 kg in the original specification. This remarkable improvement achieved during the development, a rare occurrence in the aerospace field, results mainly from the care with which the hardware specifications were drawn up.

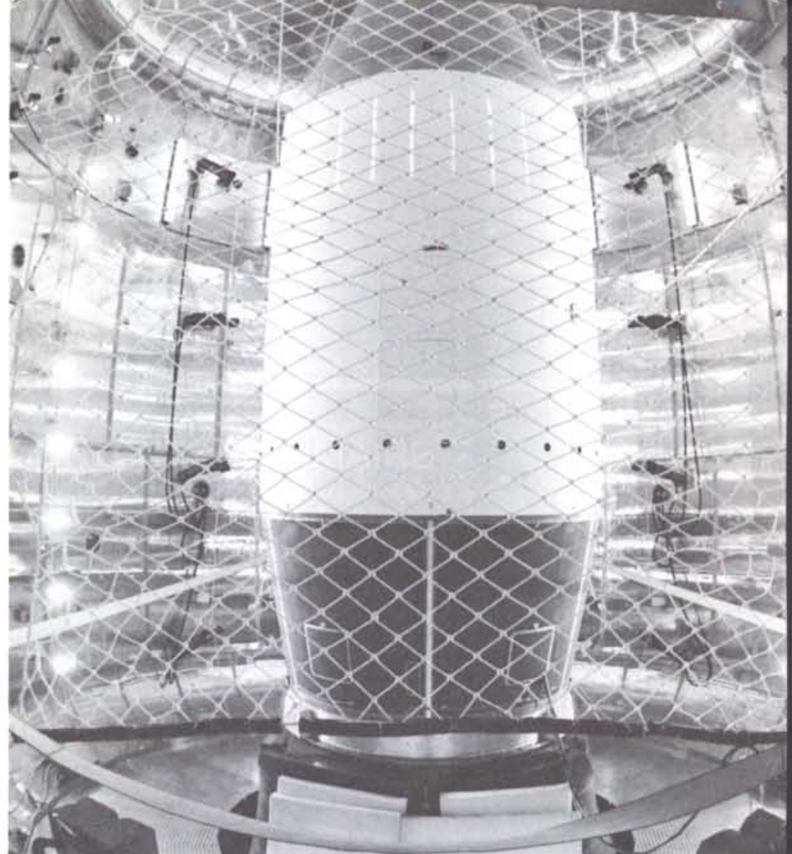
au sol et des simulations de vol, la cohérence des spécifications des sous-systèmes ainsi que les diverses marges et dispersions ont pu être contrôlées.

Il est à souligner que la performance générale garantie actuellement aux utilisateurs d'Ariane s'élève à une masse de 1700 kg de satellite en orbite de transfert (200/36 000 km), sensiblement au-dessus des 1500 kg spécifiés. Cette amélioration notable intervenue au cours du développement, fait rare dans le domaine aérospatial, résulte essentiellement de la prudence qui a présidé à l'établissement des spécifications des matériels.

Figure 5 – Fairing-separation test in large Dynamic Test Chamber at ESTEC/Essais de séparation de la coiffe dans la grande Chambre d'Essais dynamiques de l'ESTEC.

Figure 6 – First test firing of the third stage's HM-7 engine at Vernon/Premier essai du moteur HM-7 du troisième étage à Vernon.





SYSTEM TESTS

The purpose of the system tests is to check the results or to confirm the assumptions of the systems studies, and also to check the coherence between the various subsystems.

They comprise six series of tests:

- aerodynamic tests
- launcher dynamic tests
- launcher electrical tests
- guidance and flight-control simulation tests
- launcher/launch-site compatibility tests
- stage-separation tests.

The *aerodynamic tests* have already been completed. They have enabled the launcher's flight dynamics to be verified and the loads and the thermal fluxes to which the structures will be subjected to be checked.

The launcher *dynamic tests* have also been completed. They have allowed the frequencies and characteristics of the various longitudinal and transverse vibration modes to be verified, with a view to predicting and correcting the launcher's vibratory behaviour in flight. These tests were wide ranging and were conducted on real and complete structures representing the launcher configuration at various characteristic moments of flight.

ESSAIS SYSTEME

Les essais au niveau du système ont pour but d'une part de vérifier les résultats ou de confirmer les hypothèses des études système, d'autre part de contrôler la cohérence des différents sous-systèmes entre eux.

Ils comportent six séries d'essais:

- *les essais aérodynamiques*
- *les essais dynamiques du lanceur*
- *les essais électriques du lanceur*
- *les essais de simulation guidage-pilotage*
- *les essais de compatibilité lanceur-ensemble de lancement*
- *les essais de séparation d'étages.*

Les essais aérodynamiques *sont complètement terminés. Ils ont permis de vérifier le domaine de vol du lanceur, de contrôler les charges du dimensionnement et les flux thermiques supportés par les structures.*

Les essais dynamiques *du lanceur sont également terminés. Ils ont permis de vérifier les fréquences et les caractéristiques des différents modes de vibrations longitudinales et transversales afin de prévoir et corriger le comportement vibratoire du lanceur en vol. Ces essais, d'une grande ampleur, ont été effectués avec des structures réelles complètes représentant la configuration du lanceur à différents instants caractéristiques de son vol.*

The aims of the launcher *electrical tests* were firstly to verify the electrical compatibility of the launcher's various items of equipment and of its ground checkout facilities, and secondly to develop the automatic checkout software used for integration in France and for launchings in Guiana. They were conducted using a real equipment bay, a checkout system corresponding to that to be used at the time of launch, and electrical stage simulators. They were started more than a year ago and were completed in July. They took longer than was initially foreseen because of the lengthy validation of the very many automatic checkout modules required during launch.

The *guidance and flight-control simulation tests* have allowed the in-flight behaviour of the guidance and flight-control system for various dimensioning trajectories to be simulated, and dispersions to be studied. They are conducted with real elements of the system up to and including the hydraulic actuators for the nozzles and the nozzles themselves and a computer unit enabling hybrid simulation (digital and analogue) of the launcher's behaviour during flight. These tests are also well advanced and will be completed this summer.

The *launcher/launch-site compatibility tests* are intended, as their name implies, to verify the complex interfaces between the launcher and the launch site, to develop launch procedures and to train the appropriate teams. They comprise numerous simulation phases and exercises, the most important of which is erection of the launcher and the rehearsal of launch operations using a vehicle specially provided for the purpose. This operation is due to take place at the Guiana Space Centre in the period August to November. The propellant mock-up, consisting of the structures and almost all the propulsion equipment in flight configuration, left Aérospatiale's integration site at Les Mureaux in the second half of June.

Lastly, the *stage-separation tests*, which have now been completed, have permitted the proper operation of the pyrotechnic devices that cut the structures joining the stages and ignite the retro-rockets of the lower stages and the acceleration rockets of the upper stages, to be verified.

THE STAGES

The first static firing of the first stage (L 140) took place

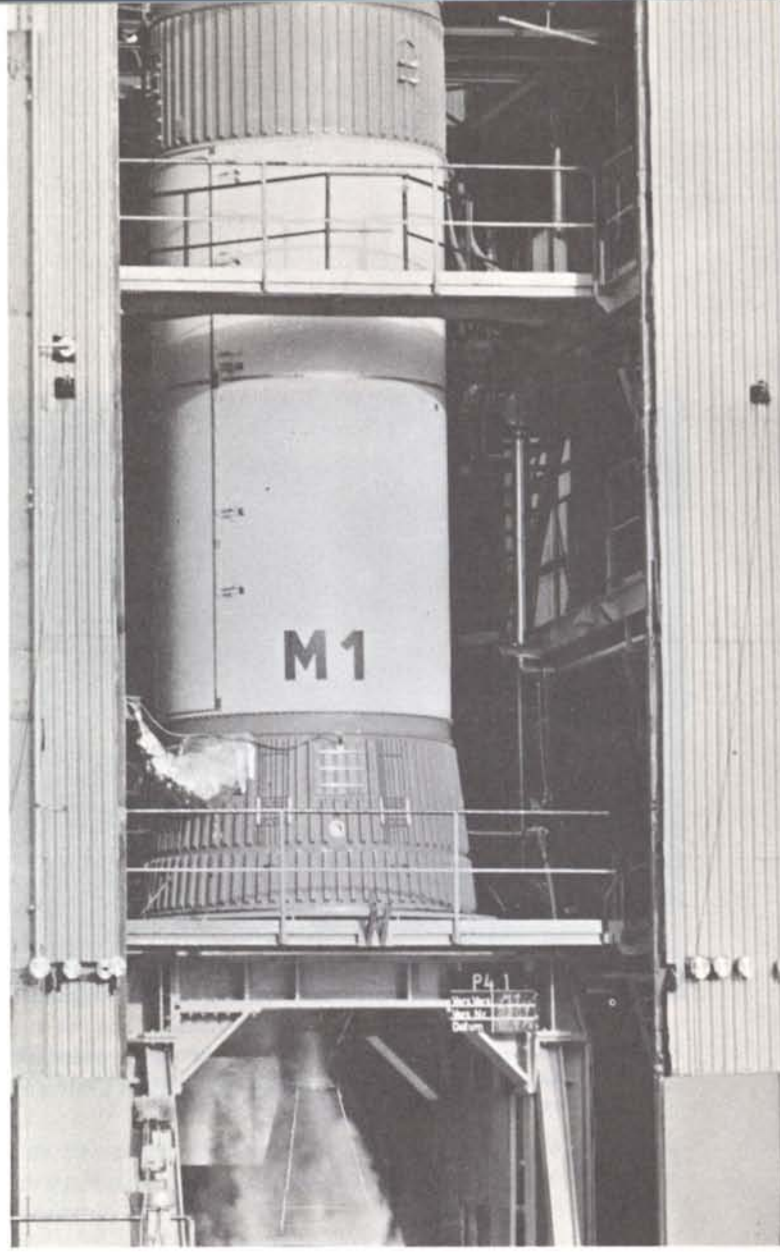
Les essais électriques *du lanceur ont pour objet d'une part de vérifier la cohérence électrique des différents équipements du lanceur et de son installation de contrôle au sol, d'autre part de mettre au point le logiciel de contrôle automatique du lanceur utilisé pour les intégrations en France et les lancements en Guyane. Ils sont effectués à l'aide d'une case d'équipements réelle, d'un banc de contrôle conforme à celui utilisé au moment du lancement et des simulateurs électriques des étages. Commencés il y a un an, ils ont été terminés en juillet 1978. Leur durée, plus importante qu'initialement prévue, s'explique essentiellement par la longue validation des très nombreux modules de contrôle automatique nécessaires au lancement.*

Les essais de simulation guidage-pilotage *permettent de simuler le comportement en vol de la chaîne de guidage-pilotage pendant le déroulement de différentes trajectoires dimensionnantes et d'étudier les dispersions. Ils comportent les éléments réels de la chaîne jusque et y compris les vérins hydrauliques d'activation des tuyères et les tuyères elles-mêmes et un groupe de calcul permettant une simulation hybride (numérique et analogique) du comportement en vol du lanceur. Ces essais sont également très avancés et seront terminés cet été.*

Les essais de compatibilité lanceur-sol *ont pour but de vérifier, comme leur nom l'indique, les interfaces complexes entre le lanceur et l'ensemble de lancement, de mettre au point les procédures de lancement et d'entraîner les équipes correspondantes. Ils comportent de nombreuses phases de simulation et d'exercices dont le plus important correspond à l'érection et à la répétition des opérations de lancement sur un lanceur prévu à cet effet. Cette opération se déroulera d'août à novembre 1978 au Centre Spatial Guyanais. La maquette ergols constituée des structures et de la presque totalité des équipements de propulsion en configuration de vol a quitté à cet effet le Site d'Intégration de l'Aérospatiale aux Mureaux dans la deuxième quinzaine de juin 1978.*

Enfin, des essais de séparation *d'éléments d'étage, maintenant achevés, ont permis de vérifier le bon fonctionnement des dispositifs pyrotechniques de découpe des structures de liaison interétages et d'allumage des fusées de freinage des étages inférieurs et d'accélération des étages supérieurs.*

Figure 7 – *First test firing of the second stage at Hardthausen (Germany)/Premier essai du deuxième étage à Hardthausen (Allemagne).*



on the SEP test stands at Vernon on 13 December 1977, and was followed by a second test on 9 March. Previously, a number of engine tests and ten propulsion-bay tests had been carried out between 17 November 1976 and 29 September 1977. The only major technical problem still unresolved concerns the behaviour of the graphite throat of the combustion chamber of the Viking engines with which the first and second stages are equipped.

Although this component satisfactorily withstood all the tests until the first test of the first stage, it proved insufficiently resistant during the long firing of the four nozzles together. This technical obstacle, which should be fairly easy to overcome by adopting other materials already qualified under the more stringent conditions prevailing in dry-propellant engines, nevertheless poses a tricky scheduling problem because of the time needed to qualify this major modification and assemble the flight-standard engines.

The third development test in June will be followed by three qualification tests late in 1978 and during the first half of 1979.

The configuration for the LO1 launcher should be validated at the end of 1978.

The first firing of the second stage (L 33) took place on the DFVLR test stands at Hardthausen (Germany) on 31 January. Two very satisfactory tests of nominal duration have now taken place. Qualification of the engine's functioning in vacuo has been practically achieved. As for the first stage, an overall development test has still to be carried out, followed by three overall qualification tests.

The first firing of the third stage (H8) took place at Vernon on 10 January and lasted 256 s. It was followed by three tests, including two of long duration (more than 500 s). Although this stage, which runs on liquid hydrogen and liquid oxygen, is by far the most complex, no major

LES ETAGES

Le premier essai à feu du premier étage (L 140) qui a eu lieu le 13 décembre 1977 sur les bancs de la SEP à Vernon, a été suivi d'un deuxième essai le 9 mars 1978. Auparavant, de nombreux essais moteurs et dix essais de baie de propulsion avaient été exécutés du 17 novembre 1976 au 29 septembre 1977. Le seul problème technique important restant à résoudre concerne la tenue du col en graphite de la chambre de combustion des moteurs Viking équipant les premier et deuxième étages.

Cette tenue, satisfaisante dans tous les essais ayant précédé le premier essai du premier étage, s'avère insuffisante en longue durée en tir quadrituyère. Ce handicap technique, qui doit être assez facilement surmonté par l'adoption de matériaux différents, déjà qualifiés dans des conditions plus sévères sur les

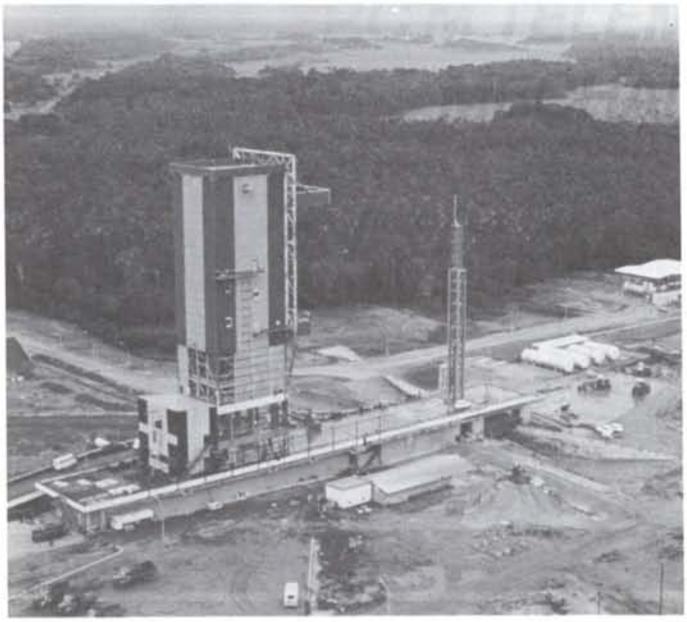


Figure 8 – The Ariane Launch Site (ELA) with the mounting tower and the umbilical mast/Ensemble de Lancement Ariane (ELA), avec la tour de montage et le mât ombilical.

technical problem has so far arisen. Nevertheless, in view of the number of items of equipment in the stage, many more tests are still required in order to ensure the necessary reliability. In addition, the overall structure has successfully undergone qualification tests.

EQUIPMENT BAY

The equipment bay houses the electronic equipment needed for navigation, guidance, flight control, telemetry, generation of sequencer commands, and safety.

A prototype of the bay was used for developing this assembly, and it was then handed over by MATRA to SNIAS with a view to overall testing of the electrical system. Currently, all the constituent electronic equipment has satisfactorily undergone its qualification testing, except for the inertial platform which is being qualified now.

propulseurs à poudre, pose cependant un problème délicat de calendrier par suite du temps nécessaire à la qualification de cette modification importante et au montage des moteurs de vol.

Le troisième essai de développement, terminé en juin, sera suivi de trois essais de qualification fin 1978 et au premier semestre 1979.

La configuration pour le lanceur L01 doit être validée à la fin de l'année 1978.

Le premier tir du deuxième étage (L 33) a été réalisé le 31 janvier 1978 sur les bancs de la DFVLR à Hardthausen (Allemagne). Deux essais très satisfaisants à durée nominale ont maintenant eu lieu. La qualification en fonctionnement dans le vide du moteur est pratiquement acquise. Comme sur le premier étage, il reste à effectuer encore un essai d'ensemble de mise au point, puis trois essais d'ensemble de qualification.

Le premier tir du troisième étage (H8) a été effectué à Vernon, le 10 janvier 1978, pendant 256 s. Il a été suivi de trois essais dont deux de longue durée (plus de 500 s). Bien que cet étage fonctionnant à hydrogène et oxygène liquides soit de loin le plus complexe, aucun problème technique important n'apparaît à ce jour. Toutefois, compte tenu du nombre d'organes équipant cet étage, il est nécessaire de poursuivre encore de nombreux essais pour obtenir la fiabilité requise. Par ailleurs, l'ensemble des structures a subi les essais de qualification avec succès.

CASE D'EQUIPEMENTS

La case d'équipements contient les équipements électroniques essentiels aux fonctions de navigation, guidage, pilotage, télémesure, génération d'ordres séquentiels et de sauvegarde.

Un prototype de la case a servi à la mise au point de cet ensemble, puis a été livré par la Société MATRA à la SNIAS en vue de subir les essais d'ensemble du système électrique. Actuellement, tous les équipements électroniques qui le constituent ont subi avec succès leurs essais de qualification, à l'exception de la centrale inertielle qui est en cours de qualification.

FAIRING DEVELOPMENT

The fairing, which protects the payload during the vehicle's ascent through the atmosphere, has been developed by the Swiss firm of Contraves.

Studies and preliminary tests have resulted in modifications to the system for separating the two half-shells. The whole assembly has been qualified following three separation tests in a large vacuum chamber.

ADAPTATION OF THE GUIANA SPACE CENTRE AND DOWN-RANGE STATIONS

Work on the Ariane Launch Site ('Ensemble de Lancement Ariane' – ELA), which makes very extensive use of the original Europa-II facilities, is coming to an end and acceptance tests are being carried out, the first launcher being due at the ELA in early August.

The work on adapting the CSG as a whole (logistics, safety and telemetry) will be completed this year, as will the links to the down-range tracking, telemetry and radar stations at Natal in Brazil and on Ascension Island (NASA and DOD stations).

It is planned to hold operational exercises for training the teams in the last quarter of 1978 and the first half of 1979.

CONCLUSION

Up to this very advanced stage in the ground testing programme, only routine technical problems have been encountered, with the one critical exception of the behaviour of the graphite throats of the Viking-engine combustion chambers.

Because of its late appearance in one of the longest cycles in the development of the launcher, this problem has considerably upset the timetable for the first-stage qualification tests, which have consequently been delayed by nearly three months.

Nevertheless, appropriate steps have been taken to ensure that the first flight test will be able to take place in June 1979 as planned. □

MISE AU POINT DE LA COIFFE

La coiffe qui protège la charge utile pendant la traversée atmosphérique est réalisée par la Société Contraves en Suisse.

Les études et des essais préliminaires avaient conduit à modifier le système de séparation des deux pétales. Trois essais de séparation effectués dans une grande chambre à vide ont permis de qualifier cet ensemble.

ADAPTATION DU CSG ET STATIONS AVAL

Les travaux de réalisation de l'Ensemble de Lancement Ariane (ELA), réutilisant très largement les installations Europa II, sont en cours de finition et de recette. L'ELA recevra le premier lanceur au début du mois d'août 1978.

Les travaux d'adaptation du CSG en général (logistique, sauvegarde, télémesure), se terminent cette année, ainsi que le raccordement, avec les stations aval de poursuite, télémesure et radar de Natal (Brésil) et Ascension (stations NASA et DOD).

Des exercices d'entraînement opérationnel des équipes sont prévus au dernier trimestre 1978 et durant le premier semestre 1979.

CONCLUSION

Alors que le programme d'essais au sol est très avancé, les problèmes techniques rencontrés jusqu'à ce jour sont normaux, le seul point critique étant la tenue des cols en graphite des chambres du moteur Viking.

Ce problème, par son apparition tardive dans l'un des cycles le plus long de réalisation du lanceur, apporte une perturbation sensible dans le planning des essais de qualification du premier étage, qui se trouve ainsi retardé de près de trois mois.

Toutefois, l'ensemble des dispositions prises sur ce point permet d'assurer la date du premier essai en vol prévu pour juin 1979. □

Ariane Launch Performance
Performance du lanceur Ariane

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The original objective of the Ariane programme was the development of a launcher capable of placing a mass of 1500 kg into a transfer orbit leading to geosynchronous orbit. In 1976, following the definition phase, it was decided to increase the performance margin by some 100 kg over the guaranteed figure. To this end, the nozzles of the first-stage Viking engines were modified and, by reducing the ullage spaces, the masses of propellants carried in the first and second stages were increased by 5 t and 1 t, respectively. In March 1977, when the results of the engine tests were known and the stages had been weighed, it proved possible to increase the guaranteed performance to 1700 kg, the difference between this and the calculated performance still being some 100 kg (Fig. 1).

L'objectif initial du programme Ariane était le développement d'un lanceur capable de placer sur orbite de transfert des satellites géostationnaires de 1500 kg. Après la phase de définition (1976), il a été décidé d'augmenter d'une centaine de kilogrammes la marge sur la performance garantie. A cette fin, l'éjecteur des moteurs Viking du 1er étage a été modifié et, grâce à une réduction des volumes morts, les masses d'ergols embarqués dans les 1er et 2ème étages ont été augmentées respectivement de cinq tonnes et d'une tonne. En mars 1977, à la suite des résultats des essais des moteurs et de la pesée des étages, la performance garantie a pu être portée à 1700 kg, la différence avec la performance calculée restant d'une centaine de kilogrammes (Fig. 1).

MAIN MISSION

The Ariane launcher has been designed to place into transfer orbit (200/35 850 km) a composite comprising a satellite and its apogee motor, the latter being used to place the satellite into its final geosynchronous orbit. The

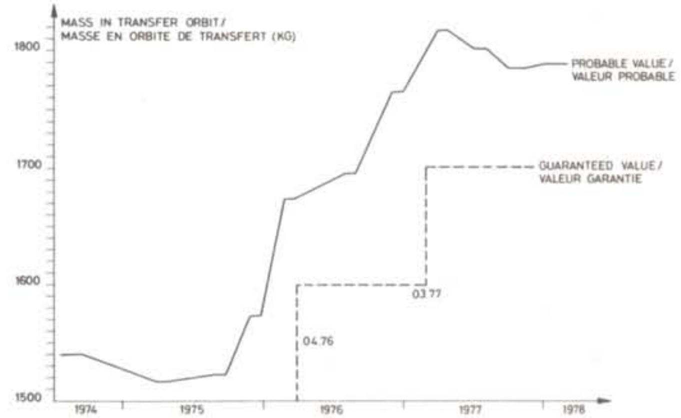

Figure 1 – Evolution of Ariane's performance during the development programme / Evolution des performances d'Ariane au cours du programme de développement.

MISSION PRINCIPALE

Le lanceur Ariane a été conçu de façon à mettre sur orbite de transfert (200/35 850 km) un composite satellite + moteur d'apogée, ce dernier servant à son tour à placer le satellite sur l'orbite de géosynchronisme. La faible latitude de la base de lancement de Guyane (5,23°N) permet une procédure de lancement particulièrement simple: chaque étage est mis à feu immédiatement après l'extinction du précédent sans phase balistique, grâce en particulier au long temps de combustion du 3ème étage (~10 mn).

L'azimut de lancement choisi permet de placer le point d'injection sur l'équateur; ce point constitue le périgée de l'orbite de transfert; de ce fait, l'apogée de cette orbite se situera lui aussi dans le plan équatorial, condition nécessaire pour entreprendre la manoeuvre de circularisation à l'aide du moteur d'apogée. L'inclinaison de l'orbite de transfert ainsi obtenue est de 9,65° (Fig. 2).

A cet égard, la procédure de lancement des lanceurs américains à partir de Cap Kennedy est relativement plus complexe, puisque la situation du champ de tir (latitude 28,5°N) nécessite une phase balistique et un réallumage du dernier étage (l'inclinaison de l'orbite de transfert étant également de 28,5°).

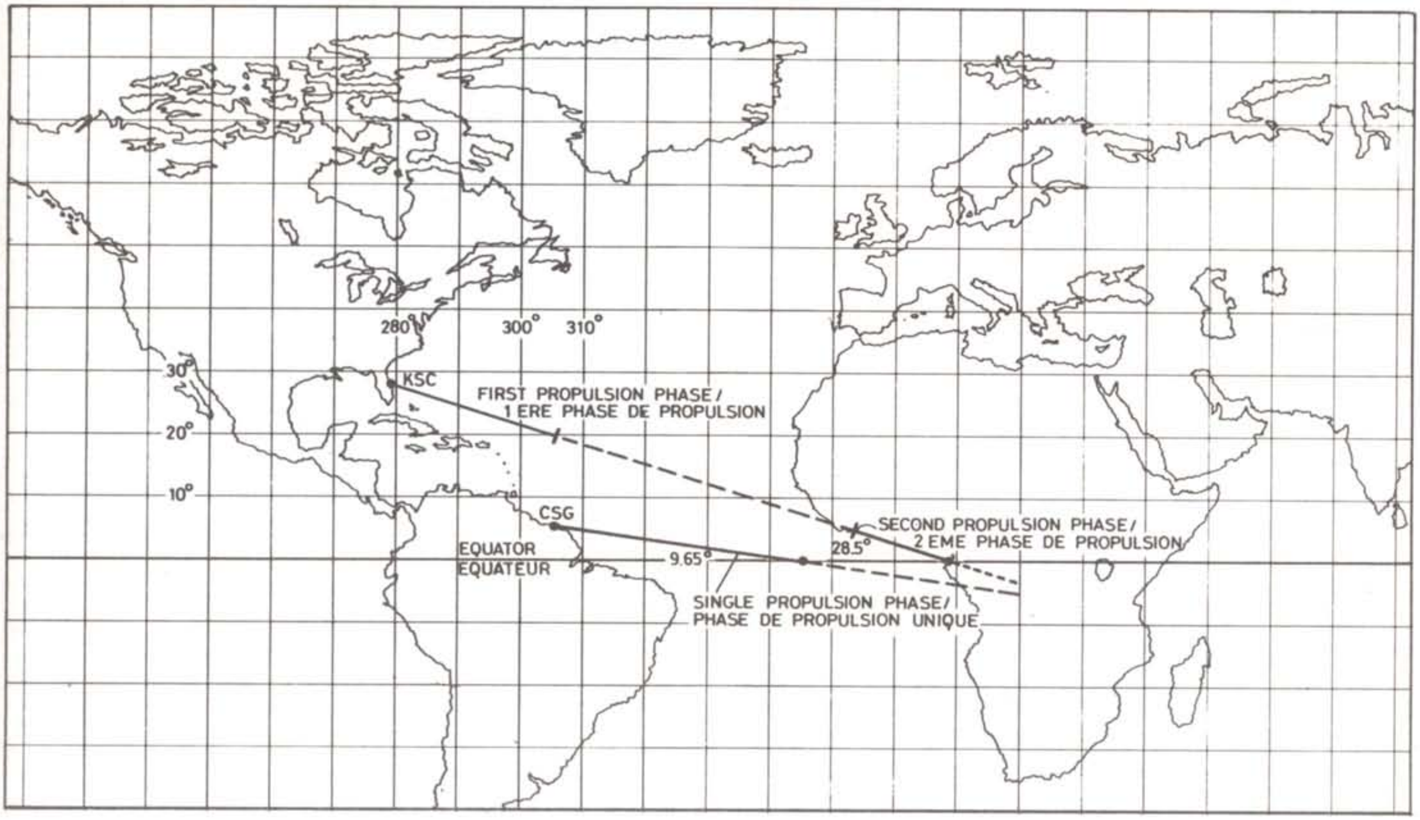

Figure 2 – Launch sequences from the Guiana Space Centre (CSG, Kourou) and from Kennedy Space Center (KSC, Cape Canaveral) and the inclinations of the corresponding transfer orbits / Séquences de lancement à partir du Centre spatial guyanais (CSG, Kourou) et du Centre spatial Kennedy (KSC, Cap Canaveral) avec les inclinaisons d'orbite correspondantes.

low latitude of the Guiana launch base (5.23°N) enables a particularly simple launch procedure to be used: each stage is ignited immediately after the burnout of the previous one, without an intermediate coast phase, thanks in particular to the long burn time of the third stage (some 10 min).

The launch azimuth selected allows the injection point for final orbit, namely the perigee point of the transfer orbit, to be located over the equator. The apogee of this orbit will therefore also be situated in the equatorial plane, which is a precondition for the circularisation manoeuvre using the apogee motor. The inclination of the transfer orbit thus attained is 9.65° (Fig. 2).

By comparison, the procedure for launching American vehicles from Cape Kennedy is relatively more complex, because the location of the base (latitude 28.5°N) entails a coasting phase and a re-light of the vehicle's last stage, the inclination of the transfer orbit also being 28.5°.

A mass of 1700 kg in transfer orbit, including a MAGE-III apogee motor (specific impulse 295 s), corresponds to a final mass in geosynchronous orbit of 1004 kg, or a satellite mass of 965 kg.

A une masse en orbite de transfert de 1700 kg correspond, après allumage du moteur d'apogée du type MAGE-III (impulsion spécifique égale à 295 s), une masse finale en orbite de géosynchronisme de 1004 kg, soit une masse de satellite de 965 kg.

Les dispersions sur les paramètres à l'injection de l'orbite de transfert sont:

Inclinaison	*: ± 0,019°*
Altitude du périgée	*: ± 0,45 km*
Altitude de l'apogée	*: ± 43,2 km*

MISSIONS SECONDAIRES

Les performances générales *du lanceur pour des azimuts de lancement de 0° et 90° sont données aux Figures 3 et 4. On notera qu'Ariane est capable de satelliser 4850 kg en orbite basse (périgée 200 km, inclinaison 5,23°). Pour les masses supérieures à 2500 kg, une vérification du dimensionnement de la partie haute du lanceur sera nécessaire.*

Mission héliosynchrone

Ce type d'orbite – caractérisé par le passage du satellite à

The parametric dispersions at injection into transfer orbit are as follows:

Inclination	: ± 0.019°
Perigee altitude	: ± 0.45 km
Apogee altitude	: ± 43.2 km

SECONDARY MISSIONS

The *general performances* of the launcher for launch azimuths between 0° and 90° are shown in Figures 3 and 4. It will be seen that Ariane can satellise 4850 kg into a low orbit (perigee 200 km, inclination 5.23°). For masses greater than 2500 kg, it will be necessary to revise the dimensioning of the upper part of the launcher.

Heliosynchronous mission
This type of orbit, the essential feature of which is that the local time of the subsatellite point remains constant, is used mainly for earth-observation missions such as meteorology and remote sensing. Such orbits are retrograde, with inclinations lying between 90° and 180°. As an example, for an 840 km circular orbit with an inclination of 98.76°, Ariane can satellise a mass of 2500 kg.

Interplanetary missions (Fig. 5)
The table below gives the performance of the launcher in various interplanetary-probe roles (declination of asymptote: −5°).

Mission	Moon	Venus	Mars	Mercury
Payload mass (kg)	1000	790	660	0

Note: Departures from the recommended launch window may lead to a degradation in performance (some 20 kg for 20 min).

ADDITION OF A FOURTH STAGE

Exosat mission
As already mentioned, the Ariane launcher has been designed to carry out a prime mission that does not call for third-stage re-light. For certain special missions requiring a long coasting phase before injection into final orbit, it will therefore be necessary to add a fourth stage to the

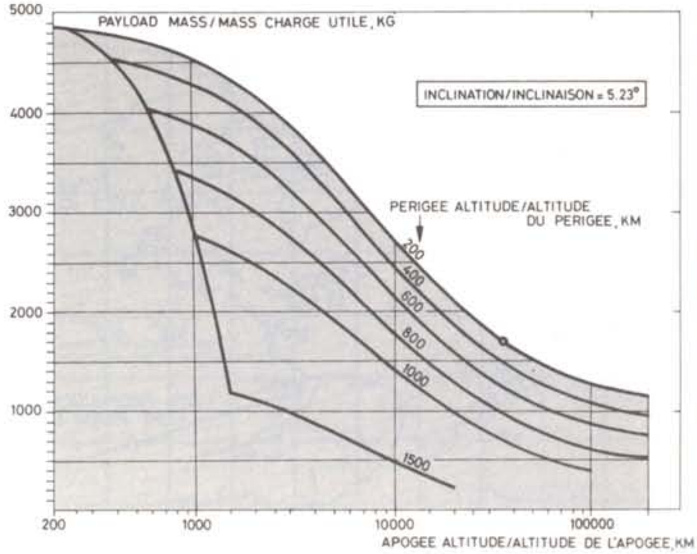

Figure 3 – Payload mass as a function of apogee altitude for an eastward launch / Masse de la charge utile en fonction de l'apogée pour un lancement plein Est.

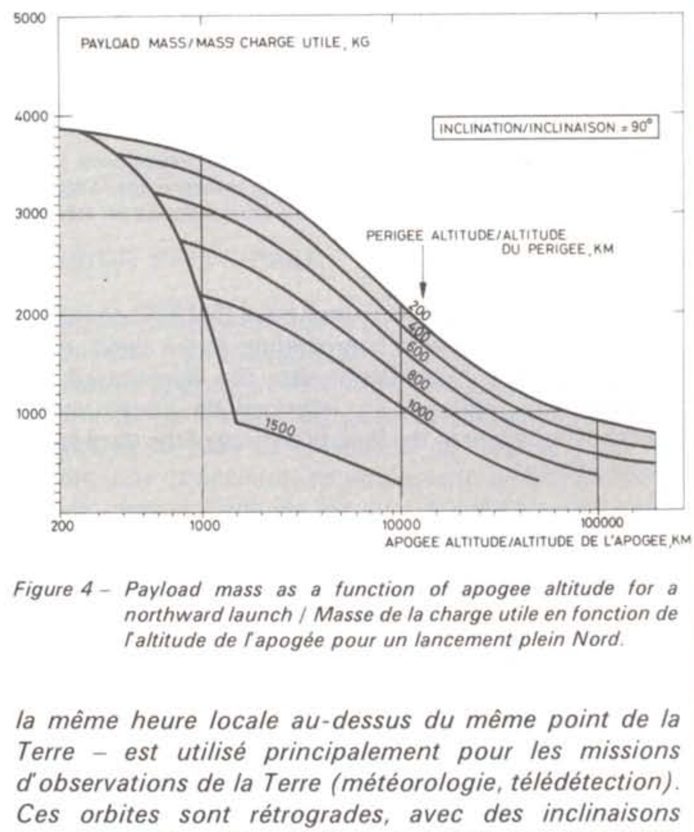

Figure 4 – Payload mass as a function of apogee altitude for a northward launch / Masse de la charge utile en fonction de l'altitude de l'apogée pour un lancement plein Nord.

la même heure locale au-dessus du même point de la Terre – est utilisé principalement pour les missions d'observations de la Terre (météorologie, télédétection). Ces orbites sont rétrogrades, avec des inclinaisons comprises entre 90° et 180°. Par exemple, pour une orbite circulaire de 840 km avec une inclinaison de 98,76°, la masse satellisée par Ariane est de 2500 kg.

Missions interplanétaires *(Fig. 5)*
Le tableau ci-dessous donne les performances du lanceur pour différentes sondes interplanétaires (déclinaison de l'asymptote: 5°).

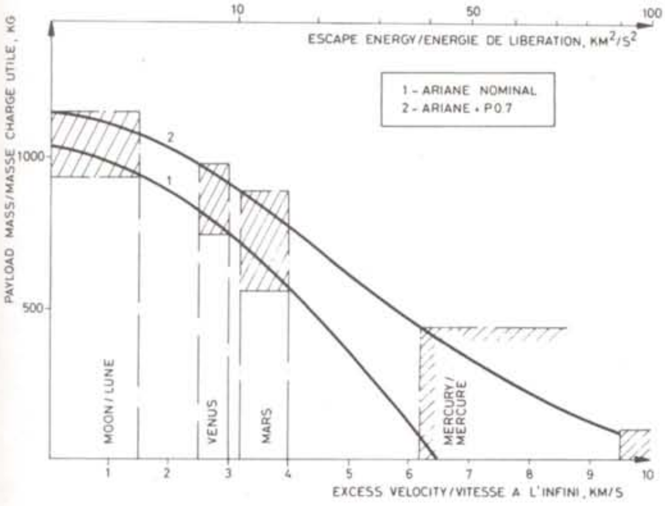

Figure 5 – Performance profiles for interplanetary missions
Performances des missions interplanétaires.

launcher. The PO.7 stage, already used as the third stage of the Diamant B.P4 launcher, has been adopted as the Ariane fourth stage for the Exosat mission. For this mission, the perigee of the highly eccentric orbit (500/200 000 km, inclination 75°) would be in the neighbourhood of the South Pole. The composite PO.7 + Exosat would therefore first be placed by the three-stage launcher into an elliptical transfer orbit of 75° inclination. After a ballistic phase of some 9000 s, PO.7 would be ignited and would then inject Exosat into the desired orbit.

It will be seen that the use of PO.7 on Ariane appreciably increases the latter's performance in interplanetary missions (Fig. 5).

Out-of-ecliptic mission

By using more complex procedures, e.g. swinging-by a planet such as Mars, Venus or the Earth, one can considerably increase the launcher's performance, if a much longer transfer time is accepted. A study has shown it would be possible to carry out an out-of-ecliptic mission by swinging by the Earth and then Jupiter and using a re-lightable fourth stage similar to the Symphonie apogee motor. The final satellite mass would be 350 kg for a heliocentric inclination of 68°, but the penalty would be a transfer time of some 600 days. □

Missions	Lune	Vénus	Mars	Mercure
Masse de charge utile (kg)	1000	790	660	0

Remarque: *Certains créneaux de lancement peuvent occasionner une dégradation de la performance (une vingtaine de kg pour 20 mn).*

ADDITION D'UN 4EME ETAGE

Mission EXOSAT

Comme indiqué plus haut, le lanceur Ariane a été défini pour remplir une mission principale qui ne nécessite pas de réallumage du 3ème étage. Pour mener à bien certaines missions particulières qui nécessitent une longue phase balistique avant l'injection sur l'orbite finale, il sera donc nécessaire d'adjoindre un 4ème étage au lanceur. L'étage P0.7 déjà utilisé comme 3ème étage du lanceur Diamant B.P4 a été retenu comme 4ème étage d'Ariane pour la mission Exosat.

Cette mission nécessite que le périgée de l'orbite fortement excentrique (500/200 000 km, inclinaison 75°) soit au voisinage du Pôle Sud. Le composite P0.7 + Exosat sera donc d'abord placé par le lanceur tri-étage sur une orbite de transfert elliptique d'inclinaison 75°. Après une phase balistique d'environ 9000 s, le P0.7 est allumé, injectant à son tour le satellite Exosat sur l'orbite désirée.

Ainsi l'utilisation du P0.7 sur Ariane augmente sensiblement les performances du lanceur en missions interplanétaires (Fig. 5).

Mission hors-écliptique

L'emploi de procédures plus complexes, comme la gravidéviation autour d'une planète (Mars, Vénus, ou la Terre par exemple) peut augmenter considérablement les performances du lanceur, au prix d'un temps de transfert nettement plus long. Ainsi une étude a montré qu'une mission en dehors du plan de l'écliptique était possible en utilisant l'assistance gravitationnelle, d'abord de la Terre, ensuite de Jupiter, et grâce à un 4ème étage réallumable du type moteur d'apogée de Symphonie. La masse finale du satellite sera de 350 kg pour une inclinaison héliocentrique de 67°, moyennant une pénalisation de 600 jours environ dans le temps de transfert. □

Increased Performance for Ariane

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Provided development work and testing continue as successfully as they have to date and flight trials are successful, Ariane will be flight-qualified by the end of 1980 and an operational European launch capability comparable to that of an Atlas-Centaur will then be available. In addition to the four vehicles for development flights, five Ariane vehicles have been authorised for production. Since the qualification of any major change in a vehicle's configuration takes several years, plans must already be made now for any further evolution in the Ariane basic design.

THE NEED FOR A PERFORMANCE INCREASE

In the past, many nonmilitary satellites have been designed for launch on Delta or Atlas-Centaur launch vehicles. The Delta-3914 launcher can transport about 900 kg and the Atlas-Centaur about 1850 kg into geostationary transfer orbit (from which the satellite can be injected into the geostationary orbit by an apogee boost motor). These two weight classes have become so much a standard for satellite designers that, despite the planned phase-out of the Delta and Atlas vehicles by the time the Space Shuttle comes into operation, a considerable number of such satellites will still have to be launched in the early 1980s.

NASA has made special provisions for their launch aboard the Space Shuttle (STS-Space Transportation System). For Delta-class payloads, an upper stage called a Payload Assist Module (PAM) is being developed which can be used in conjunction either with the conventional launch vehicle or with the Shuttle. The Shuttle can launch several satellites in the course of one flight.

Ariane is to be launched from the Guiana Space Centre in Kourou (French Guiana), which is some 5° north of the equator, into geostationary transfer orbits that have lower inclinations than those of US launchings from Eastern Test Range in Florida (approx. 28° north of the equator). The velocity increment needed to rotate the Ariane transfer orbit into the equatorial plane and circularise it is therefore approximately 300 m/s less, which means in turn that less propulsion is needed from the satellite's apogee boost motor for a given satellite mass.

The standard Ariane vehicle will be able to inject a payload of at least 1700 kg into geostationary transfer orbit with a perigee of 200 km and an inclination of 9.5°. This performance is sufficient for the launching of an Atlas-Centaur class satellite (910 kg in geostationary orbit). Dual launchings would significantly improve the competitivity of Ariane for Delta-class payloads. The technical feasibility of a double launch of two independent satellites has already been established, but the present Ariane payload capability allows only the launch of an STS/PAM-D and a Delta-2914 class satellite, whereas after 1980 mainly satellites of the Delta 3910/PAM-D and STS/PAM-D class will be built.

Two payload-capability levels have been identified that would allow Ariane to launch several convenient combinations of Delta-class satellites in the 1980s, namely 1950 kg and 2300 kg.

PROGRAMME OBJECTIVES

Mission models show that the ability to launch 1950 kg would already be advantageous at the end of 1981, whereas the need for the 2300 kg level is likely to arise in 1983. In view of this, work has to start in 1979 to allow vehicle modifications to be qualified and for the necessary modifications to be introduced into the production vehicles at the right time.

The choice of an appropriate complementary programme has to be based on the following criteria:

- high efficiency in terms of performance increase versus additional development cost
- short lead time
- compatibility with on-going development and facilities utilisation, and with production.

Consequently, the following short-term goals are being set for the Ariane performance increase:

- first possible launch of 1950 kg in early 1982
- first possible launch of 2300 kg in early 1983.

A POSSIBLE APPROACH

Studies have shown that the following steps constitute the most efficient means of achieving these objectives:

Step 1: Increase in payload capability to 1950 kg, by

- an increase in Viking-IV and -V chamber pressures from 54 to 58 bar
- an increase in third-stage tank capacity from 8 to 10 t (tanks carrying only 9.5 t in this step).

Step 2: Increase in payload capability to 2300 kg, by

- the addition of two 6 t strap-on boosters on the first stage
- full third-stage tanks (10 t)

A lengthening of the fairing by 300-500 mm to accommodate two STS/PAM-D satellites may also be envisaged.

Detailed studies are being carried out this year by CNES and the industrial firms concerned, with a view to submitting a proposal in the autumn of 1978 to the ESA Council.

FUTURE DEVELOPMENTS

The plans and studies that have been discussed are concerned only with development work in the immediate future, up to the end of 1983, and are intended as an improvement package for the basic Ariane configuration already under development. The ESA Executive will soon start to consider the longer-term evolution of Ariane and the needs and possibilities for new developments in the launcher field. The most difficult problem will be to estimate the long-term trend in payload-capability requirements. □

Sylda – A Dual-Launch System for Ariane

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In view of the planned existence of several Delta-class payloads – requiring approximately half of Ariane's available performance – in the early 1980s, and in order to increase Ariane's competitiveness, it has been decided to build a carrier structure capable of supporting and releasing two independent spacecraft. The development of such a dual-launch system, called 'Sylda' (Système de Lancement Double Ariane), was initiated by ESA in June 1978.

The Sylda system consists essentially of a support structure, three separation systems (one for each satellite and one for the structure itself). In its baseline configuration (shown in Figure 1), it offers the upper satellite the same volume as is available to an STS/PAM-D* satellite; the lower satellite can be similar in size to Marecs. The mechanical and electrical interfaces at the separation plane are the same for both satellites, and identical to those specified for the PAM-D.

Cut-outs or doors in the Sylda structure provide both access to the lower satellite and radio-frequency transparency for communications with this satellite. Separation is provided by classical Marman clamp bands released by pyrotechnically operated bolt cutters.

The structure is made of an aluminium honeycomb core, covered with carbon-fibre layers. Use of this advanced technology results in a very light structure, the complete Sylda system weighing only about 165 kg. It will be bolted onto the conical structure of Ariane's equipment bay in place of the vehicle's standard payload adapter. As this standard adapter weighs 44 kg, the payload penalty resulting from the double-launch system is some 120 kg, leaving 1580 kg of mass in transfer orbit for the two satellites.

The Sylda structure is dimensioned on the basis of rigidity rather than load requirements. In fact, longitudinal vehicle resonance oscillations are expected during flight mainly in two frequency bands (11-18 Hz and 28-35 Hz) and the structure has to be so designed that the first longitudinal resonance frequency of the Sylda/satellite composite will lie between these bands. The first lateral resonance frequency of this composite is required to be about 6 Hz.

*Space Transportation System/Payload-Assist Module Delta

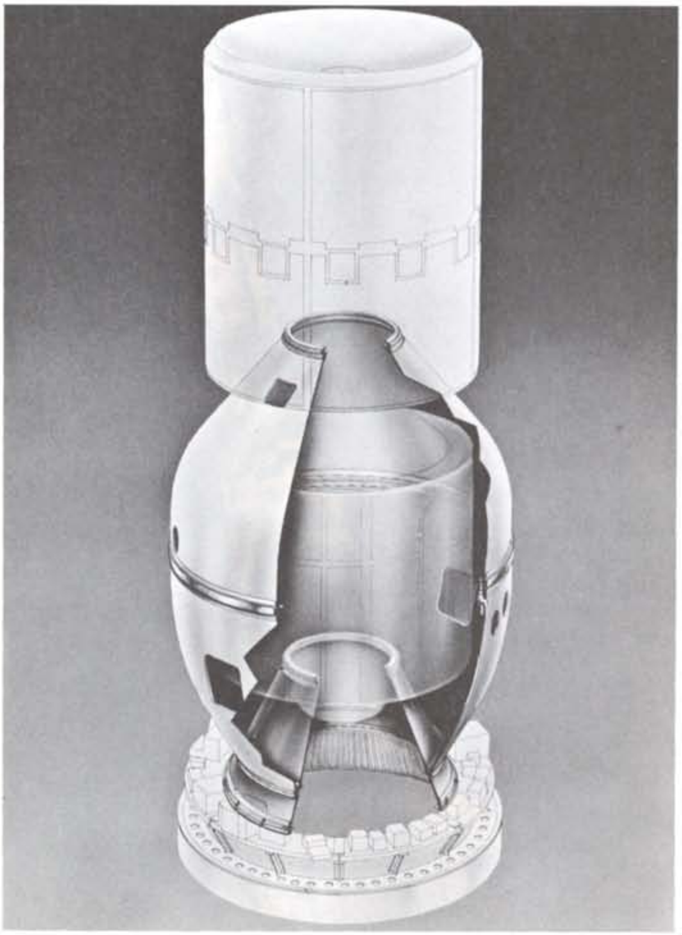

Figure 1 – The Sylda (Système de Lancement Double Ariane) system.

The vibrational environment to which satellites carried on Sylda will be subjected is being studied using mathematical models of the launch vehicle, of Sylda and of two typical satellites; the first results are expected to be available in October 1978. The environment for the lower satellite is expected to be very similar to that predicted for single Ariane payloads.

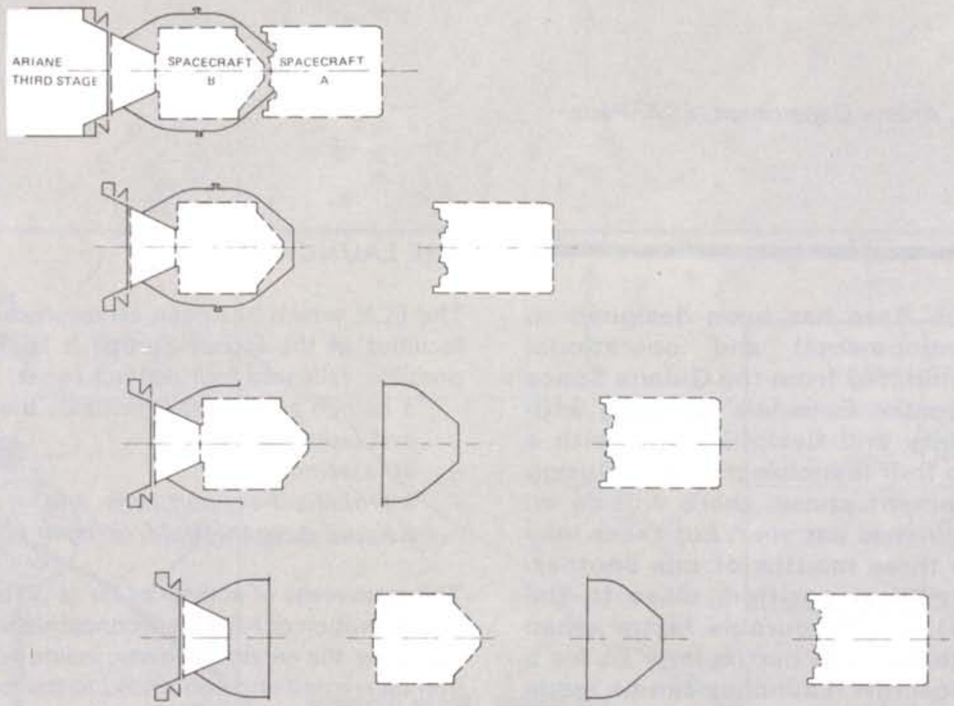

Figure 2 – Artist's impression of the double-launch concept for Ariane.

Sylda will be equipped with accelerometers to detect the in-flight level of vibrations near the satellite separation planes up to a frequency of at least 50 Hz. The measurements will be transmitted to ground via the launch vehicle's telemetry system.

IN-FLIGHT OPERATION

After cut-off of Ariane's third-stage motor, the attitude-control system of this stage will orient the two Sylda-carried satellites in any desired direction and spin the composite payload up to 5 to 10 rpm. The attitude-control system will then be switched off. The upper satellite will be the first to be separated, then the upper half of the Sylda structure, and finally the lower satellite, all separations taking place along the longitudinal axis of the third stage with relative velocities imparted by springs.

Due to third-stage orientation errors, third-stage and satellite static and dynamic imbalances, and perturbations introduced by the separation mechanism itself, the orientation in space of the separated satellites deviates from the desired one and the satellite's spin axis moves on a nutation cone around the satellite's angular momentum vector, the apex of the cone being located at the satellite's centre of gravity. For satellites with an inertia ratio of unity, the pointing error of the angular momentum vector is not expected to exceed 5-7° and the nutation cone half angle should not be larger than 2-4°. The specifications require that during separation of the upper part of the Sylda structure and of the lower satellite, the separating bodies must at no time come closer to each other than 30 mm. Analysis has shown that a spin rate of 10 rpm would reduce satellite pointing error and nutation, whilst a lower spin rate would help in respecting the clearance requirement. Furthermore, to avoid collision, the distance between all separated bodies must steadily increase. All in all, this means that both the initial spin rate and the relative separation velocities (and hence the spring forces), must be carefully chosen and optimised.

FUTURE DEVELOPMENT

It is planned to expand the cylindrical part of the Sylda structure by about 500 mm at a later date in order to provide the volume needed to house two STS/PAM-D type satellites. The fairing volume would have to be expanded accordingly and Ariane's performance uprated to 2300 kg in transfer orbit. As readers of the article preceding this one will be aware, a complementary development programme along these lines is already under study. □

The Ariane Launch Base

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The Ariane Launch Base has been designed to allow both developmental and operational launches to be conducted from the Guiana Space Centre ('Centre Spatial Guyanais' or CSG) with the necessary safety and flexibility and with a frequency of up to four launches per year. During the initial development phase, there will be an average of two launches per year, but these may take place within three months of one another. The base's geographical position, close to the equator (5.2368°N), is a favourable factor when launching any satellite, and particularly so for a geostationary spacecraft. Launches can be made from the base on azimuths from −10.5° through north to +93.5°.

The Ariane Launch Base (Fig. 1) lies about 18 km from the town of Kourou, and consists essentially of two elements:

- the *Ariane Launch Site* ('Ensemble de Lancement Ariane' – ELA), located within the Centre's perimeter and containing the specific facilities needed for final assembly, checkout and launch operations
- the *Additional Ariane Facilities* ('Moyens Complémentaires Ariane' – MCA), comprising the Centre facilities or adaptations thereof and the down-range stations needed for carrying out the particular mission in question.

In addition, the base includes payload facilities, which will be made available to users for final preparation of their satellites.

The ELA belongs to the European Space Agency, as do the other facilities and equipment financed and provided under the Ariane Programme. The agreement between ESA and the French Government, concluded in May 1976, guarantees the Agency and its Member States freedom of access to and use of the ELA for the purposes of their programmes.

THE LAUNCH SITE

The ELA, which has been established by modifying the facilities of the former Europa-II launch site wherever possible, falls into four distinct zones:

- a *launch zone*, which includes the *launch-pad area* and *launch centre*
- an *assembly zone*
- a *propellant-support zone*, and
- a *liquid-oxygen/liquid-nitrogen* plant.

The main areas of activity as far as preparation, checkout and operation of Ariane are concerned will be the launch-pad area, the servicing tower, inside which the launcher will be erected and connected to the ground equipment, and the launch centre, where nearly all checkout activities are to be conducted (Fig. 2). The propellant-support zone and the liquid-oxygen/liquid-nitrogen plant can be considered ancillary launch-site facilities.

The *launch-pad* area is made up of the following main elements:

- The foundation, which supports the launch table on which the launcher rests (Fig. 3).
- The launch platform, which provides the main access to the servicing tower, and protects the premises containing the equipment needed for launcher check-out.
- The forward erection area, in which the launcher elements are erected with the help of the servicing tower's travelling crane.
- The rear access ramp, which provides access to the launch platform, table and servicing tower.
- The servicing tower (Fig. 4), which is fully air-conditioned and can enclose the launcher on its table as well as the umbilical mast.
- The umbilical mast, which acts as a support for the various connectors and umbilical arms, as well as for the cable ducts, pipework and umbilical junction boxes.
- The peripheral equipment and buildings, comprising essentially:
  - two plants for discharging, storing and transferring the toxic UDMH and N_2O_4 propellants
  - new toxic-propellant storage facilities, comprising two 115 m^3 tanks for UDMH and a further two for N_2O_4

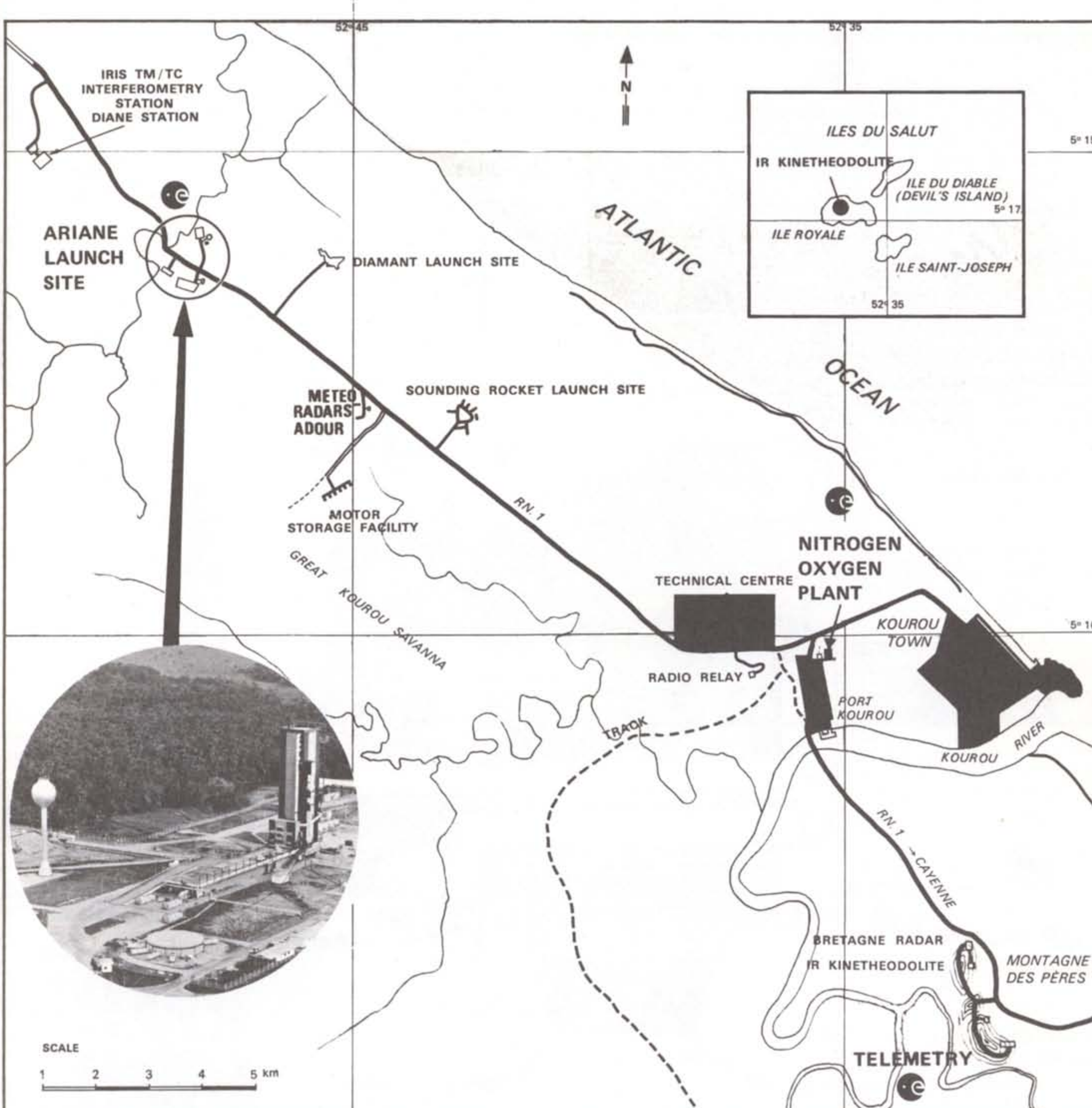


Figure 1 – The Ariane Launch Site (ELA), situated within the CSG perimeter.

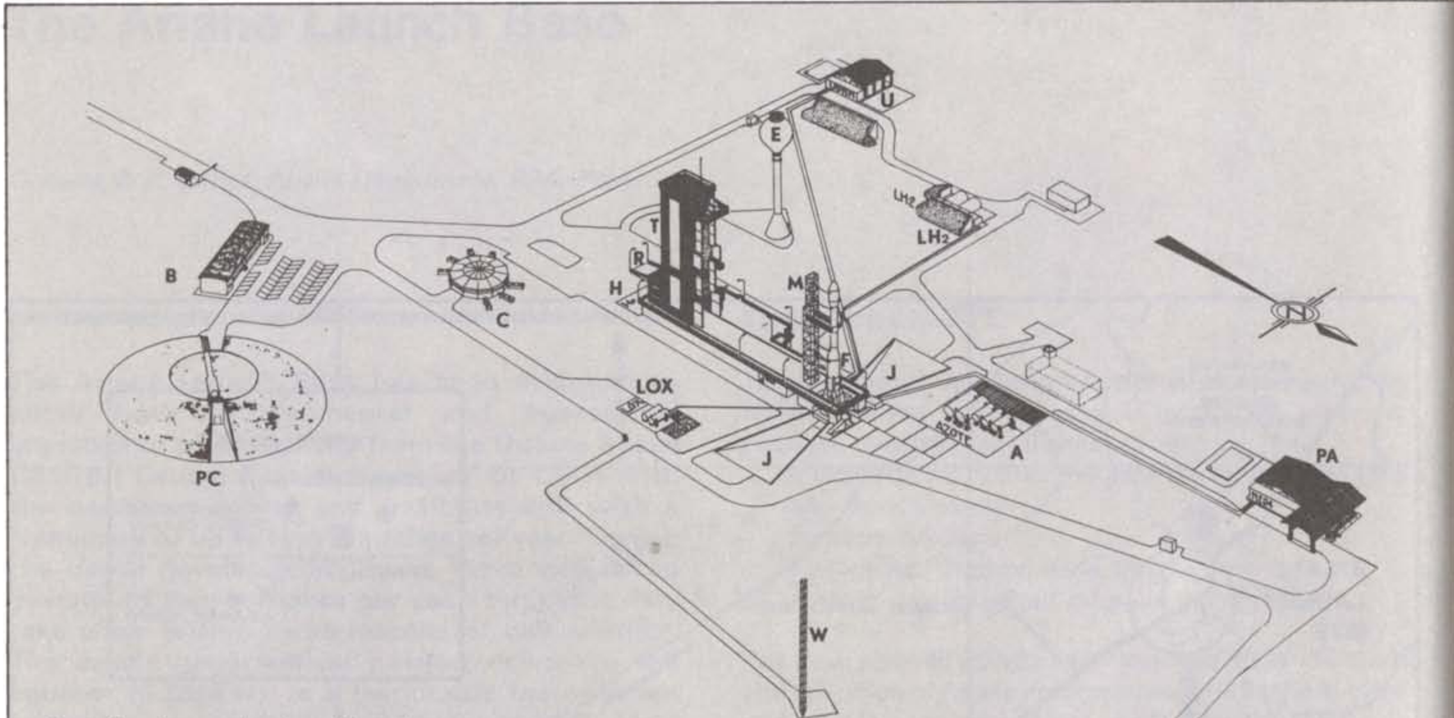
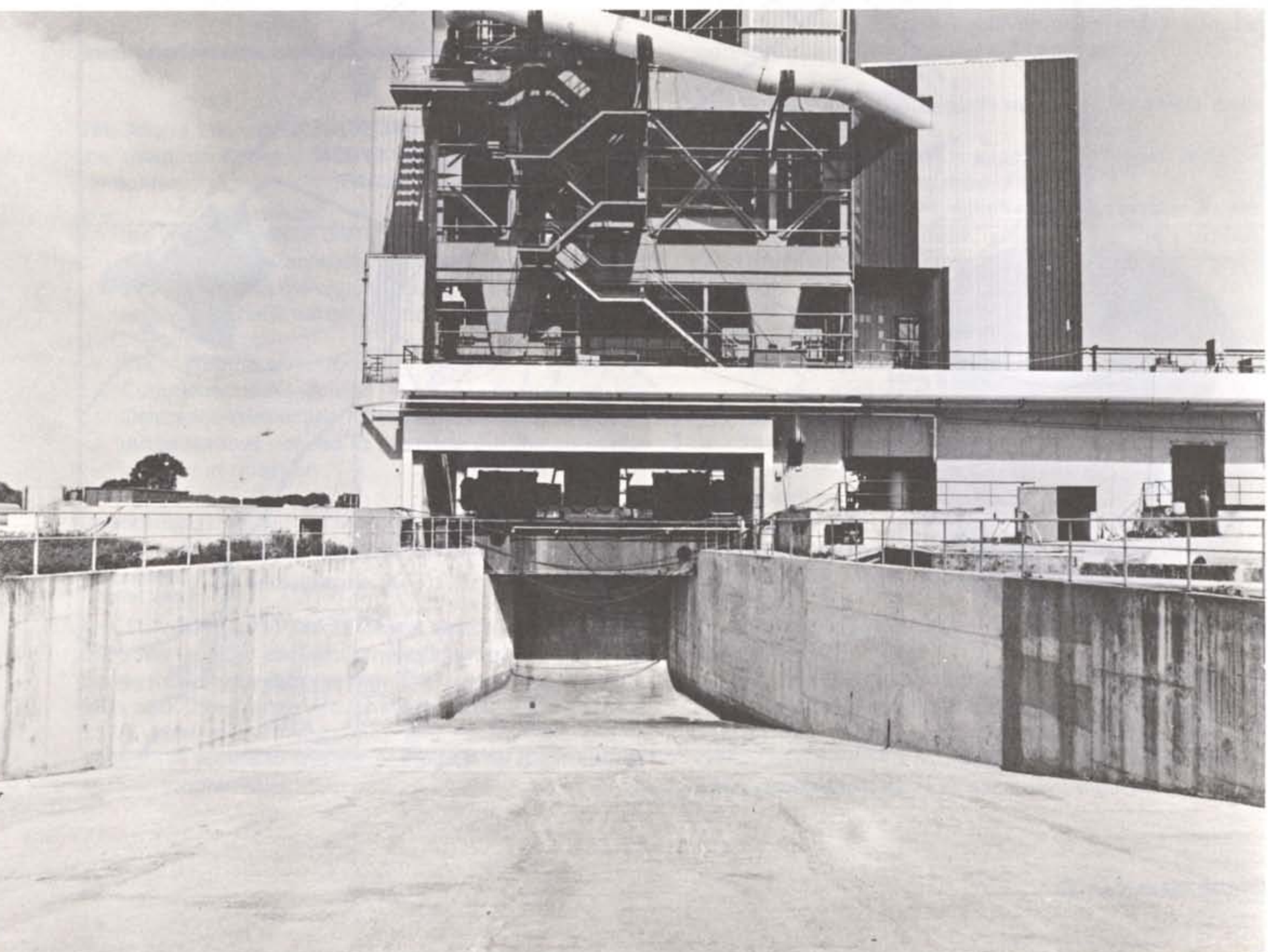


Figure 2 – Perspective view of launch zone.



B : SUPPORT SERVICES BUILDING
PC : LAUNCH CENTRE
C : ICED-WATER PLANT
H : HELIUM STORAGE
R : LAUNCH-PLATFORM ACCESS RAMP
T : MOBILE SERVICING TOWER
M : UMBILICAL MAST
F : LAUNCH VEHICLE PAD
J : FLAME TRENCHES
A : LIQUID-NITROGEN STORAGE
PA : N_2O_4 STORAGE
LH_2 : LIQUID-HYDROGEN STORAGE
U : UDMH STORAGE
E : WATER TOWER
W : METEOROLOGICAL MAST

- two facilities for storing and transferring cryogenic propellants
- a facility for storing 300 m³ of liquid nitrogen (five tanks) and producing gaseous nitrogen at high pressure
- a plant for producing and storing the iced water needed for air-conditioning
- a support-services building
- a safety building, including a guardroom, and a full-time firefighting service for the whole site.

The working area around the launcher is served by seven fixed platforms at convenient levels and a mobile platform, allowing any part of the payload to be reached. A room inside the servicing tower, between the mobile platform and the travelling crane, constitutes the clean area in which payloads will be prepared for mechanical assembly with the launcher. All working levels are served by a 1000 kg lift. All levels are also served by an internal and an external staircase, and there is a system for emergency evacuation.

The *launch centre*, sited 200 m from the foundation, is a heavily protected, blockhouse-type building providing adequate protection for personnel during the final preparation, propellant filling and launch operations. It houses the checkout and control equipment for monitoring launcher-preparation operations.

◀ *Figure 3 – Support structure and launch table.*

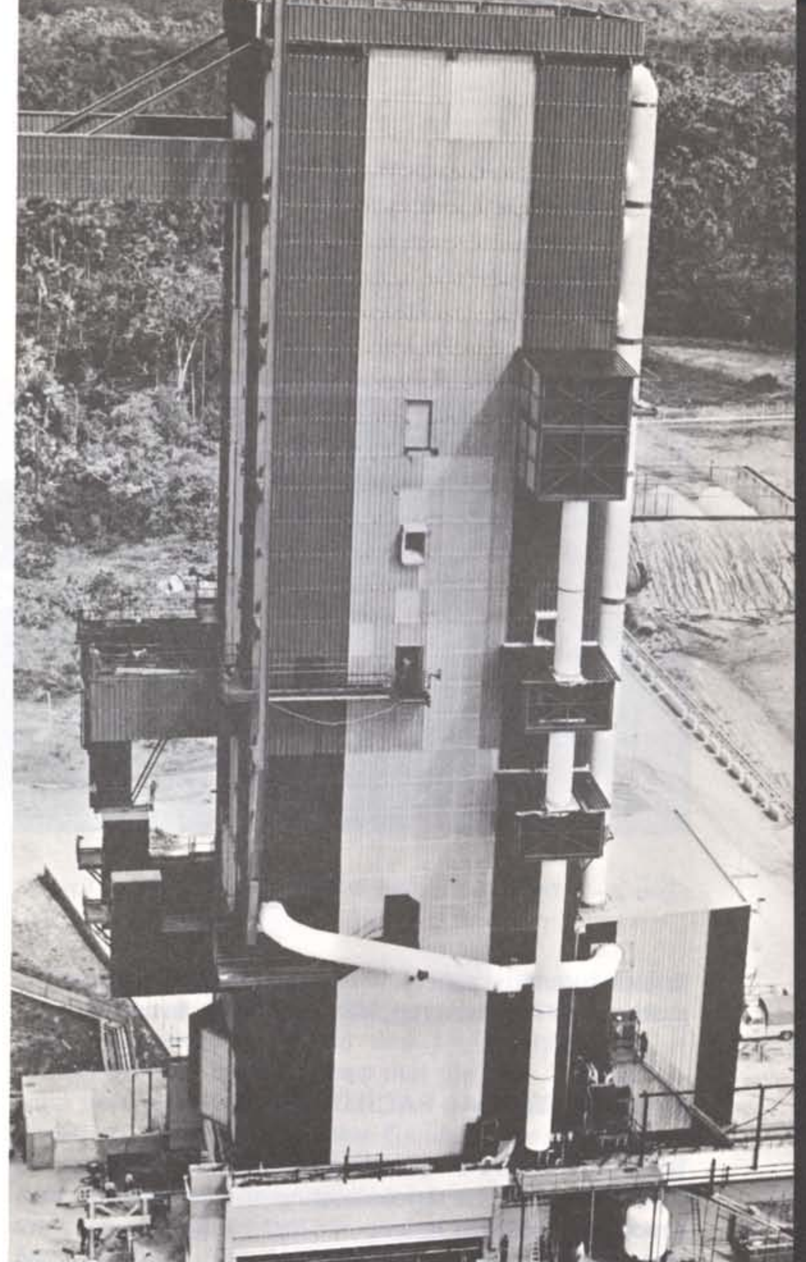


Figure 4 – The mobile servicing tower.

The *assembly zone* consists essentially of:
- an assembly building, to which the Ariane stages are taken on arrival in Guiana, for visual inspection and preparation prior to erection in the tower
- a stores building for site and launcher spares
- an office building.

The *propellant-support zone*, comprising two main storage facilities (Fig. 5), two garages for tanker trailers and a propellant-analysis laboratory, is used only for logistic support.

The *liquid-oxygen/liquid-nitrogen plant*, located in the

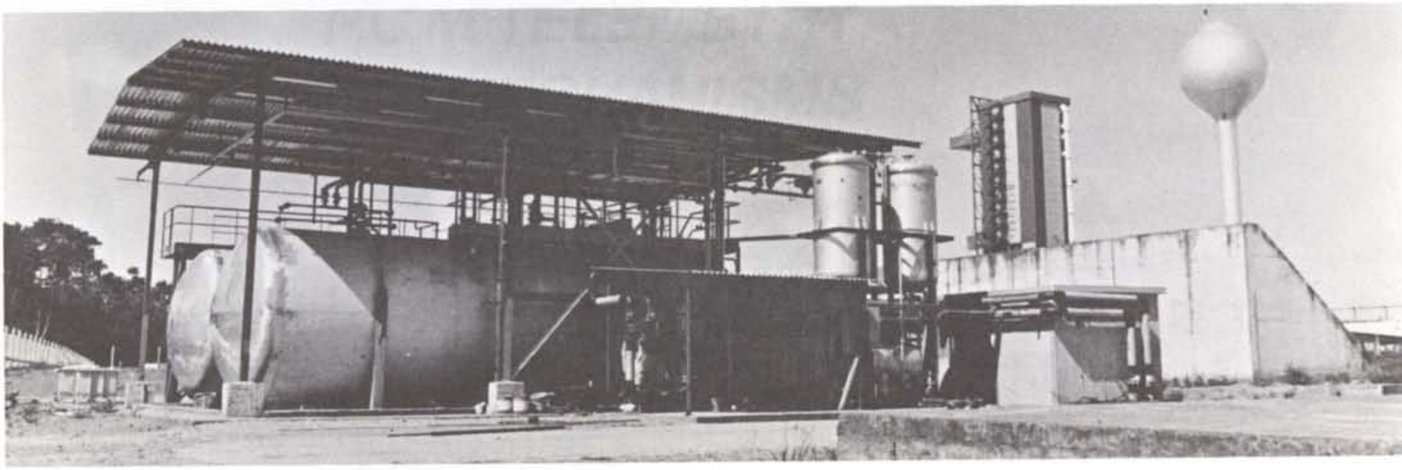


Figure 5 – The UDMH storage facility.

Kourou industrial zone, will produce these two cryogenic products to meet the requirements of the base.

THE ADDITIONAL FACILITIES

The additional Ariane facilities (MCA) embrace all the support needed for co-ordinating the preparation and execution of launch operations, including measurements that relate to the conduct of the launch and on-board experiments and ensure the safety of both personnel and property during operations. They consist essentially of the CSG measurement facilities (tracking, telemetry, etc.), located along the coastal strip near Kourou, with further facilities on the Iles du Salut, and the associated down-range stations.

TRACKING

The CSG tracking system has four radars (two acquisition radars located 5 km from the ELA, and two high-precision tracking radars, one of which is located near Kourou and the other near Cayenne), two infrared tracking kine-theodolites, computers, data-transmission systems and display equipment. All these facilities are interconnected and they will allow Ariane's trajectory to be monitored by radar until 200 s after orbital injection and provide accurate optical attitude-restitution data from the moment of lift-off until the vehicle passes out of visual range.

To allow the whole of the launch trajectory to be monitored, down-range stations in the form of the Natal radar facilities (Fig. 6) located within the CLFBI (Brazilian launch base), and the Ascension Island radar facilities (DOD), from which the orbital injection of payloads can be observed, are also employed (Fig. 8).

TELEMETRY

The configuration of the CSG ground-telemetry stations and the down-range stations is such that it is possible:

- to acquire without interruption all the telemetry data transmitted in the E-band (2200-2290 MHz) by the launcher and the Ariane technological capsule ('Capsule technologique Ariane' – CAT) during the launch phase, from the final preparatory operations on the pad, until 200 s after third-stage cut-off for vehicle-equipment-bay telemetry, and until loss of visibility by the station covering injection for the capsule telemetry
- to acquire all the telemetry information transmitted in the A-band (136-138 MHz) by the technological capsule, from final preparations on the launch pad until fairing jettison

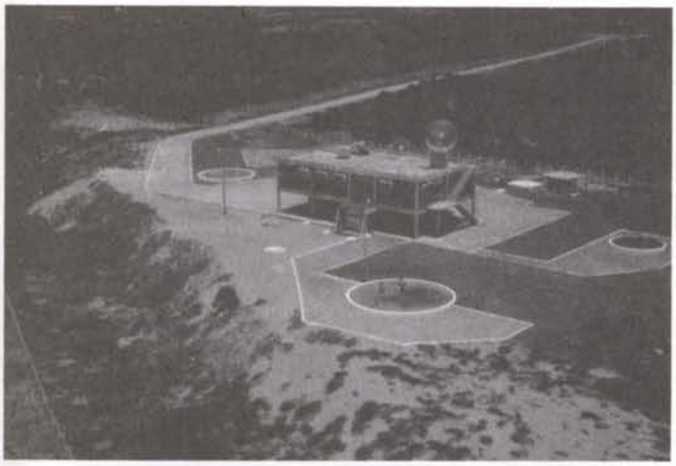


Figure 6 – Natal station: the Béarn radar.

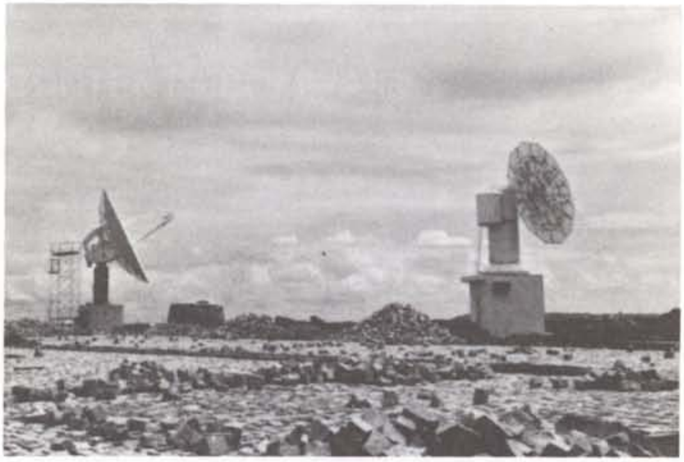


Figure 7 — Natal station telemetry antennas.

- to register all telemetry transmissions received on magnetic tape
- to reconstitute in real and deferred time the telemetry information received.

The telemetry facilities include the Montagne des Pères (Kourou) and Cayenne-Montabo receiving stations, both operating in the 2200-2290 MHz band, and the Diane-Iris station, which forms part of the satellite control network, operating in the 136-138 MHz band.

The Ariane programme also provides for setting up two new telemetry reception stations in Brazil; one, a mobile station, in the neighbourhood of Bélem, and another in Natal at the CLFBI (Fig. 7). The NASA telemetry reception station on Ascension Island will be used to cover the launcher's last powered phases and the placing of the satellite in orbit.

THE PAYLOAD FACILITIES

The payload facilities ('Moyens Charges Utiles' – MCU) are comprised of all the facilities made available by ESA to Ariane users for preparing their satellites, from arrival in Guiana until launch. They include the payload installations ('Installations Charges Utiles' – ICU) – buildings and equipment, specifically intended for preparing Ariane payloads – and the various services provided for payload installation and satellite transport and preparation. To avoid any misunderstanding, it should perhaps be mentioned that the term 'payload' is used here to denote the mass that the Ariane launcher places in orbit for the customer. Generally speaking, this is the *satellite*, i.e. a mission module and a service module, and the *propulsion module*, which is an apogee motor in the case of a geostationary mission, but may also be a perigee motor (for certain missions there will be no propulsion module).

The ICU include several buildings dispersed geographically according to the activities to which they are assigned:

- Satellite-preparation and checkout building (B1)
- Propulsion-module preparation building (B2)
- The satellite/propulsion-module integration building (B3)
- Propulsion-module storage building (B4)
- Upper platform of the servicing tower (platform 8)
- Storage buildings (B5)
- Launch centre (payload, technical and operational consoles)
- Operations centre (payload operational console).

Building B1 and the operations centre are located in the CSG technical centre, 5 km west of Kourou. Building B4 is

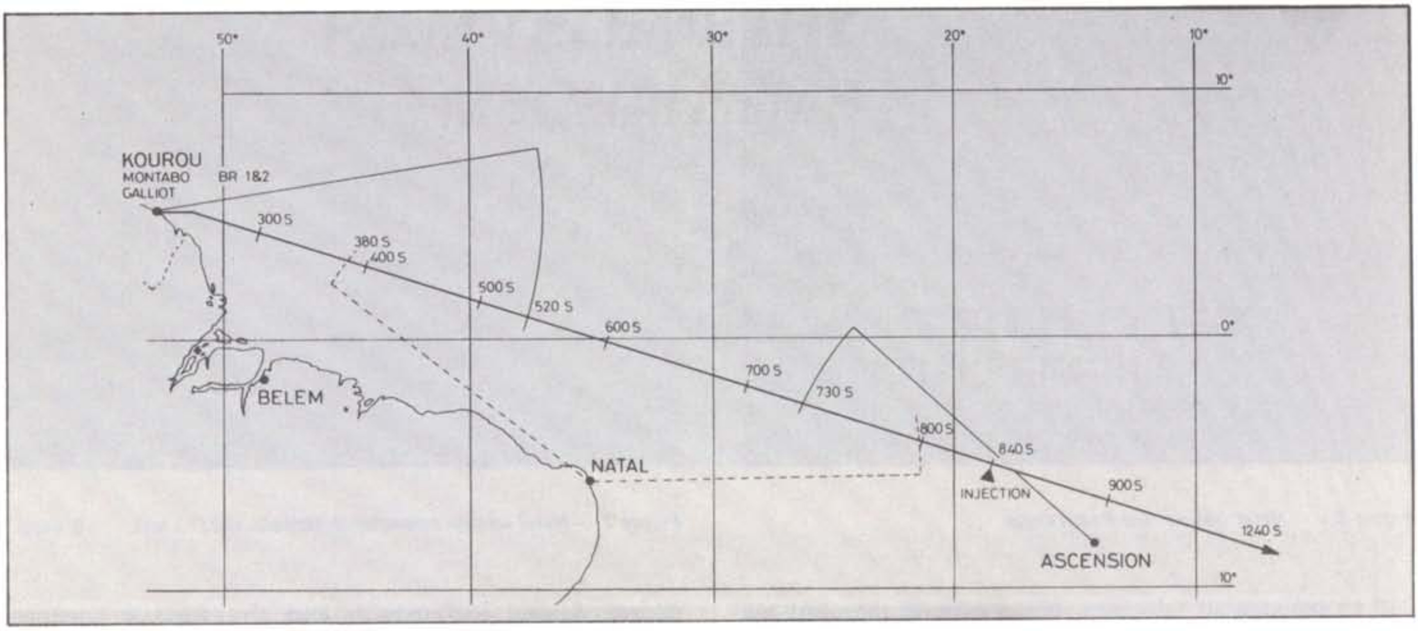


Figure 8 — Locations of ground tracking stations, with indications of radar visibility.

located in the storage zone for solid-propellant thrusters, 8 km west of the technical centre. The other buildings, B2 and B3, are in the ELA assembly zone, 1.5 km south of the launch zone. The storage buildings are situated at various points within the Guiana Centre.

The ICU as a whole has been designed to handle satellites compatible with Ariane's maximum performance. The distribution of the operations between several buildings allows the length of the launch campaign to be kept to a minimum even in the case of a double satellite launch in the same payload.

Building B1, intended for satellite preparation and checkout, provides a 420 m² clean room which can be divided up for the simultaneous preparation of two smaller satellites for double launches.

Buildings B4 and B2 provide for solid-propellant thrusters to be stored, refrigerated, submitted to X-ray inspection and prepared before transport to building B3. The engines for both large and small satellites can also be processed in buildings B4 and B2.

Provision is made in building B3 for filling satellites with propellant and integrating the payload. In the case of a double launch, the two payloads will be integrated separately and then mounted on the Sylda* to form the payload composite, which is then placed in a special container.

Communications between the satellite and its checkout system are provided by landline and radio relay. In principle, the checkout system is located in building B1, but space is available in the launch centre for a checkout system of reduced dimensions along with the payload operation consoles. Telephone, interphone and television circuits can be set up on request between the various locations where payload activities are taking place, and all the buildings include suitable ancillary facilities such as offices, stores, laboratories and cloakrooms (specially equipped for propellant-work and clean-room clothing). □

* 'Système de Lancement Double Ariane', the Ariane double launch system, described elsewhere in this Bulletin.

Altitude-Simulation Testing of Ariane's Second-Stage Engine

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G. Tofahrn, DFVLR, Hardthausen, Germany

When developing the propulsion system for a particular stage of a launch vehicle, one of the major unknowns that has to be investigated is how that engine will function (ignition, performance, etc.) under the conditions prevailing at stage-separation altitude. Development testing must therefore be carried out by simulating the ambient conditions that the propulsion system will incur at its operating altitude. In the case of Ariane's second stage, this testing has been conducted at DFVLR's facilities at Hardthausen.

The second stage takes over propulsion of the Ariane vehicle 52 km into the launch and carries it to a final altitude of 135 km in 138 s. During this period, the vehicle's velocity is increased from 2260 to 5160 m/s, with a final acceleration of 45 m/s^2. After first-stage separation, the vehicle weighs 5×10^4 kg, and this falls to 1.6×10^4 kg as further propellants are used up. The same propellants are used as in the first stage, namely N_2O_4 (nitrogen tetroxide) and UDMH (unsymmetrical dimethylhydrazine), and they are contained in a tank with two compartments each of 15.5 m^3 separated by a common bulkhead. Feed pipes carry the propellants to the Viking-IV turbopump engine, which delivers the thrust.

The engine is started up via a control system which opens three main valves and activates the tank pressurisation systems. An eventual fall-off in acceleration signals propellant depletion and initiates third-stage separation.

THE VIKING-IV ENGINE

As one of the Viking family of rocket engines developed in France by SEP, the Viking-IV is specially designed to propel the upper stages of launch vehicles. In the case of Ariane,

- it propels the second stage, by producing a specified thrust level
- it provides the gases needed to power the flight-control servomotors and the roll-control system
- it provides hydraulic correction of Pogo effect (oscillations resulting from vibrational coupling between the launcher's structure and propulsion system).

The main elements of the engine are:

- A turbopump, which augments the pressure of the propellants drawn from the stage tanks and injects them into the combustion chamber.
- A gimbal with two degrees of freedom, which allows the thrust vector to be swivelled through 4°, as required by the flight-control system.
- A thrust-unit ensuring combustion of the propellants and ejection of the gas produced.
- A gas generator, in which part of the main propellants are burnt and then cooled by injecting water, and which regulates the engine thrust. This gas is the energy source for the turbine, the servomotors and the roll-control system.
- The main valves, which control engine start-up and cut-off by admitting propellants and water.
- The Pogo correction systems (N_2O_4 and UDMH), which absorb fluctuations in flow to the pumps to prevent their being coupled with the vibrations of the structure and the propulsion system.

The operating principle and primary characteristics of the engine are shown schematically in Figure 1.

GENERAL TEST OBJECTIVES

The engine is being developed in three phases and the objectives of the accompanying test series can be summarised as follows:

- Turbopump tests, aimed at determining performances, and checking the mechanical endurance and settings of the gas generator.
- Complete engine tests under normal atmospheric ground conditions, with a nozzle whose exit pressure is suited to operation at atmospheric pressure. The main objectives of these tests are to verify the mechanical resistance of the hardware, the stability of combustion when running steadily, and the correct adjustment of the propellant mixture. The engine is used in this configuration for complete-stage tests, the purpose of which is also to study compatibility

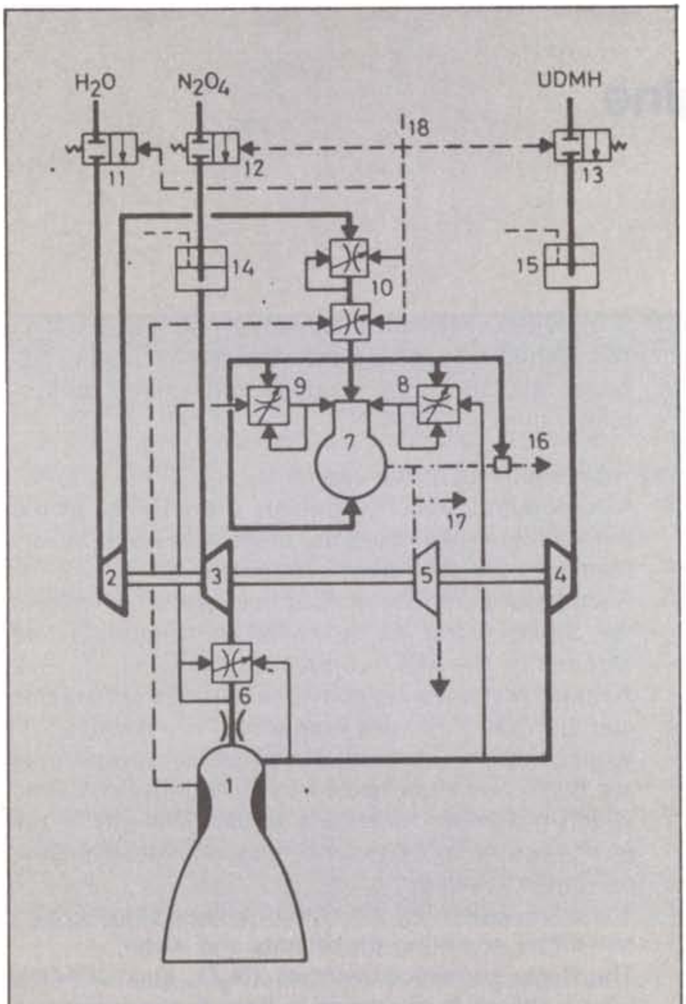


Figure 1 – Schematic of the workings of the Viking-IV engine.

Total thrust (in vacuo)	713	kN
Specific impulse	295.8	s
Total flow	245.7	kg/s
Combustion chamber pressure	52.2	bar
Chamber throat diameter	0.306	m
Chamber exit diameter	1.7	m
Chamber exit pressure	0.23	bar
Turbopump speed	9420	rpm
N_2O_4 pump overpressure	61.5	bar
UDMH pump overpressure	59.5	bar
H_2O pump overpressure	59.5	bar
N_2O_4 pump flow	157.8	kg/s
UDMH pump flow	84.4	kg/s
H_2O pump flow	3.5	kg/s
N_2O_4 pump NPSP	2.15	bar
UDMH pump NPSP	1.3	bar
H_2O pump NPSP	0.7	bar
Generator chamber pressure	32	bar
Turbine inlet temperature	600°C	
Turbine exhaust temperature	400°C	
Total generator flow	5.7	kg/s

LEGEND
1 Thrust unit – 2,3,4 Pumps – 5 Turbine – 6 Mixture regulator – 7 Generator – 8,9,10 Regulators – 11,12,13 Valves – 14,15 Pogo correctors – 16 Servo-motor feed – 17 Roll-control system feed – 18 Control pressure.

between the various subsystems. Testing of the turbopump and engine alone is carried out on the PF2 test stand at SEP, Vernon (France) and that of the complete stage at DFVLR, Hardthausen (Germany).

– Engine tests with altitude simulation, the objectives being the measurement of propulsion performances, mechanical and thermal behaviour of the nozzle, and engine start-up under simulated flight conditions. This latter objective covers the stability of combustion, conditioned by the vaporisation of the propellants, the pressure at ignition and the build-up of chamber pressure produced by pressure in the tanks and the acceleration of the stage. The test facilities are required to provide an ambient pressure of 1.5 mbar at ignition, and during run-up a level allowing supersonic expansion. These tests are also carried out at DFVLR.

THE TEST FACILITIES

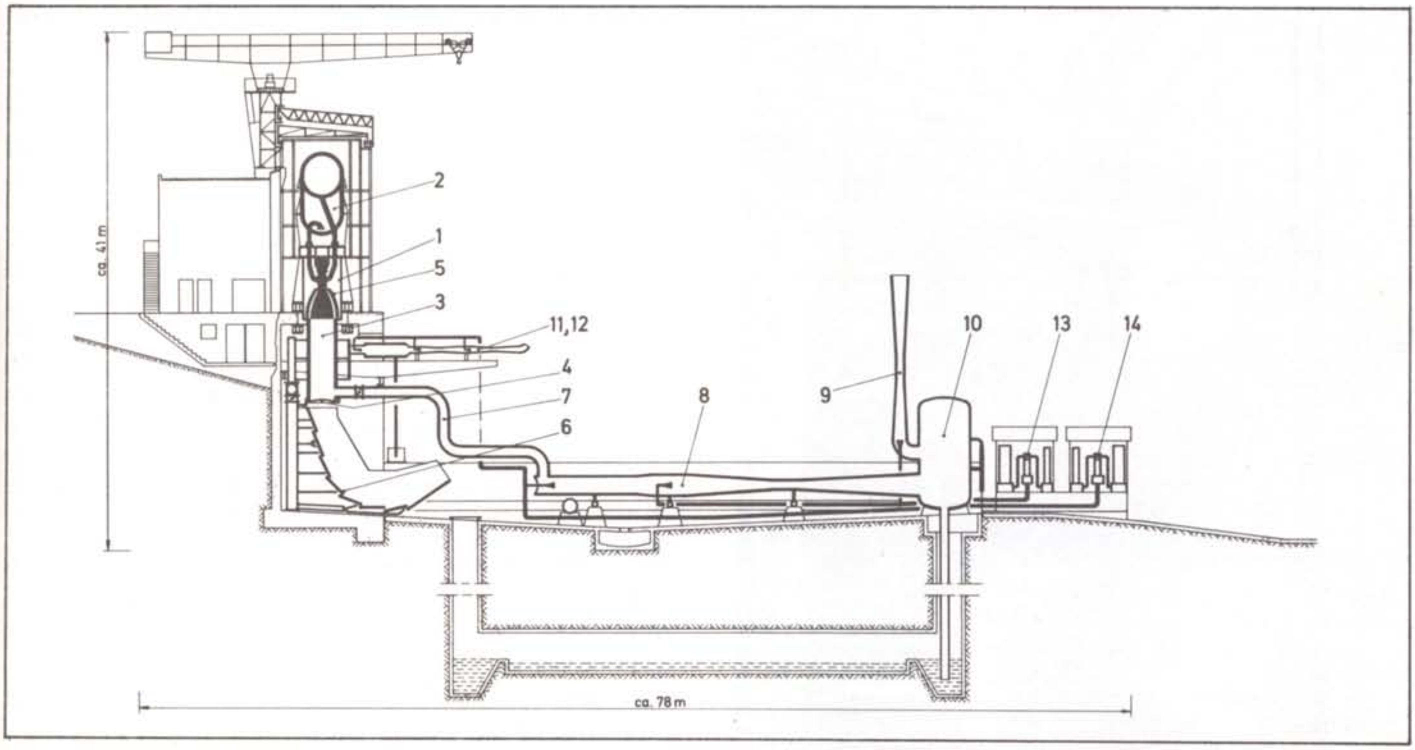
The test stand (Fig. 2) is an adaptation of the P4.2 stand at DFVLR, previously used for altitude-simulation testing of Europa-II's third-stage engine. The vacuum chamber (1), in which the engine is installed, is 2.8 m square and 4.9 m high. The propellant tanks (2), each with a capacity of 23 m^3, are installed above the vacuum chamber and arranged in a similar way to those of the second stage. They are pressurised by nitrogen so as to reproduce the pump-inlet pressure variations that occur in flight.

The gases exit from the nozzle at a speed of 3000 m/s, a stagnation temperature of 2900 K, and a static pressure of 230 mbar. They pass through a supersonic diffuser (3), which recompresses them to atmospheric pressure.

To allow a vacuum to be created in the chamber before engine start-up, the diffuser outlet is blanked off by a membrane (4) which burns in the jet after ignition. The engine nozzle is surrounded by a screen (5), cooled by a water jacket, intended to absorb the thermal energy radiated by the nozzle wall, the temperature of which reaches 1100°C.

At the exit of the diffuser, the vertical gas jet is deflected obliquely (6). The cooling system of the deflector and diffuser requires a coolant flow of 600 l/s.

Figure 2 – Principal features of the P4.2 test stand.



An 800 mm pipe (7) connects the diffuser to the steam ejector (8 and 9), which draws off the engine gases during the start-up phase. Part of the steam is condensed in an injection cooler (10) and the condensate falls into an underground sump.

The flow of turbine exhaust gases is drawn off throughout the running of the engine by two steam ejectors (11, 12). Part of the steam is also condensed by an injection cooler.

The steam required for all nine ejectors is produced by two vaporisers (13 and 14), each of which comprises a rocket-engine combustion chamber producing hot gases (by burning kerosene and nitric acid) into which water is injected to obtain steam.

CONDUCT OF THE TEST

When the mechanical and measurement facilities of the test stand have been duly prepared, a primary vacuum of a few millibars is first created in the chamber by a mechanical pump. The tanks are automatically filled with propellant and the sealing of all the propellant and vacuum circuits is checked.

Two minutes before engine start-up, the steam generators are started and proper operation of the ejectors and generators is checked by observing the pressure, which must remain less than 1.5 mbar. When this level is reached, the valves between the ejectors and the vacuum chamber are opened.

The automatic test sequence begins 40 s before engine start-up. Ignition is achieved by opening the engine's main valves. During this phase, the automatic sequencer transmits commands to the test-stand systems: propellant circuits, diffuser cooling film, and measurement devices.

At 0.2 s after the command to open the valves, a first increase in chamber pressure is noted; thereafter, increases of pressure to 25 mbar at the nozzle exit and

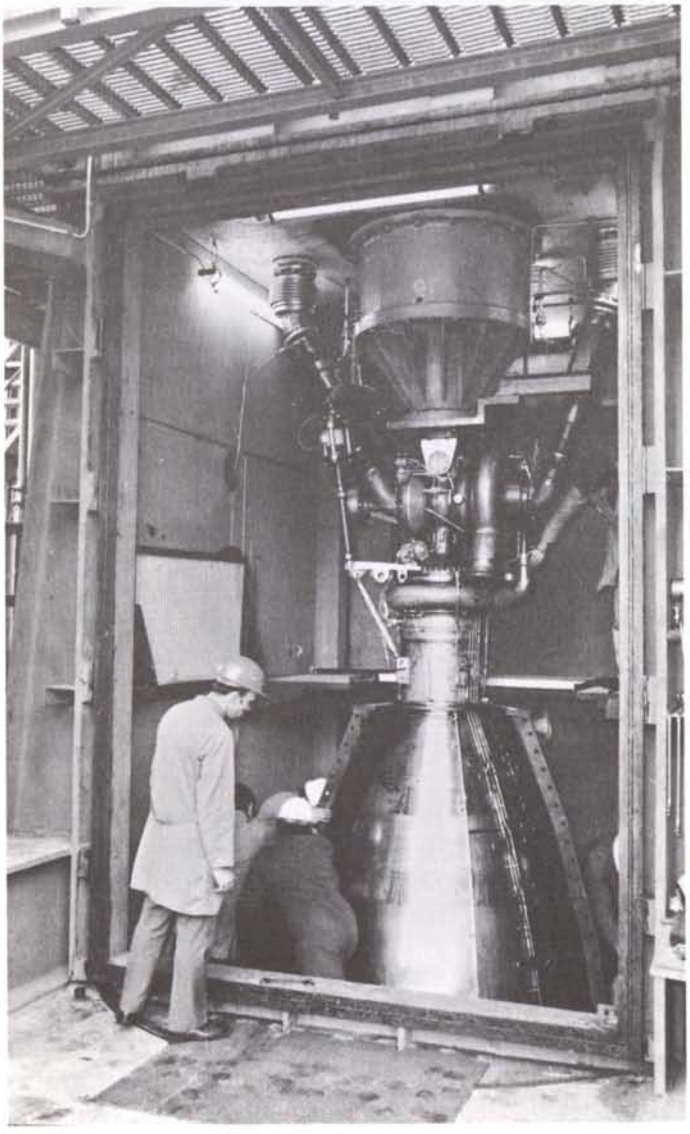


Figure 3 – Ariane's second-stage engine being readied for test (test stand P4.2).

200 mbar in the combustion chamber denote the vaporisation of the N_2O_4. The cooling due to this vaporisation produces a slight fall in pressure. Ignition results in an increase in chamber pressure from 0.2 bar to 3.5 bar, at 0.7 s. At that moment, the nozzle-exit pressure reaches 0.9 bar and the blanking membrane opens. The engine continues to run up and steadies out at 3 s; simultaneously, the suction due to the engine jet brings the vacuum-chamber pressure to 40 mbar when the nozzle-exit pressure reaches 230 mbar.

Depending on the test objectives, the chamber pressure and consequently the thrust or the mixture ratio, can be varied. After a maximum period of 180 s, cut-off is initiated by closing the main engine valves.

During the test, 220 measurements are recorded and 70 commands transmitted. The functioning of the motor and the test stand are monitored by ten sensors which automatically terminate the test if certain parameters exceed prescribed limits.

Figure 3 shows the Viking-IV engine being installed in the vacuum chamber on the test stand, linked by its gimbal to the thrust-measurement gauge and with the main valves connected to the propellant feed lines.

MAIN RESULTS

In the course of the Ariane development programme, eight tests of the type just described are due to be conducted, including two qualification tests. So far, five of these tests have been completed, three lasting more than 140 s, two short ones lasting less than 15 s (total 515 s) and one re-light. The three remaining tests should bring the total time in vacuum to 1000 s.

All the main test objectives that were set for the altitude-simulation tests on the second stage have been successfully achieved, including measurement of an engine impulse of 295.8 s, nozzle-wall temperatures identical to those foreseen, and near-nominal combustion-engine pressures on start-up. □

Mechanical In-Flight Environment of Ariane Payloads

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During the flight of a satellite launcher, the payload is subjected to complex combinations of static and dynamic loads. The sources of excitation are either of aerodynamic origin (winds, gusts during ascent through the atmosphere, buffeting at the sound barrier) or are due to the operation of the launcher stage propulsion systems (longitudinal and transverse accelerations, transients on light-up or burnout of engines, coupling between structure and propulsion system, etc.). This article describes the payload environment of the Ariane vehicle and outlines the theoretical and experimental elements used as a basis for this assessment.

SINUSOIDAL VIBRATIONS

In considering here the spectra of sinusoidal vibrations affecting the base of the payload during the launcher's flight, only considerations of a general nature can be given as the specific mass, inertial, and dynamic characteristics of the various possible payloads cannot be taken into account. This information and that resulting from the analysis of combined payloads constitute elements for initial dimensioning.

Longitudinal vibrations
Low-frequency longitudinal sinusoidal vibratory phenomena are mainly due to Pogo-type excitations and to transient excitations at engine burnout. The stability studies for Ariane are based on sophisticated theoretical models confirmed by tests (dynamic mock-up, hydraulic and engine), tests that have shown that stability can be assured by the provision of hydraulic Pogo-correction systems on the launcher's first and second stages. The development flights will provide an opportunity to make any necessary adjustments to these systems and to guarantee that there will be no such excitation effects on the operational flights. Nevertheless, until the first flight tests have confirmed the accuracy of the mathematical models, it seems erudite to assume that instabilities of limited amplitude could still appear in the frequency ranges in which a Pogo-type instability can occur when there is no correction system.

Such instabilities may occur in the 11-18 Hz and 28-35 Hz frequency bands, in which the first longitudinal modes of the first and second stages lie.

In processing the information derived from the tests on both engines and complete stages, it has been found that recordings of pressure at burnout show a vibration phase of a few tenths of a second during transition to half thrust capable of exciting Ariane's structure. This is the classical 'chugging' phenomenon, encountered with varying degrees of severity in most launchers. With Ariane, maximum energy occurs around 50-60 Hz.

Transverse vibrations
During the flight of the first stage, the vibrations with the greatest amplitudes correspond to the frequency range of the first five lateral modes of the launcher (2-15 Hz), which are excited over just a few cycles by gusts of wind (estimated vibration level 1.5 g). In the 15-100 Hz range, the vibrations are produced by transient excitations during thrust decay (estimated vibration level 1 g).

During flight of the second stage, the main sources of excitation are those corresponding to engine burnout. The vibration responses are highest in the 5-18 Hz range, corresponding to the frequencies of the first three bending modes (vibration level 1 g, and in the 18-100 Hz range, 0.6 g).

The sources of excitation during the third stage's flight are weak and do not give rise to any dimensioning vibration levels.

ACOUSTIC VIBRATIONS

The most significant acoustic environments as far as Ariane's payload is concerned occur at lift-off, during passage through the sound barrier, and at the time of maximum dynamic pressure (approximately 85 seconds into launch). The maximum acoustic level that occurs within the fairing is 142 dB, and this during lift-off.

The study of Ariane's acoustic environment, in terms of both overall level and spectral distribution, has been

TABLE 1 – *Low-Frequency Static and Dynamic Accelerations*

Flight events	Longitudinal axis (g)			Lateral axis (g)		
	Static	Dynamic	Total	Static	Dynamic	Total
Maximum dynamic pressure (85th second)	−1.9	±1.6	−3.5	±0.1	±1.6	±1.7
First-stage burnout	−4.3	±1.9	−6.2	±0.2	±0.9	±1.1
Second-stage burnout	−4.7	±3.1	−7.8	±0.4	±0.8	±1.2

based on systematic experimentation with 1/20 and 1/10 scale models, and this has made it possible to arrive at a complete description of the pressure field during the lift-off phase. Extrapolation to full-scale has been based on simple similitude laws confirmed by tests.

In its nominal form, the launcher is provided with acoustic protection, now nearing full development, which furnishes an overall attenuation of 5 dB. This figure does not take into account the influence of fairing vents, which is still being evaluated.

RANDOM VIBRATIONS

The acoustic vibrations due to the operation of Ariane's engines and to the effects of boundary layer noise on the external structures of the upper part of the vehicle are the main phenomena that can give rise to random vibrations at the base of the payload. Maximum levels occur at lift-off and during passage through the sound barrier during the flight of the first stage, (root-mean-square estimate 7.3 g). These estimates are based on interpretation of the correlation between acoustic levels and random levels at the bases of payloads on other launchers, this approach being preferred to a theoretical one which is considered too uncertain.

SHOCKS

The most significant shock levels as far as the payload is concerned occur when the fairing is jettisoned during the flight of the second stage and during launcher/payload separation. Initial processing of equipment-bay/fairing separation-test data has shown that the shock level at the base of the payload was of the order of 700 g for a duration of 1 ms. Processing of the launcher/payload separation-test data has not yet been completed.

COMBINATION OF DIMENSIONING LOADS

During flight, the various static and dynamic loads that have been mentioned are superimposed and the design and dimensioning of the main payload structures must therefore allow for the most severe load combinations that can be expected at any given moment.

From the point of view of quasi-static loading, the most significant load factors occur at the times of maximum dynamic pressure, and first and second-stage burnouts.

At the preliminary dimensioning stage, to avoid dynamic couplings between launcher and payload it is preferable for the fundamental lateral frequency of the satellite (assumed to be secured at its base) to be higher than 10 Hz, and its longitudinal frequency greater than 35 Hz.

There is also a need in the preliminary design phase to try to avoid the 50-60 Hz frequency band, in which the sinusoidal excitations due to engine burnout which have already been mentioned are to be found. These may give rise to local effects on the secondary structures and flexible elements (antennas, solar panels) which must be designed so as to avoid locating their resonance frequency within this band.

Table 1 shows the combinations of low-frequency static and dynamic accelerations occurring at the times of critical flight events. Longitudinal and lateral accelerations act simultaneously at the centre of gravity of a typical Ariane-launched satellite (1700 kg).

ARIANE/PAYLOAD COUPLING STUDIES

The vibration levels and combined loadings that have just been described constitute the basic data for pre-dimensioning, and a detailed analysis is still necessary at the final dimensioning stage. This is the purpose of the coupled analysis that is to be carried out to make a detailed estimate of the loads that will be induced by Ariane at various points on the satellite. From a combination of the structural model of the payload with the longitudinal and lateral models of the launcher in respect of given excitation forces, the mechanical loads on the payload can be calculated. Analysis of the results allows the dimensioning that has been adopted to be confirmed.

MECHANICAL LOADINGS ON ARIANE AND OTHER LAUNCHERS

It is perhaps of interest to compare the mechanical loads

TABLE 2 – *In-Flight Sinusoidal Vibration Levels*

Axis	Ariane		TD-2914, TD-3914, TD-3910 + PAM		STS/PAM		Atlas-Centaur	
	Frequency (Hz)	Level	Frequency (Hz)	Level	Frequency (Hz)	Level	Frequency (Hz)	Level
Longitudinal	5-7 7-100	5.6 mm (O-peak) 1.5 g	5-6.2 6.2-15 15-21 21-100	6.35 mm (O-peak) 1.0 g 3.5 g 1.0 g	5-35	0.75 g	5-8.5 8.5-200	5.1 mm (O-peak) 1.5 g
Lateral	5-5.3 5.3-15 15-100	11 mm (O-peak) 1.5 g 1.0 g	5-100	0.7 g	5-35	0.75 g	5-8.0 8.0-200	3.8 mm (O-peak) 1.0 g

TABLE 3

Launcher	Overall random-vibration level (g_{rms})	Overall acoustic level* (dB)
Ariane	7.3	137
TD-2914	7.0	141
TD-3914 + 3910/PAM	8.0	143
STS/PAM	11.3	145
Atlas-Centaur	6.2	141

* *All launchers fitted with acoustic protection. (Ref. 2×10^{-5} pascal)*

TABLE 4

	Maximum axial load accelerations (g_{rms})		Maximum radial load accelerations (g_{rms})	
	Axial	Lateral	Axial	Lateral
Ariane	−6.7	±1.9	−3.4	±2.0
TD-2914	−11.4	±1.0	−2.4/+1.0	±2.0
TD-3914 +3910/PAM	−11.2	±1.0	−2.4/+1.0	±2.0
STS/PAM 90°	−5.0 3.3	+3.5 ±5.1	−3.3	±5.1
Atlas-Centaur	−6.4	±2.0	–	–

Minus sign indicates compression.

to be expected on payloads flown on Ariane with those sustained during Thor-Delta, Atlas-Centaur and Space Shuttle (STS) launches.

It can be seen from Table 2 that the in-flight *sinusoidal vibration* levels at the payload base during an Ariane launch are comparable to those on an Atlas-Centaur, but higher than those for a Shuttle (STS) plus Payload-Assist Module (PAM) launch. As far as *random vibration* at the payload base is concerned also, Ariane's levels are much lower than those for an STS/PAM launch and only slightly higher than those experienced on an Atlas-Centaur (Table 3).

The analysis of *acoustic-environment* data applied to Ariane payloads shows that the European launcher, with its acoustic protection, is the best performer in this respect (Table 3).

As Table 4 shows, the maximum *combined loadings* applied to the payload centre of gravity are also comparable on Ariane to those on an Atlas-Centaur, the longitudinal loads being lower than those of Thor Delta, although the associated lateral loads are higher, and overall probably lower than those of STS/PAM.

CONCLUSION

As the foregoing should hopefully have served to indicate, comparison of Ariane's mechanical in-flight environment with those of other launchers does not bring to light any feature that could be considered to constitute a penalty as far as a payload launch by Ariane is concerned. In-flight development tests, for which a very complete plan has been set up, particularly as regards the technological capsules, should make it possible to confirm and in some cases refine the estimates that have been quoted in the Ariane User's Manual. □

Essais dynamiques d'ensemble du véhicule Ariane

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Des essais dynamiques ont été réalisés au Site d'Intégration du Lanceur (SIL) à l'Aérospatiale (les Mureaux) sur le véhicule Ariane à l'aide d'une maquette à l'échelle 1. La structure de cette maquette était conforme au standard de vol, les équipements électriques étaient représentés par des lests. Ces essais ont été effectués en soumettant la maquette à des excitations longitudinales et transversales pour les principales configurations de vol.

La conduite des essais était guidée par des calculs prévisionnels établis par l'Aérospatiale; la confrontation avec les résultats expérimentaux est à la base de la démarche recherchée pour adapter et valider les modèles mathématiques de l'Aérospatiale. Les résultats d'essai et les calculs présentent en général une assez bonne concordance pour les premiers modes; l'investigation a pu être poussée jusqu'à 100 Hz avec satisfaction et même jusqu'à 200 Hz pour quelques configurations afin de fournir des valeurs expérimentales des entrées au niveau de la charge utile dans cette gamme de fréquence.

INTRODUCTION

Il n'existe pas de méthode permettant de supprimer totalement à la source les vibrations qui environnent un lanceur au cours de sa vie (transport, vol). La solution consiste à concentrer les efforts d'analyse et de calcul en vue de caractériser ces sources vibratoires et d'éviter les couplages avec la structure, donc à rechercher les domaines de stabilité dynamique dans les différentes phases de la vie du lanceur. On peut citer à titre d'exemple l'importance que présente la stabilité de la boucle de pilotage et de la boucle Pogo. En effet, les forces engendrées par les mouvements de tuyère pour le pilotage constituent une source d'excitation pour la structure. Un des critères que devra prendre en compte l'étude du pilotage sera donc d'éviter un couplage avec les modes de flexion du véhicule, ce qui nécessite la connaissance des fréquences, masses généralisées, déformées et amortissements des modes de flexion. Pour le phénomène Pogo, la source d'excitation a pour origine les fluctuations de poussée qui constituent le bruit de fond de la combustion dans la chambre du moteur; mais c'est le couplage de ces petites instabilités, inoffensives en elles-mêmes, avec la structure et les lignes fluides qui peut engendrer une très forte instabilité qui provoque alors des charges dynamiques considérables que l'on désigne sous le nom de Pogo. L'étude de ce phénomène requiert donc la connaissance des caractéristiques des modes longitudinaux axisymétriques de la structure et les fonctions de transfert des lignes fluides.

La tendance à l'instabilité est liée dans ce cas à la valeur de la masse généralisée du mode correspondant, à la déformée de pression dans les réservoirs et enfin à l'amortissement qui semble, en particulier, être un paramètre déterminant dans la manifestation du phénomène.

OBJECTIFS GENERAUX DES ESSAIS

Grâce aux moyens de calcul nouvellement développés par l'Aérospatiale à l'occasion du programme Ariane, les caractéristiques modales peuvent être appréhendées de façon théorique avec une précision supérieure à ce qui avait pu être réalisé pour les programmes antérieurs. La représentativité des résultats reste toutefois étroitement liée à la modélisation de la structure et aux caractéristiques mécaniques introduites dans les calculs. Il faut aussi noter que, l'amortissement n'étant pas accessible au calcul, il intervient donc sous la forme d'un paramètre qui permet de faire des balayages: par mesure de sécurité on retient a priori une valeur assez faible pour le coefficient d'amortissement, mais cette démarche est souvent pénalisante pour le projet.

Pratiquement, dans un programme de développement de lanceur, cette nouvelle situation créée par l'évolution des moyens de calcul modifie la logique dans laquelle viennent s'insérer les essais dynamiques d'ensemble: en effet les essais dynamiques ne sont plus la source unique qui fournit au bureau d'études les caractéristiques modales du véhicule, mais un moyen de valider les modèles mathématiques. Cette démarche permet par la

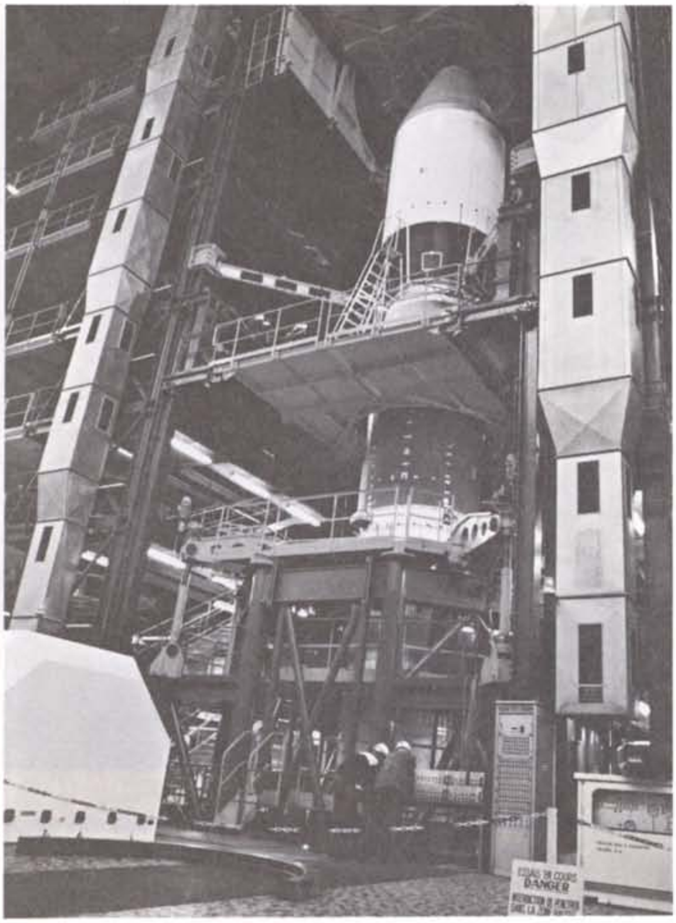


Figure 1 – Essai en configuration L33 avec coiffe: vue d'ensemble.

étages a donc subi tous les contrôles définis pour le véhicule réel.

Les équipements électriques et les câblages n'étaient pas représentés par des éléments réels mais par des lests. Les ergols étaient simulés par de l'eau, sauf pour le réservoir d'hydrogène du 3ème étage qui n'était pas rempli. La densité de l'hydrogène liquide est très faible; toutes solutions visant à simuler l'ergol, outre les complications de mise en oeuvre, risquent plus d'altérer les résultats que d'approcher la réalité. Les canalisations d'alimentation des moteurs étaient remplies jusqu'au niveau entrée pompe. La pressurisation des réservoirs était assurée par une alimentation extérieure de bouteilles d'azote.

La maquette, placée en configuration verticale, moteur en ligne de tir, était suspendue de telle sorte que les liaisons des différents sous-ensembles puissent travailler en compression de la même façon qu'en vol (à la valeur près de l'accélération due à la poussée du moteur).

suite de prévoir par le calcul l'influence de modifications mineures de la structure sur le comportement dynamique sans avoir nécessairement à repasser par la voie expérimentale. C'est la raison pour laquelle les objectifs principaux suivants ont été retenus dans la spécification générale du système véhicule Ariane:
- Qualifier et compléter les modèles mathématiques représentant la dynamique d'ensemble du véhicule.
- Etudier certains modes locaux et mesurer les coefficients de surtension au niveau des équipements lourds.

PRINCIPES DE DEFINITION DE L'INSTALLATION

SITE D'ESSAI
Le bâtiment d'intégration du véhicule Ariane à l'établissement de l'Aérospatiale des Mureaux a été retenu comme site des essais dynamiques d'ensemble: les aménagements internes nécessaires à la réalisation de ces essais ont donc été prévus dès la construction de ce bâtiment.

MAQUETTE
La structure de chaque étage a été demandée conforme au standard de vol, au moment de sa fabrication. Chacun des

MISE EN OEUVRE
Les mesures de mise en oeuvre nécessaires pour mettre la maquette en configuration d'essai d'une part, et d'autre part pour la surveillance pendant les phases de vibration ou les phases d'attente, étaient totalement indépendantes des mesures opérationnelles de l'expérimentation.

Les opérations de levage, de remplissage et de pressurisation étaient commandées à distance pour des raisons de sécurité.

Pour rendre la maquette libre, simulant l'état dans lequel le véhicule se trouve en vol, il faut pouvoir reprendre le poids total par une liaison qui assure en même temps un découplage suffisant vis-à-vis de la fréquence du mode le plus bas que l'on veut étudier: c'est le rôle que doit assurer le système de suspension. Le choix du principe de suspension détermine en grande partie les autres sous-ensembles de l'installation et la qualité du montage d'essai: c'est la raison pour laquelle les principales solutions théoriquement possibles ont d'abord été examinées: suspension fluide, suspension mécanique par ressorts ou par sandows.

C'est finalement cette dernière solution qui a été retenue après qu'aient été vérifiées par des essais, sur plusieurs lots, les caractéristiques des sandows, leur sensibilité à la température, à l'humidité et au vieillissement sous charge. Ces essais ont permis de pallier le phénomène de fluage dans le temps qui aurait pu perturber le déroulement des essais dynamiques: la suspension a été conçue de telle sorte que les sandows sont maintenus pré-tendus à 90% de leur charge nominale, ce qui élimine pratiquement tout fluage (Fig. 2).

Le coût des sandows est aussi relativement peu élevé par rapport aux ressorts métalliques, ce qui a permis d'adapter un type de sandow pour chaque configuration de maquette.

- Sandow ϕ 25 mm: configuration 1er étage ($\simeq$200 t)
- Sandow ϕ 18 mm: configuration 2ème étage ($\simeq$40 t)
- Sandow ϕ 12 mm: configuration 3ème étage ($\simeq$8 t)

STABILISATION STATIQUE ET DYNAMIQUE

Le centre de gravité de la maquette se trouvant situé au-dessus de la liaison avec la suspension, le système mécanique peut être statiquement instable. L'étude a montré qu'il était en effet nécessaire de prévoir un dispositif de stabilisation. Comme pour la suspension, il a été envisagé d'avoir recours à un dispositif soit pneumatique, soit mécanique.

Après étude comparative, c'est un dispositif mécanique avec quatre bras se reprenant à la partie supérieure de la maquette qui a été retenu. Chaque stabilisateur était équipé d'un système élastique à ressorts métalliques assurant un effort de rappel progressif en fonction du basculement et un découplage dynamique suffisant entre la maquette et le portique pour ne pas altérer son état libre lorsqu'elle était suspendue. Compte tenu du très large éventail de masse mise en jeu par les trois configurations de maquette (de 8 t à 200 t), il a été nécessaire de prévoir trois calibres de stabilisateurs. Les points de reprise sur la maquette avec ce dispositif se trouvaient pratiquement imposés: il n'est en effet pas possible de se reprendre en dehors des brides d'assemblage des sous-ensembles de la structure du véhicule. Un compromis a donc été recherché pour prévoir ces liaisons le plus près d'un noeud du premier ou du deuxième mode et le plus haut possible pour que les efforts statiques exercés par les stabilisateurs soient acceptables.

Figure 2 - Essai en configuration L33. Vue d'une boîte à sandows de la suspension avec son capteur de déplacement qui mesure l'élongation.

L'ensemble mécanique constitué par la maquette, les stabilisateurs et la suspension est par ailleurs assimilable à un pendule complexe qui, sous l'effet d'excitations harmoniques longitudinales forcées, pouvait présenter des caractères d'instabilité. Les domaines de stabilité de ce système ont été étudiés sur machine analogique sur la base d'une modélisation de masses et de ressorts.

PORTIQUE D'ESSAI ET BATI DE REPOS

En phase de vibration, le poids de la maquette était repris par un portique très rigide; en phase d'attente la maquette était déposée sur un bâti de repos.

Cet ensemble mécanique, portique, bâti, suspension et la maquette elle-même était dynamiquement isolé du sol et du bâtiment par l'intermédiaire d'un massif de réaction de 350 t suspendu à 3,5 Hz (Fig. 1).

EXCITATION HARMONIQUE

Les niveaux d'accélération recherchés au cours de ces essais sont en général assez faibles; il suffit en effet que la réponse donne un signal exploitable. Pour les configurations d'excitations transverses où il est possible de déplacer les points d'introduction des efforts en vue d'adapter la force d'excitation, on a utilisé des excitateurs délivrant respectivement à puissance maximale 200 N et 1000 N: ce qui correspond à des pots de petit calibre. Par

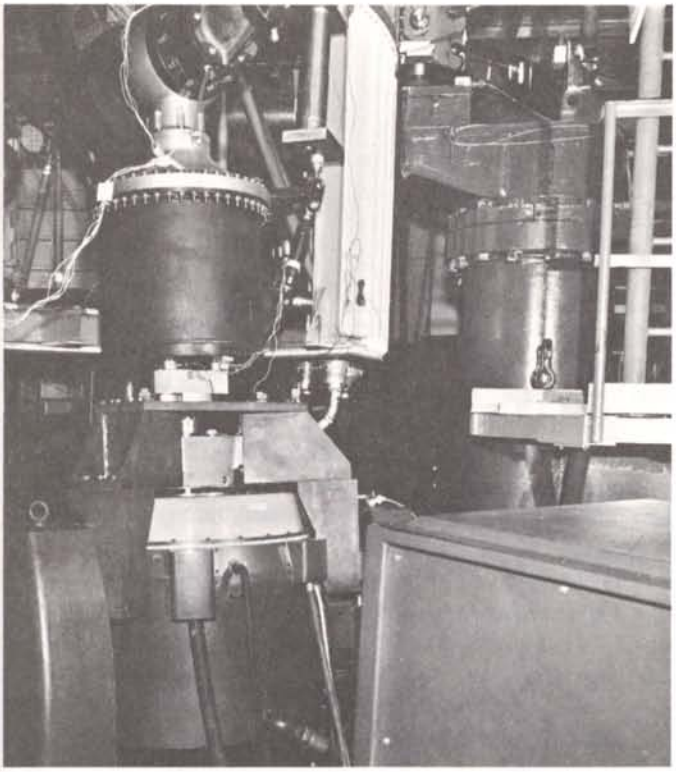


Figure 3 – Essai en configuration L140. Vue d'un excitateur 18 000 N du transmetteur et d'un moteur maquette.

contre pour les configurations d'excitations longitudinales, l'introduction des efforts ne peut s'effectuer qu'aux extrémités haute et basse de la maquette et, pratiquement, le point privilégié correspond à l'attache du ou des moteurs de l'étage inférieur. Il faut donc alors pouvoir disposer d'une force considérablement plus élevée que pour les modes transverses. On a utilisé des excitateurs délivrant une force maximale de 18 000 N, ce qui correspond à des pots de gros calibre qui pèsent chacun près de 3 t et nécessitent des servitudes beaucoup plus complexes que les pots de petit calibre. On peut citer à titre d'exemple que, si pour les pots de 1000 N la pièce de transmission d'effort entre la structure et la bobine mobile peut être réalisée à l'aide d'une simple tige filetée en acier, comportant localement une entaille qui permet une rupture en cas d'anomalie, il a fallu étudier un transmetteur beaucoup plus complexe pour pouvoir introduire 18 000 N en excitation longitudinale. Ce transmetteur devait en effet permettre d'introduire la force maximale jusqu'à 200 Hz et autoriser des mouvements parasites transverses de la maquette sans que les efforts de cisaillement et les couples rapportés sur la bobine mobile ne dépassent les valeurs prescrites par le constructeur (Fig. 3).

Par ailleurs, afin d'aligner la direction de la force d'excitation avec précision, selon l'axe de la poussée des

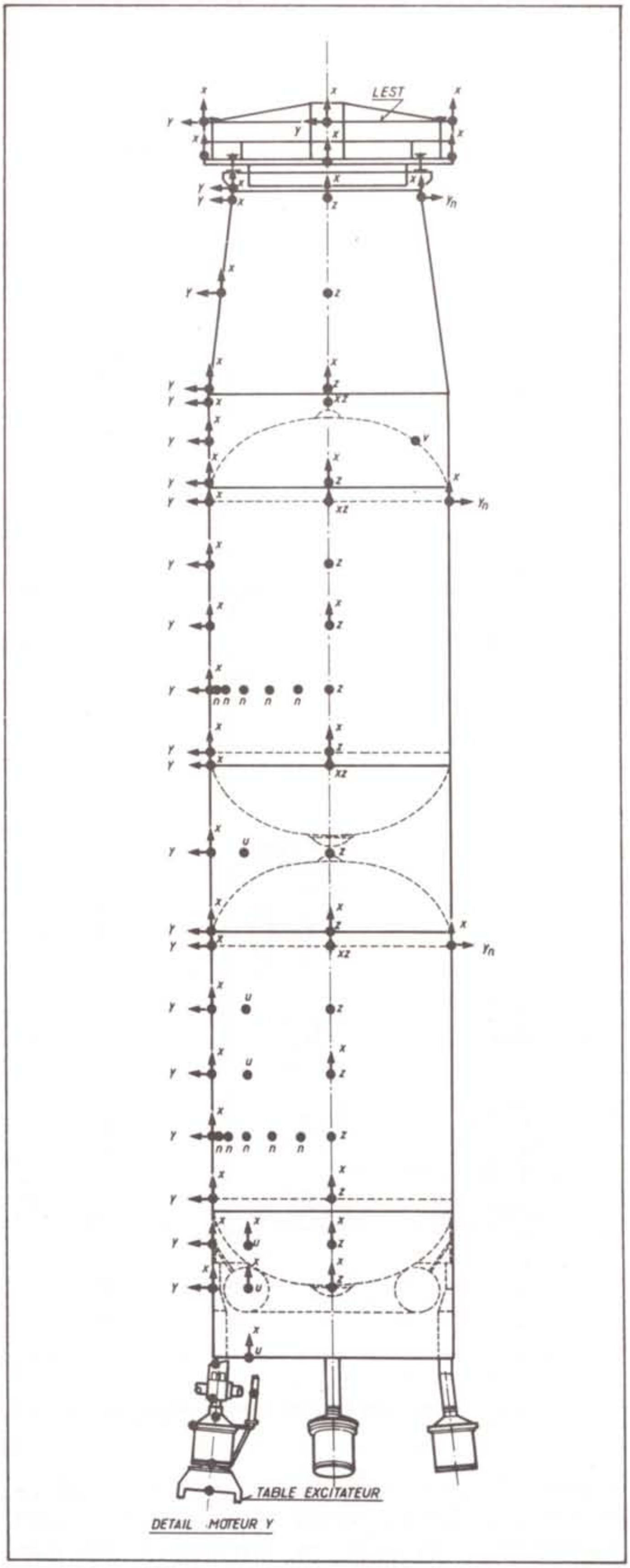


Figure 4 – Implantation des mesures sur l'étage L140.

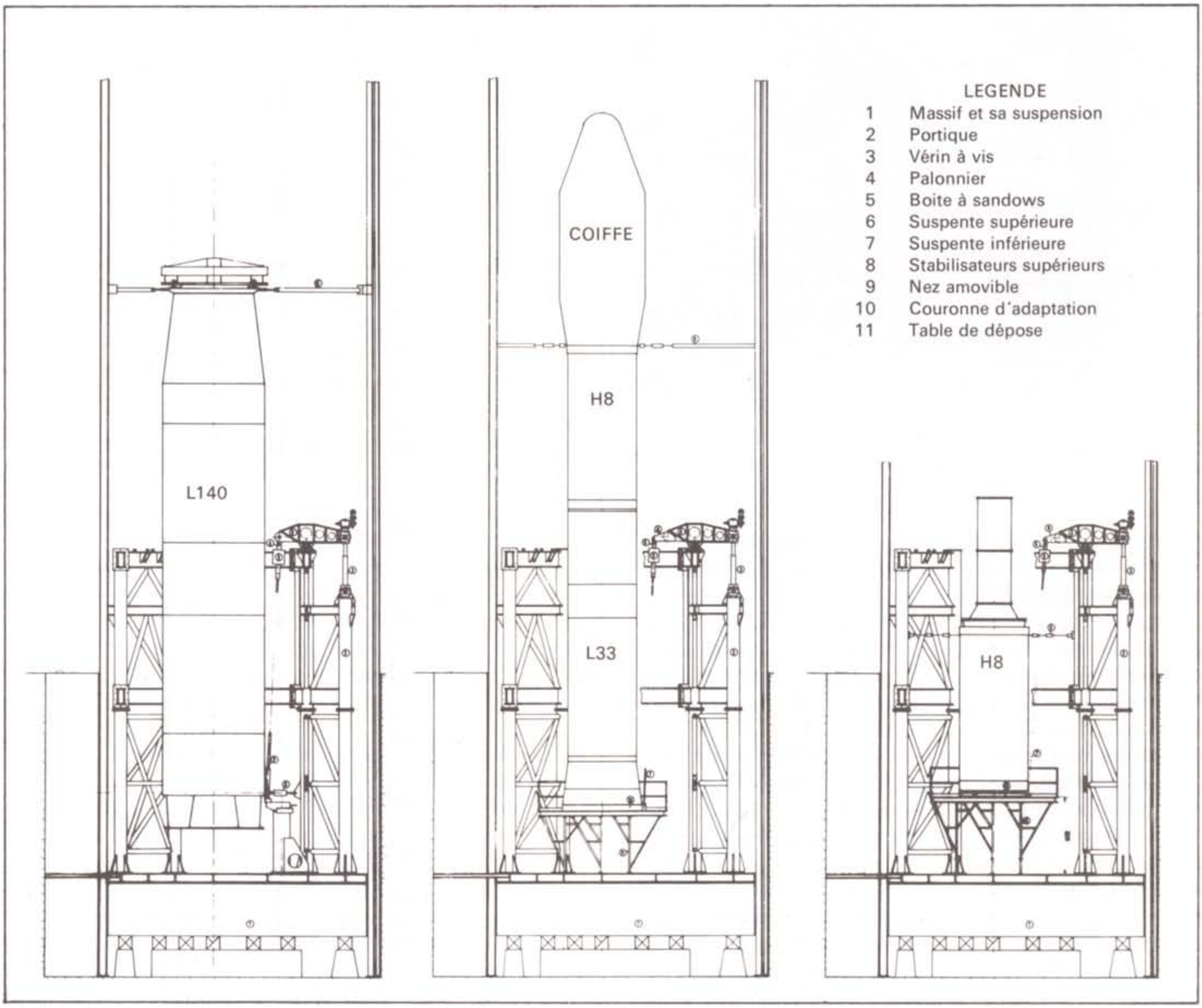


Figure 5 – Configurations des maquettes dans le dock 3 du SIL.

moteurs, le positionnement des excitateurs de 18 000 N a été effectué à l'aide d'un système de coussins d'air adapté directement sur les affûts: les moyens de manutention classiques étaient en effet inutilisables au fond de la fosse d'essai et sous le culot du véhicule.

INSTRUMENTATION DE MESURES OPERATIONNELLES ET ACQUISITION

L'essai était essentiellement équipé de capteurs d'accélération et de pression. Les premiers étaient utilisés pour déterminer les caractéristiques modales de la structure: la mesure de l'accélération a été préférée à celle du déplacement ou de la vitesse qui nécessitent une référence fixe, ce qui eût été pratiquement irréalisable, compte tenu de la complexité de l'installation d'essai. Les capteurs de pression étaient implantés dans les réservoirs et dans les canalisations: ces mesures étaient plus directement associées à l'étude du Pogo. Le nombre de points de mesure était compris entre 350 et 500 selon la configuration de maquette: la Figure 4 représente à titre d'exemple une des planches du plan de mesure. Cette instrumentation était par ailleurs complétée par des débitmètres à ultrasons et des gyromètres situés sur la structure, conformément à leur implantation en vol.

Les mesures étaient enregistrées sous forme brute de façon à conserver toute l'information contenue dans la réponse de la structure pour les traitements ultérieurs: un dépouillement était effectué sur le site à partir des enregistrements pour s'assurer de la qualité de l'essai, avant d'entreprendre le changement de configuration.

PROGRAMME D'ESSAI

Le programme comportait un certain nombre d'essais visant à caractériser le véhicule dans toutes ses configurations de vol. Pour la clarté de la présentation, on peut classer ces configurations en trois types:
- Configuration de maquette qui définit le composite et la phase de vol (Fig. 5).
- Configuration de remplissage des réservoirs qui définit l'instant du vol.
- Configuration d'excitation qui définit pour des raisons d'analyse expérimentale la nature des modes que l'on cherche à identifier: soit transverses, soit longitudinaux.

Les configurations de maquette étaient donc au nombre de trois, chacune correspondant à la composition du véhicule respectivement aux phases de vol propulsé par le 1er étage L 140, le 2ème étage L 33, et le 3ème étage H 8. C'est pratiquement ce qui a été réalisé pour les 2ème et 3ème étages. Pour le 1er étage, le site retenu, bien que conçu et réalisé en prenant en compte les interfaces avec les essais de maquette dynamique, ne permettait pas d'avoir la hauteur sous crochet suffisante: la partie du composite située au-dessus de la jupe interétage 1/2 a donc été simplifiée et simulée par un lest de masse équivalente suspendu de façon à être représentatif du composite réel pour les deux premiers modes longitudinaux. Dans ces conditions la maquette ne pouvait pas être représentative pour les modes de flexion; la configuration d'excitation transverse n'a donc pas été retenue dans le programme d'essais.

L'eau ayant été choisie comme liquide de remplacement pour les ergols stockés dans les réservoirs principaux du véhicule, sauf pour l'hydrogène, il est apparu que la meilleure simulation consistait à faire des remplissages non pas en simulant les volumes de liquide, mais en simulant les masses: on voit en effet que, à part l'oxygène liquide, les masses spécifiques des autres ergols diffèrent très sensiblement de l'eau.

METHODOLOGIE DES ESSAIS

Bien que l'ensemble structure et équipements maquettes puisse être considéré comme représentatif du véhicule de vol, les contraintes d'ordre pratique imposaient des adjonctions de structures d'adaptation pour assurer les liaisons d'une part avec la suspension, d'autre part avec l'excitation. Ces éléments de structure pouvant modifier légèrement la réponse dynamique par rapport à la configuration vol, la modélisation du véhicule a été complétée et des calculs prévisionnels spécifiques à la maquette dynamique ont été effectués avant les essais. Ces calculs ont permis de:
- guider la conduite des essais
- définir les domaines de sécurité
- valider et adapter les modèles mathématiques sur la base de la configuration réelle d'essai.

Partant des principes généraux de définition mentionnés plus haut, les essais ont été conduits de telle sorte qu'avant d'entreprendre un changement de configuration (maquette, remplissage ou excitation), les réponses enregistrées au cours de la phase d'acquisition nominale devaient avoir subi un traitement de validation sur le site. Ce traitement consistait à effectuer un début de dépouillement, à l'aide de l'enregistrement, sur les premiers modes et d'en présenter les résultats à l'équipe du bureau d'études ultérieurement chargée d'en faire l'exploitation.

Pour déterminer les conditions dans lesquelles devait être réalisée chaque phase d'acquisition nominale (découpage en plages de fréquence, nombre de points de fréquence, force d'excitation), il était procédé à un essai préliminaire dit phase exploratoire. Cette phase effectuée manuellement permettait de préparer le découpage de la gamme de fréquence à explorer en plusieurs plages: le critère de découpage consistait à retenir une valeur du pas de fréquence la mieux adaptée pour isoler correctement des modes voisins ou faiblement amortis, et à choisir la force d'excitation (constante dans la plage de fréquence) permettant de respecter les niveaux d'accélération à ne pas dépasser pour rester compatible avec la sécurité. Ces éléments une fois définis déterminaient les conditions de la phase d'acquisition nominale qui pouvait alors être lancée en automatique.

RESULTATS

Quelques résultats de dépouillement sont présentés ci-dessous. Ils illustrent la forme sous laquelle il est possible de transcrire la réponse d'une structure par des paramètres de caractérisation dynamique. L'exploitation représente un volume de travail très important: pour en indiquer un seul aspect matériel, on peut rappeler que la première phase de dépouillement qui sort les parties réelles et imaginaires en fonction de la fréquence pour chaque plage a déjà donné lieu au tracé de 90 000 courbes.

FREQUENCE DE RESONANCE

D'une façon générale les fréquences des modes identifiés au cours des essais concordent bien avec les prévisions. L'évolution des fréquences des modes en fonction du taux de vidange pour les quatre premiers modes longitudinaux de l'étage H 8 montre que les écarts entre prévision et essais sont très faibles: les valeurs de la prévision se situent pratiquement à l'intérieur de la zone d'incertitude qui résulte de la précision de la mesure et des calculs de dépouillement.

FORMES PROPRES DES MODES

L'allure des formes est en général bien restituée par le modèle mathématique. On peut noter cependant que les écarts entre calculs et résultats d'essai ont tendance à être plus importants que ceux que l'on peut observer pour les fréquences; ces écarts se répercutent par ailleurs sur les valeurs des masses généralisées. Dans certains cas les différences semblent provenir de détails de fabrication ou de technologie dont l'importance a été sous-estimée ou qui n'ont pas été suffisamment spécifiés pour la modélisation.

DEFORMEES DE PRESSION

Les déformées de pression ou loi de pression à l'intérieur des réservoirs et des canalisations intéressent plus directement le phénomène Pogo. La comparaison entre les résultats expérimentaux et les prévisions est satisfaisante: la courbe de pressions dans les réservoirs L 140 montre qu'il y a une très bonne concordance dans l'allure des lois.

AMORTISSEMENT

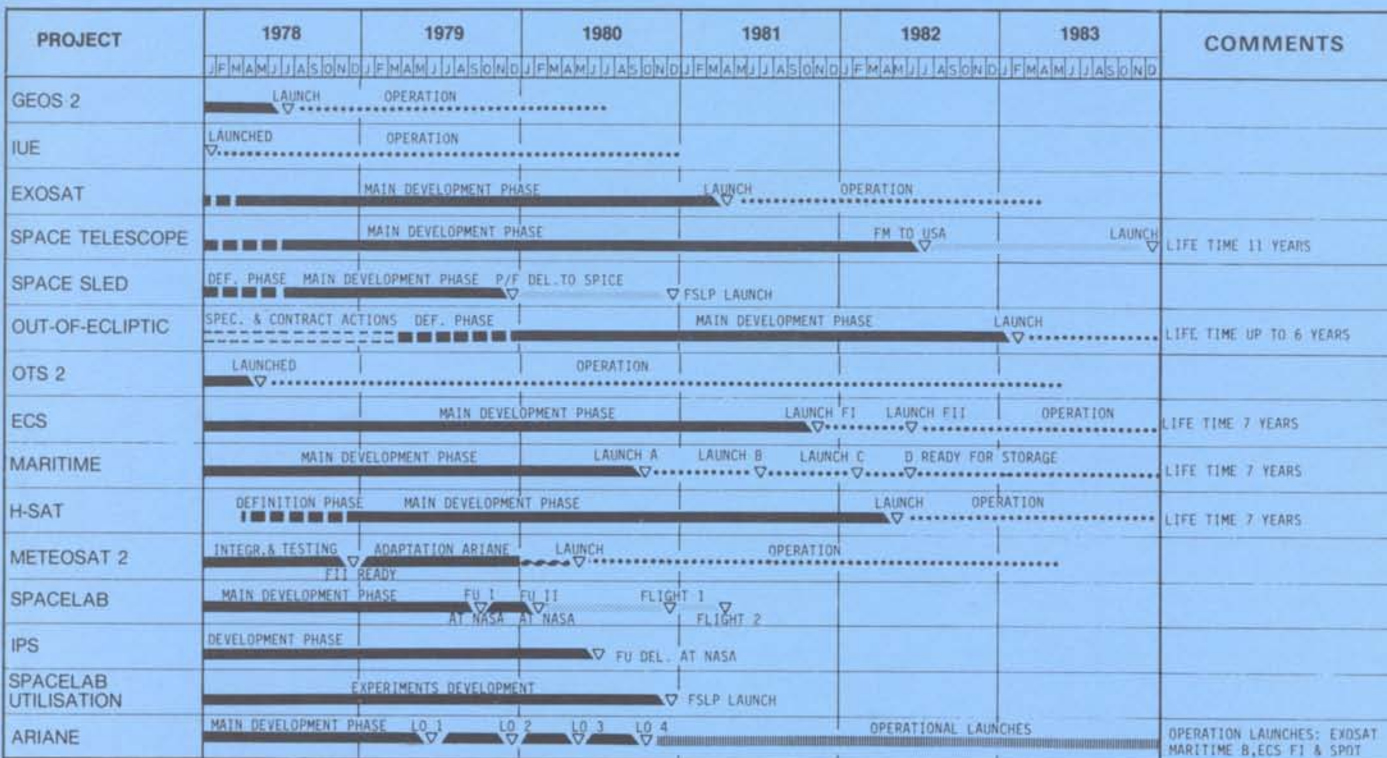
Ce paramètre est uniquement déduit des essais puisque la valeur de cette caractéristique n'est pas accessible au calcul. Il apparaît que l'amortissement peut varier très rapidement en fonction de la déformée, selon que des déplacements importants concernent des zones très dissipatives ou au contraire faiblement dissipatives; l'observation des réponses au cours des balayages en fréquence, pendant les essais, montre clairement ce phénomène. Il faut aussi noter que l'amortissement n'est pas en général indépendant des niveaux; pour des excitations plus puissantes que celles auxquelles le matériel a été soumis au cours de ces essais dynamiques, avec des accélérations et des déplacements importants, la valeur du coefficient d'amortissement aurait tendance à augmenter.

CONCLUSION

La correspondance entre les fréquences de résonance identifiées au cours des essais et celles calculées est en général satisfaisante même pour les modes élevés. En ce qui concerne la déformée et la masse généralisée, le recoupement entre les essais et les calculs semble dépendre de la complexité des structures, mais aussi de détails technologiques plus ou moins pris en compte dans la modélisation. Les essais et le recalage des modèles apparaissent donc indispensables et complémentaires pour garantir une connaissance correcte des caractéristiques dynamiques d'un lanceur. □

Projects under Development
Projets en cours de réalisation

THE ESA DEVELOPMENT AND OPERATION PROGRAMME (END MAY 1978)



GEOS-2

Refurbishment of the reserve flight model of Geos was completed on 21 April. All functional and environmental tests were completed successfully. A Flight-Worthiness Review was held on 15 February and the Review Board declared the spacecraft flightworthy.

NASA had allotted a launch slot on 22 June, but technical difficulties with the launcher schedule have since forced them to change their planning, and launch is now scheduled for 14 July. This change was announced only after the spacecraft had been shipped to Eastern Test Range on 4 May, and the launch campaign had already started. It was therefore decided to proceed with spacecraft preparation as far as possible and to introduce a holding period at a convenient break point.

Apart from a few minor problems, which could be solved immediately, preparations proceeded smoothly. Several experiments which had been held back at the experimenters' institutes for calibration and overhaul were successfully reintegrated.

The spacecraft entered the above-mentioned 'hold phase' on 26 May and the second phase of the launch campaign will commence on 14 June. This will hopefully lead to a successful launch in July.
(See page 85 for latest information).

EXOSAT

Satellite
Efforts related to completion of Phase-B activities have been concentrated on providing technical documentation and associated plans in support of conclusion of the Phase C/D contract, now scheduled for the second half of June.

While it can be assumed that the engineering-model configuration baseline documentation may be

GEOS-2

La remise en état du modèle de vol de réserve de Geos s'est achevée le 21 avril. Les essais fonctionnels et les essais d'ambiance ont tous été couronnés de succès. Un examen d'aptitude au vol s'est déroulé le 15 février et la Commission d'examen a estimé que le véhicule spatial était prêt.

La NASA avait alloué un créneau de lancement le 22 juin. Toutefois en raison des difficultés techniques intervenues dans le calendrier du lanceur, elle a dû modifier son planning et le lancement est actuellement prévu pour le 14 juillet. Cette modification a été annoncée après que le véhicule spatial ait effectivement été embarqué à destination de l'Eastern Test Range, le 4 mai, et que la campagne de lancement ait débuté. Il a donc été décidé de poursuivre aussi loin que possible les préparatifs du véhicule spatial et de prévoir une interruption au moment qui conviendrait le mieux.

A l'exception de quelques problèmes mineurs qui ont été résolus immédiatement, les préparatifs se sont déroulés de façon satisfaisante. Plusieurs expériences que les Instituts des expérimentateurs avaient conservées pour étalonnage et modification ont été réintégrées avec succès.

Le 26 mai a commencé pour le véhicule spatial la période d'interruption susmentionnée; la deuxième phase de la campagne de lancement débutera le 14 juin et devrait s'achever par un lancement réussi en juillet.

EXOSAT

Satellite

Les activités liées à l'achèvement de la phase B du contrat ont essentiellement porté sur la documentation technique et les plans connexes devant permettre la passation du contrat de phase C/D actuellement prévue pour la deuxième moitié de juin.

Si l'on peut supposer que la documentation de référence de la configuration du modèle d'identification permettra de passer à la phase C/D, il est évident que certains secteurs du calendrier proposé par le contractant pour la phase de réalisation des matériels (C/D) restent incompatibles avec les spécifications de l'Agence notamment en ce qui concerne les structures du modèle mécanique et du modèle d'identification. La solution de rechange proposée par le contractant pour respecter la date contractuelle de lancement, fixée au 30 avril 1981, augmente les risques prévus à l'origine, car elle raccourcit le délai nécessaire pour la prise en compte des résultats des essais avant le démarrage de la fabrication du modèle de vol et son intégration.

L'augmentation constante de la masse du satellite, intervenue depuis l'adoption de la solution Ariane (Variant), a été stoppée, une limite maximale de 500 kg pour le satellite dont 120 kg pour la charge utile scientifique a en effet été fixée. De même, on s'est entendu sur la masse maximale totale du composite (satellite plus 4ème étage d'Ariane) qui est désormais fixée à 1400 kg, étant entendu que la masse du satellite pourra être portée à 510 kg si nécessaire.

Au cours d'une récente réunion de coordination Ariane/Exosat organisée par le CNES, les contraintes de sécurité sur la base ont entraîné une modification des paramètres nominaux de l'orbite. La possibilité d'adopter une orbite plus inclinée est en cours d'étude sous l'angle de la stabilité et de la visibilité à partir de la station sol. Cette modification de l'orbite et les augmentations de masse susmentionnées auront également pour conséquence une prolongation de la phase de vol balistique: le contractant étudie actuellement les incidences de cette prolongation sur le satellite.

Il ressort des récentes prévisions de performance du lanceur Ariane qu'en raison de ces augmentations de masse, il reste très peu de marge pour atteindre l'orbite initialement spécifiée. L'augmentation de la masse a par ailleurs entraîné une détérioration des rapports d'inertie du satellite, d'où la nécessité de redéfinir le concept de freinage de la rotation. La solution de référence proposée par le contractant comportait un système autonome de freinage de la rotation du satellite qui aurait été activé après la séparation du 4ème étage d'Ariane. Le contractant étudie actuellement un nouveau concept faisant appel à un dispositif de 'yo-yo' ajouté au 4ème étage et qui serait libéré après l'extinction du moteur de cet étage de façon à freiner avant la séparation la rotation du composite 4ème étage/satellite.

Charge utile

Les travaux de développement (phase II) se poursuivent de façon satisfaisante sur les principaux éléments de la charge utile à la suite des modifications qu'il a été décidé d'apporter aux dispositifs d'anti-coïncidence des détecteurs de l'expérience 'moyenne énergie' pour obtenir une meilleure capacité d'élimination du bruit de fond. La configuration de l'ensemble d'instruments situés au plan focal du bloc 'faible énergie' a également été revue pour l'adapter au concept du banc optique proposé par le contractant.

La définition et la conception (phase I) du compteur proportionnel à scintillation à gaz sont pratiquement achevées et un examen critique de la conception est prévu pour la mi-juin.

Les spécifications du logiciel d'applications du calculateur embarqué (OBC) destiné aux unités de la charge utile ont été mises au point et publiées. Le logiciel proprement dit est en cours de production.

Les impératifs en matière d'essais de logiciel et de matériel pour la charge utile ont été définis et arrêtés avec les contractants.

ESOC

Le matériel de référence destiné au traitement au sol des données scientifiques a été complètement défini au cours des travaux du groupe 'Opérations et gestion des données', composé de scientifiques et de

Part of the Multi-Satellite Support System (MSSS) at ESOC.

Une partie du système de soutien multi-satellite (MSSS) à l'ESOC.

adequate to proceed with Phase C/D, it is obvious that the schedule submitted by the contractor for the hardware phase (C/D) still contains a number of areas incompatible with the Agency's requirements, notably with respect to the structures for mechanical and engineering models. A 'work around' solution proposed by the contractor in order to meet the contractual launch date of 30 April 1981 imposes higher risks than originally foreseen, due to a loss in feedback times between availability of test results and start of manufacture and integration of the flight model.

The steady growth in satellite mass which has occurred since the Ariane solution (Variant) was adopted has been halted by imposing a maximum ceiling for the satellite of 500 kg, which includes 120 kg for the scientific payload. Similarly, an agreement has been reached on the total maximum mass of the composite (satellite plus fourth stage of Ariane), now set at 1400 kg, with the understanding that the satellite mass may increase to 510 kg if required.

Range safety constraints introduced by CNES during a recent Ariane/Exosat Co-ordination Meeting have resulted in a change in nominal orbit parameters. A higher inclined orbit is currently being investigated for stability and ground-station visibility. A further consequence of the change in orbit and mass increases mentioned above will be an extension of the coast phase and the implications of this at satellite level are currently being investigated by the contractor.

It has become evident from the recent performance predictions for the Ariane launch vehicle that, due to the mass increases, very little margin exists for achieving the orbit initially required. A further consequence of the mass increases has been a worsening of the satellite's inertia ratios, leading to a redefinition of the despin concept. The baseline proposed by the contractor included an autonomous satellite despin system to be activated after separation from Ariane's fourth stage.

A new concept is now under study using a yo-yo device attached to the fourth stage itself. The yo-yo would be released after fourth-stage burn-out to despin the fourth-stage/satellite composite prior to separation.

Payload

Development work (Phase II) on the major payload elements is proceeding satisfactorily following changes to the anticoincidence provisions of the medium-energy detectors introduced to ensure a higher background rejection capability. The low-energy focal-plane assembly has also been reconfigured to be compatible with the optical-bench concept proposed by the contractor.

Definition and design (Phase I) of the gas-scintillation proportional counter is nearing completion and a Critical Design Review is scheduled for mid-June.

Requirements for On-Board Computer (OBC) application software for payload units have been finalised and issued. In the meantime actual software production is under way.

Test requirements for both payload software and hardware have been defined and agreed with the contractors.

ESOC

The hardware baseline for ground-based scientific data processing has been fully defined through the workings of the Operations and Data-Handling Panel, whose members included scientists and ESA representatives. The hardware set-up is based on the existing Multi-Satellite Support System (MSSS), with the addition of two Hewlett Packard computers. The two HP machines will be operated by the observers/users in compliance with the concept of a real-time observatory.

A detailed schedule for modifications to the Villafranca ground-station facilities shows that interruption to the IUE support operations can be further reduced.

Review of the ESOC Ground System Design Status is now scheduled for the second half of June, the main objectives being to check completeness, adequacy and consistency of the proposed solution with technical and financial project requirements.

représentants de l'ESA. La structure du matériel est fondée sur le système de soutien multisatellite (MSSS) existant auquel sont ajoutés deux calculateurs Hewlett Packard. Ces deux derniers calculateurs, qui existent déjà, seront exploités par les observateurs/utilisateurs selon la conception d'un observatoire en temps réel.

Un calendrier détaillé des modifications à apporter aux installations de la station sol de Villafranca indique qu'il serait possible de réduire encore l'interruption des opérations de soutien du satellite IUE.

Un examen de la conception du système au sol de l'ESOC est actuellement prévu pour la deuxième moitié de juin: cet examen aura essentiellement pour but de s'assurer que la solution proposée est complète, appropriée et compatible avec les impératifs techniques et financiers du projet.

TELESCOPE SPATIAL

Réseau solaire

L'examen de la configuration de référence, qui a été quelque peu retardé par suite d'un retard intervenu dans l'examen des impératifs de projet du Télescope spatial de la NASA, a eu lieu de 7 avril à l'ESTEC. Le but de cet examen était d'établir la configuration de référence du réseau solaire en vue de sa mise en oeuvre dans la phase C/D. L'examen des liasses de données a révélé un certain nombre de divergences mineures qui sont faciles à corriger. Il est cependant apparu qu'un travail de conception supplémentaire était nécessaire afin d'être en mesure d'approuver la configuration de référence générale, en particulier dans le domaine du mécanisme de déploiement secondaire. Pour que ce travail puisse être exécuté, la phase B a été prolongée jusqu'au 14 juillet.

Chambre

A la suite du choix, par la NASA, de la dotation complète d'instruments scientifiques dans le Télescope spatial et de l'attribution à Dornier System du contrat pour la chambre, l'équipe 'Science des instruments' a examiné de façon approfondie la configuration de la chambre pour objets à faible luminosité, en vue de la rendre optimale sur le plan scientifique. L'équipe a recommandé que le second trajet optique comporte un relais d'une focale de f/48 et comprenne une fente fixe et un réseau réfléchissant pour pouvoir faire de la spectrographie. En outre, elle a recommandé d'augmenter la mémoire des données scientifiques. Etant donné le grand intérêt scientifique que représentent ces recommandations, la faisabilité de leur incorporation a été étudiée pendant la période considérée. Le travail de conception du système d'ensemble s'est poursuivi et s'est traduit par une définition progressivement améliorée de la configuration de référence.

Détecteur de photon (PDA)

Les activités ont porté sur la mise au point de la conception du système PDA en vue de son Examen préliminaire de conception qui a commencé avec la livraison des liasses de données le 7 juin 1978. Des résultats d'essais satisfaisants ont été obtenus en ce qui concerne la mise au point d'un aimant permanent pour la focalisation de l'intensificateur et en ce qui concerne les performances du premier jeu de tubes intensificateurs, équipés d'une fenêtre au fluorure de magnésium et rendus plus robustes pour l'espace.

Activités de la NASA

La NASA a participé à l'examen de la configuration de référence du réseau solaire. En outre, une réunion a eu lieu avec des représentants du Goddard Space Flight Center, au cours de laquelle on a examiné de façon approfondie les détails du programme de la chambre pour objets à faible luminosité et des interfaces associées avec la NASA. Les premières discussions sur les interfaces techniques avec la participation de représentants de la Société Perkin Elmer – contractant de la NASA pour le télescope optique – et Dornier ont également eu lieu.

TRAINEAU SPATIAL

Le programme de développement du Traîneau est entré dans la phase de conception détaillée et on a constaté un rythme élevé d'activités dans tous les secteurs. Quant aux interfaces avec les ensembles d'expériences, elles sont soit définies (pour les expériences européennes), soit déjà en partie réalisées (pour les deux ensembles d'expériences fournis par la NASA).

Le feu vert a été donné pour l'approvisionnement des articles à long délai de livraison et pour la réalisation de modèles sur table de sous-systèmes critiques. La fabrication des montages et outillages pour la structure a également commencé. A la suite d'une enquête spéciale, il a été également décidé de réduire la masse totale prévue du Traîneau qui reste néanmoins critique puisqu'elle se situe au-dessus de la limite spécifiée pour la première charge utile du Spacelab.

Au début de la phase de conception détaillée il est apparu nécessaire de revoir partiellement la conception du sous-système de traitement des données afin de réduire au minimum les frais de soutien globaux pour les opérations en vol. La nécessité de trouver des solutions aux problèmes rencontrés se traduit en définitive par un glissement de deux mois de l'ensemble du programme. La date prévue pour la livraison du prototype de vol reste toutefois compatible avec celle qui a été fixée pour son intégration avec la première charge utile du Spacelab.

Les groupes responsables des expériences, tant européens qu'américains, se préparent à passer à la conception détaillée après avoir terminé l'évaluation de la conception d'ensemble et réalisé un nombre limité de modèles sur table d'éléments critiques.

SPACE TELESCOPE

Solar array
The Baseline Configuration Review, delayed somewhat due to a slippage of the NASA Space Telescope Project Requirements Review, was conducted at ESTEC on 7 April 1978. The purpose of the Review was to establish the baseline solar array system configuration for implementation during the main development phase (Phase C/D). Review of the data package revealed a number of minor discrepancies, which are easily corrected. In addition, however, it became apparent that some further design effort was required in order to be able to approve the overall baseline configuration, particularly that for the secondary deployment mechanism. In order to be able to carry out this work, the definition phase (Phase B) has been extended until 14 July 1978.

Camera module
Following NASA's selection of the total complement of scientific instruments for the Space Telescope, and contract award for the Camera Module to Dornier System, the Instrument Science Team has thoroughly reviewed the Faint Object Camera with the aim of optimising its configuration in terms of the science to be conducted. The team has recommended that the secondary optical path should have a f/48 relay and include a fixed slit and reflective grating to allow some spectroscopy. Furthermore, they recommend that the Scientific Data Store be extended. In view of the great scientific interest of these recommendations, the feasibility of incorporating them has been studied during the reporting period. Overall systems design has continued and has resulted in a gradual improvement in baseline definition.

Photon-detector assembly
Activities have been concentrated on finalising the PDA systems design ready for the Preliminary Design Review, starting on 7 June 1978. Satisfactory test results have been obtained in the development of a permanent magnet for focussing the intensifier, and in the performance testing of the first set of intensifier tubes, which have a magnesium-fluoride window and are 'space ruggedised'.

NASA activities
NASA participated in the Solar-Array Baseline Configuration Review. An extensive meeting also took place with NASA representatives from Goddard Space Flight Center on the details of the Faint-Object-Camera programme and the associated interfaces with NASA. The first technical interface discussions with participation by representatives of Perkin Elmer – the NASA contractor for the Optical Telescope Assembly – and Dornier have also taken place.

SPACE SLED

The Sled Facility development programme is now in the detailed design phase, with design activities proceeding at high pace on all fronts. Interfaces to the European Sled Experiment Packages have been established and interfaces to the two US supplied experiment packages have been partially realised.

Authorisation has been given to proceed with procurement of long-lead items and to initiate breadboarding activities of critical subsystems of the Sled Facility. Manufacture of jigs and tools for the structure has also been initiated. The total predicted mass of the Sled Facility had been reduced as a result of a special investigation, but the mass is still critical as it is above the allowance for the First Spacelab Payload. During the early part of the detailed design phase it was found necessary to partially redesign the data-handling subsystem in order to minimise overall support costs to flight operations. The net effect of having to find solutions to the problems encountered is a slippage in the overall programme of two months. The predicted delivery date of the Sled protoflight unit is, however, still compatible with the need-date for integration with the First Spacelab Payload.

Both the European and US Sled Experimenter Groups are preparing to start detailed design, after having completed their overall design evaluation and limited breadboarding of critical parts.

OUT-OF-ECLIPTIC

Overall status of the project
The overall status of the Out-of-Ecliptic project remains good. At the time of the last Bulletin, the project had been formally approved by ESA whereas NASA was still going through the necessary procedures to obtain Congressional approval and consequent funding. In the intervening period the project has been approved by both Congressional authorisation committees and has also passed the House of Representatives Appropriations Committee, albeit with funding somewhat reduced from that originally proposed by NASA. The decision of the Senate Appropriations Committee is expected very soon.

Science Working Team
The first meeting of the Science Working Team took place in early May at Jet Propulsion Laboratory, Pasadena, California. The majority of time was taken up by mutual information exchange, but nevertheless considerable progress was made in defining the mission boundaries and the overall configuration of the two spacecraft in the launch phase. Prior to this meeting, the ESA experiment engineers had clarification meetings with each experimenter on the ESA spacecraft and a plan for information transfer was evolved.

The individual meetings and the general SWT may all be considered as extremely successful.

Subsystem studies
Four short industrial studies at subsystem level intended to clarify areas of special concern for the OOE mission are now nearing completion. These have been concerned with the attitude and orbit control, the data handling and the thermal control of

MISSION HORS-ECLIPTIQUE

Situation générale du projet
La situation générale du projet Hors-Ecliptique demeure bonne. Au moment où paraissait le précédent Bulletin, le projet avait été formellement approuvé par l'ESA tandis que la NASA continuait de parcourir les différentes étapes de la procédure nécessaire pour obtenir l'approbation du Congrès et les crédits en résultant. Dans l'intervalle, le projet a été approuvé par les deux Comités d'autorisation du Congrès et est également passé devant la Commission des crédits de la Chambre des Représentants, qui l'a entériné avec toutefois une certaine réduction des moyens de financement par rapport à la proposition initiale de la NASA. La décision de la Commission des crédits du Sénat doit intervenir incessamment.

Groupe de travail scientifique
La première réunion du Groupe de travail scientifique s'est tenue début mai au Jet Propulsion Laboratory, Pasadena (Californie). La majeure partie du temps de cette réunion a été consacrée à des échanges d'informations, mais un grand pas a néanmoins été fait dans la définition des limites de la mission et de la configuration d'ensemble des véhicules spatiaux pour la phase de lancement. Auparavant, les ingénieurs chargés des expériences à l'ESA avaient eu des réunions exploratoires avec les expérimentateurs au sujet du véhicule spatial de l'ESA et un plan avait été mis au point pour la transmission des informations.

Les rencontres individuelles comme la réunion pleinière du Groupe de travail peuvent être qualifiées de réussites totales.

Etude des sous-systèmes
Les quatre petites études industrielles du niveau sous-système, destinées à tirer au clair des problèmes particulièrement préoccupants pour la mission Hors-Ecliptique, sont en voie d'achèvement. Elles ont trait à la commande d'orientation et aux corrections d'orbite, au traitement des données et à la régulation thermique du véhicule spatial. Les résultats de ces études figureront dans l'appel d'offres de phase B qui sera lancé pour le véhicule spatial.

Appel d'offres de Phase B1
La principale activité de l'équipe de projet de l'ESA au cours des derniers mois a été la préparation de l'appel d'offres pour la phase de conception du système (Phase B1) du véhicule spatial de l'Agence. L'ensemble de la documentation a été rassemblé et approuvé par les autorités internes compétentes et le texte anglais est actuellement à l'impression, tandis que les corrections finales sont apportées au texte français.

Programmes futurs
A la demande des industriels, la date de publication de l'appel d'offres a été reportée du 1er au 24 juillet et la date de réponse de fin septembre à fin octobre. L'évaluation qui suivra sera également retardée, mais on rattrapera en partie le temps perdu en utilisant la période Noël-Nouvel an afin d'obtenir les approbations nécessaires pour les deux contractants retenus pour la Phase B1. On espère donc que la Phase B1 démarrera avec seulement une dizaine de jours de retard, soit vers le 20 janvier 1979. Cette phase s'achèvera vers la mi-juillet, après quoi un unique contractant sera choisi pour les phases de conception détaillée (B2) et de réalisation du matériel (C/D). Il est prévu de mettre en route la phase B2 en septembre 1979 et la phase C/D en janvier 1980.

OTS-2

Le satellite OTS-2 a été lancé avec succès à partir de Cap Canaveral (Floride), le 11 mai à 22h59 GMT, par une fusée américaine McDonnell Douglas Delta 3914 et mis sur une orbite de transfert presque parfaitement nominale. Le 13 mai, par télécommande de l'ESOC (Darmstadt), le moteur d'apogée a été mis à feu pour placer le satellite sur une orbite de dérive quasi synchrone. Après des opérations normales de dérive, OTS-2 a été mis à poste, le 28 mai, à la position prévue: longitude 10°Est, altitude 35 900 km. L'entrée de la mission dans sa phase de routine a été annoncée le 29 mai.

Outre les manoeuvres de routine effectuées pendant la phase de dérive, l'ESOC a procédé à la mise en fonctionnement des six répondeurs SHF de la charge utile et un premier échange de signaux effectué le 18 mai, avec la station de contrôle et d'essais du satellite à Fucino (Italie), a confirmé le bon fonctionnement du véhicule spatial et de sa charge utile.

Au cours des prochains mois, l'ESA procédera à des mesures des performances du satellite tandis que débutera le programme d'essai de communications qui doit durer au moins trois ans.

ECS

Les dernières négociations portant sur le prix du contrat principal de développement sont en cours, elles prennent en compte les révisions intervenues au cours des six derniers mois dans la répartition géographique et le calendrier. Les calendriers ECS et Marecs sont évidemment étroitement liés en raison de l'utilisation de matériels communs pour la plate-forme. Pour simplifier le contrôle, une base de documentation technique et contractuelle commune a été mise au point. Le développement des équipements et des sous-systèmes se déroule conformément aux plans.

Le programme d'essai de télécommunications du satellite OTS qui a été lancé en mai sera utilisé pour préparer les Administrations des PTT à l'exploitation ultérieure des satellites opérationnels qui seront fournis au titre du programme ECS.

SATELLITE MARITIME

Satellites maritimes A et B
Les satellites maritimes A et B dont la

the spacecraft. The resultant study reports will be included with the Invitation to Tender for Phase B of the spacecraft when it is issued.

Phase-B1 tender
The major activity of the ESA project team over the last few months has been the preparation of the Invitation to Tender for the System Design Phase (Phase-B1) for the ESA spacecraft. All the documentation is now complete and approved by the relevant internal authorities, and the English text is being printed. The final corrections to the French text are now being made.

Future schedule
At the request of Industry, the issue date of the Invitation to Tender has been delayed from 1 July to 24 July and the reply date by one month from late September to late October. The consequent evaluation will also be delayed, but part of the lost time will be saved by using the Christmas – New Year period to obtain the necessary approvals for the two contractors selected for Phase-B1. As a result, it is hoped to start this phase only about 10 days late, on or about 20 January 1979. This phase will last until mid-July, after which a single contractor will be chosen for the detailed design (B2) and hardware (C/D) phases. It is planned to start Phase-B2 in September 1979, and Phase C/D in January 1980.

OTS-2

OTS-2 was launched successfully from Cape Canaveral, Florida, by a McDonnell Douglas Delta 3914 launcher at 22.59 GMT on 11 May 1978. The satellite was placed into an almost perfectly nominal transfer orbit. On 13 May, by command from ESOC (Darmstadt), the apogee boost motor was fired to place the satellite into a near-synchronous drift orbit. Following normal drift operations, the satellite was brought to its nominal on-station position of 10°E at an altitude of 35 900 km, on 28 May. The mission was declared to be in a 'routine phase' as of 29 May.

As well as commanding the routine manoeuvre during the drift phase, ESOC activated the six SHF transponders of the payload and on 18 May the first exchange of signals with the Satellite Control and Test Station (SCTS) at Fucino (Italy) confirmed the correct functioning of both spacecraft and payload.

Over the next few months, the operations to be carried out with the spacecraft will comprise measurement of the satellite's performance and the commencement of the communications test programme, which will last for at least three years.

ECS

The final price negotiations for the main development contract are under way, based on the revised geographical-distribution requirements and schedule revisions that have evolved over the past six months. The schedules for ECS and Marecs are, of course, interwoven because of the use of common platform hardware. In order to facilitate control, a common technical and contractual documentation baseline has been established. Equipment and subsystem development is proceeding according to schedule.

The communications test programme for OTS will be used to prepare the P&T administrations for the subsequent exploitation of the operational satellites being supplied under the ECS programme.

MARITIME SATELLITE

Maritime A and B
The Maritime A and B satellites based on an ECS type platform are now designated Marecs A and B. The definition of the technical and schedule baselines is proceeding towards the Preliminary Design Review, set for late June. The spacecraft design is progressing satisfactorily and the configuration and performance of the communications subsystem are being consolidated. The Ariane launch-vehicle interface activities are also under way.

Joint Venture for a global maritime system
At the end of March 1978, the Agency submitted an offer for two maritime satellites, in addition to Marecs A and B, to the 'Joint Venture' of nations interested in participating in a global maritime satellite system. This offer has subsequently been updated and will be reviewed by the Joint Venture during June.

HEAVY SATELLITE

A Preliminary Phase-B contract with SNIAS (France) as the Prime Contractor commenced on 12 April 1978 and is scheduled to be completed by the end of the year. A decision on the subsequent phases of the programme is under discussion by the Joint Communications Programme Board. The main development contract is expected to commence at the beginning of next year.

METEOSAT

Space segment
Meteosat-1, launched more than six months ago, is performing extremely well, in spite of occasional (about 1 per week) status changes due to surface discharges, resulting from the presently rather high solar activity.

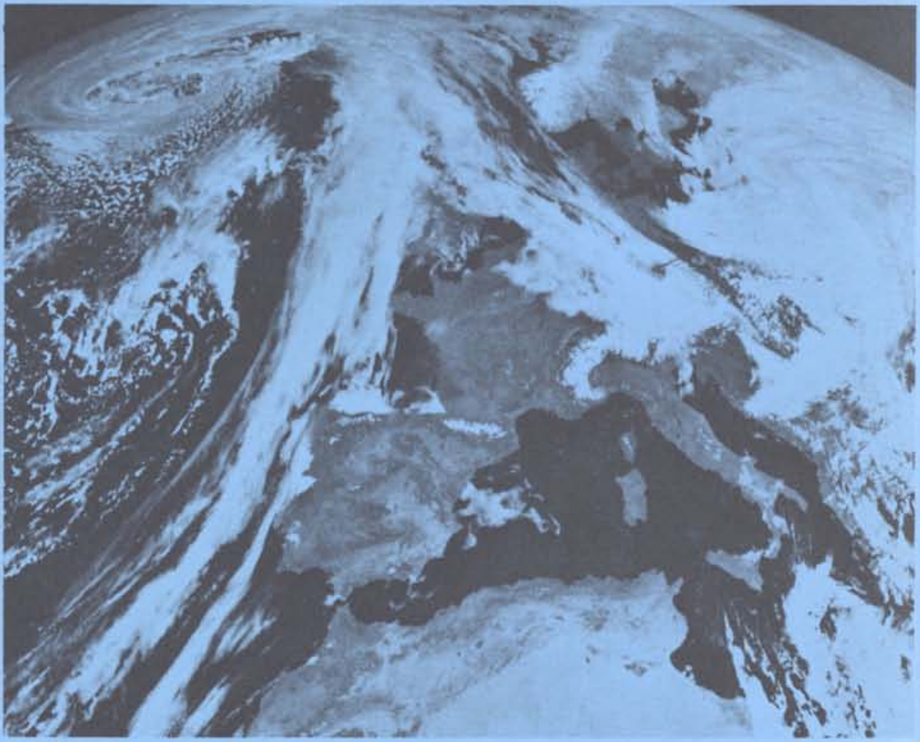
Meteosat-2, having passed its performance tests, is now undergoing environmental testing in Toulouse. Design and manufacture of strengthening components for the Meteosat structure, to allow it to withstand Ariane launch loads, are under way.

Operations
About 95% of the images transmitted by Meteosat-1 every half hour in the various spectral bands are now being

conception est basée sur une plate-forme de type ECS sont désormais dénommés Marecs A et B. La définition des concepts de base sur le plan technique et sur le plan du calendrier approche de l'examen préliminaire de la conception fixé à fin juin. La conception du véhicule spatial progresse de façon satisfaisante tandis que la configuration et les performances du sous-système de communications sont en cours de mise au point. Les activités d'interfaces avec le lanceur Ariane sont également en cours.

Association d'intérêts pour un système maritime mondial

Fin mars, l'Agence a soumis une offre portant sur deux satellites maritimes, en complément à Marecs A et B, à l'Association d'intérêts composée des nations désireuses de participer à un système mondial de satellites maritimes. Cette offre a par la suite été actualisée et sera réexaminée courant juin par l'Association d'intérêts.



SATELLITE LOURD

Un contrat préliminaire de phase B, avec la SNIAS (France) comme contractant principal, a débuté le 12 avril et doit être achevé à la fin de l'année. Une décision sur les phases ultérieures du programme est à l'examen par le Conseil directeur commun des programmes de satellites de communications. Le démarrage du contrat principal de développement est prévu avant le début de l'année prochaine.

METEOSAT

Secteur spatial

Météosat-1, lancé voici plus de six mois, fonctionne extrêmement bien, en dépit de commandes intempestives provoquées de façon aléatoire (environ une par semaine) par des décharges à la surface du véhicule spatial en raison de l'activité solaire dont le niveau est actuellement assez élevé.

Météosat-2, après avoir subi avec succès les essais de performance, est en cours d'essais d'environnement à Toulouse. On travaille à l'étude et à la fabrication des renforts de structure qui doivent permettre au satellite de résister aux contraintes de lancement d'Ariane.

Exploitation

Environ 95% des images envoyées par Météosat-1 toutes les demi-heures dans les différentes bandes du spectre sont désormais emmagasinées sur bandes magnétiques, soit sous forme brute soit après traitement. Plus de la moitié des images sont actuellement traitées. Selon un calendrier arrêté en accord avec les utilisateurs, 141 fac-similés météorologiques (WEFAX) et 17 images à haute résolution, ainsi qu'un certain nombre de mires d'essai et de messages administratifs, sont diffusés chaque jour via le satellite. L'extraction de paramètres météorologiques (concernant par exemple les vents) est en progression.

Démonstration/activités expérimentales

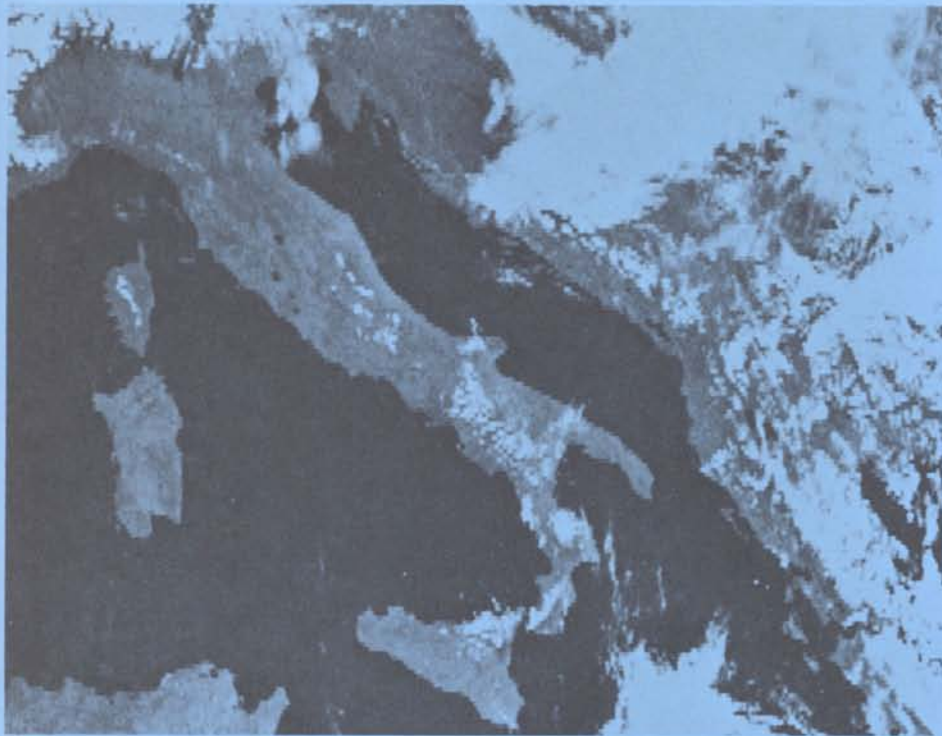
Les résultats de la première campagne de collecte de données, menée avec un navire français, sont en cours d'analyse. D'autres essais sont prévus avec des bâtiments danois et britanniques.

La station secondaire d'utilisateurs de données (SDUS) mobile est actuellement à Athènes après avoir été présentée au Caire et avant d'être envoyée à Tunis et Alger.

L'utilisation de données d'images Météosat pour la télévision et la presse est à l'étude. Une campagne expérimentale de télévision a été programmée avec l'Union européenne de Radiodiffusion pour la fin de juin et le mois de juillet; des boucles de films (séquences de 12 à 18 images) serviront à montrer les mouvements de nuages et autres phénomènes atmosphériques à l'appui des prévisions météorologiques. De plus, l'ESA est en relation avec la Communauté économique européenne (CEE), l'Organisation météorologique mondiale (OMM) et l'Organisation pour l'Alimentation et l'Agriculture (FAO), qui s'intéressent vivement à l'utilisation du système Météosat, en particulier pour l'Afrique.

Projet GOES

On est parvenu à un accord sur la solution technique du projet



Images received from Meteosat by the Telespazio Primary Data User Station (digital reception).

Images de Météosat reçues par la station primaire d'utilisateurs de données (PDUS) de Telespazio (réception numérique).

stored on magnetic tape in either raw or processed form. More than half of the images are presently being processed. On the basis of a schedule agreed with the users, 141 Weather Facsimile (WEFAX) formats and 17 high-resolution formats, as well as certain test patterns and administrative messages, are disseminated via Meteosat-1 each day. Extraction of meteorological parameters (such as winds) is progressing.

Demonstrations/experimental activities

The results of the first data-collection campaign with a French ship are being analysed. Further tests are scheduled with a Danish and a British ship.

The mobile Secondary Data User Station (SDUS) has been presented in Cairo, is now in Athens, and will subsequently be demonstrated in Tunis and Algiers.

The use of Meteosat image data by TV and the Press is being studied. An experimental TV campaign has been agreed with the European Broadcasting Union for the end of June, whereby Meteosat film loops (sequences of 12 to 18 images) will be used to show cloud movements and other meteorological phenomena in support of weather forecasts. Furthermore, ESA is in contact with the European Economic Community (EEC), the World Meteorological Organisation (WMO) and the UN Food and Agriculture Organisation (FAO), who are very much interested in the use of the Meteosat system, for Africa in particular.

GOES project

Agreement has been reached on a technical solution for the NOAA/ESA project (bridging by the US GOES satellite of the gap over the Indian Ocean caused by the delay in the Russian geostationary meteorological satellite programme, ESA being charged with control of GOES), i.e.

- installation of antenna and data stretcher at Villafranca,
- satellite monitoring and control from ESOC.

Furthermore, the Programme Board agreed to WMO's request to extend the archiving of GOES data from 8 to 24 h per day and to perform certain data-processing functions in Europe, in addition to those carried out in the United States.

SPACELAB

Selection of payload specialists for the first Spacelab mission

On 18 May the three scientists who will be retained as Payload Specialists to support the first Spacelab mission, scheduled for the end of 1980, were named by ESA. They are:

- Ulf Merbold (27), research scientist from Germany
- Claude Nicollier (34), astronomer and pilot from Switzerland
- Wubbo Ockels (32), physicist from The Netherlands.

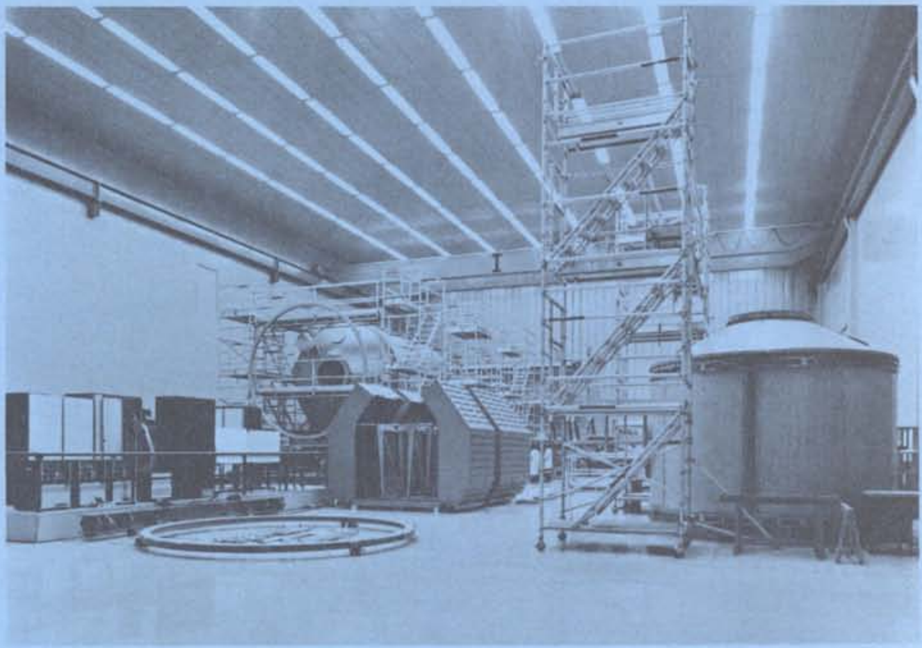
Only one of these three will actually fly, together with one NASA payload specialist. The final choice will be made some months before the flight. The other two will serve in a back-up role and will participate in ground-based activities carried out during the flight, at NASA's Johnson Space Center.

Marshall Space Flight Center is responsible for overall payload-specialist training as part of its management responsibility for the first Spacelab mission. The SPICE team (ESA) is responsible for training activities in Europe. A NASA/ESA co-

NOAA/ESA: combler au moyen du satellite américain GOES le hiatus provoqué au-dessus de l'Océan indien par le retard du programme de satellite météorologique géostationnaire russe, l'ESA étant chargée de contrôler GOES; les modalités pratiques seront les suivantes:

- *installation de l'antenne et du dispositif d'étirement des données à Villafranca;*
- *contrôle et commande du satellite à l'ESOC.*

De surcroît, le Conseil directeur du programme est convenu, à la demande de l'OMM, de faire passer l'archivage des données GOES de 8 à 24 heures par jour et de procéder à certains travaux de traitement des données en Europe, en plus des activités menées aux Etats-Unis.



Vue générale du Hall d'intégration et d'essais de Spacelab à ERNO, Brême.

General view of the Spacelab Integration and Test Hall at ERNO, Bremen.

SPACELAB

Sélection des spécialistes charge utile pour la première mission du Spacelab

L'Agence a désigné le 18 mai un groupe de trois scientifiques qui feront office de spécialistes charge utile pour la première mission du Spacelab, dont la date est fixée à la fin de 1980. Les candidats européens retenus sont:

- *Ulf Merbold (37 ans), chercheur, de nationalité allemande.*
- *Claude Nicollier (34 ans), astronome et pilote, de nationalité suisse.*
- *Wubbo Ockels (32 ans), physicien, de nationalité néerlandaise.*

Sur les trois candidats retenus comme spécialistes charge utile, l'un s'envolera effectivement dans l'espace avec un spécialiste charge utile de la NASA. Le choix définitif sera fait quelques mois avant le vol. Les deux autres assumeront un rôle de renfort et participeront pendant la mission aux activités menées au sol au Johnson Space Center.

Le Marshall Space Flight Center est chargé de l'ensemble des activités de formation des spécialistes charge utile dans le cadre de ses responsabilités de gestion pour la première mission du Spacelab. L'équipe SPICE (ESA) a la responsabilité des activités de formation en Europe. La NASA et l'ESA ont adopté un plan de formation coordonné pour les spécialistes charge utile.

Appel de propositions pour la production ultérieure

L'ESA a diffusé en mai un appel de propositions (RFP) pour la production ultérieure du Spacelab par l'industrie européenne. Les documents ont été envoyés aux contractants principaux responsables du développement du Spacelab (ERNO) et du système de pointage d'instruments (Dornier System). Le matériel couvert par le RFP correspond approximativement à un exemplaire du Spacelab identique au matériel livré à la fin du programme de développement. La réponse de l'industrie au RFP doit intervenir en septembre sous forme d'une proposition à prix forfaitaire.

Intégration et essais au niveau système

Le premier essai au niveau système du modèle d'identification (essai d'assemblage) a été mené à bien. On continue d'apporter à la structure primaire du module des modifications après-coup en préparation d'un essai du module au niveau sous-système, que suivra un essai au niveau système d'une configuration module long + 1 porte-instruments.

Les essais d'intégration du système électrique (ESI) ont démontré que son fonctionnement répond dans l'ensemble aux spécifications. Certaines déficiences de conception ayant été mises en lumière, les modifications nécessaires ont été apportées. L'équipement électrique de soutien au sol a été réceptionné après essai et le logiciel provisoire validé.

ARIANE

Ensemble de Lancement Ariane (ELA)

La réalisation de l'ELA, commencée à la mi-1975 avec les travaux de génie civil, s'est poursuivie en 1976 et 1977 avec la fourniture et l'installation de la quasi totalité des équipements. Au cours des premiers mois de 1978 ont été installés les derniers équipements (bras cryogénique et système de largage du lanceur).

Le banc de contrôle du lanceur, arrivé ordinated payload-specialist training plan has been agreed.

Request for proposals for follow-on production
In May ESA released a Request for Proposal (RFP) for the follow-on production of Spacelab by European industry. The RFPs were sent to the Prime Contractors for the Spacelab development work (ERNO) and for the Instrument Pointing System (Dornier System). The hardware content of the RFPs amounts to approximately one Spacelab unit identical to the hardware delivered at the end of the development programme. The industrial response to the RFPs is expected in the form of a fixed-price proposal in September.

System-level integration and testing
The first system-level test on the Engineering Model (Assembly Test) has been successfully completed. Retrofit modifications to the module primary structure are continuing in order to prepare for a module subsystem test, followed by system testing of a long module plus one pallet configuration.

The Electrical System Integration (ESI) tests have shown that, in general, the system is performing as specified. Some design deficiencies have been discovered and the necessary modifications implemented. The Electrical Ground Support Equipment has been acceptance-tested and the provisional software validated.

ARIANE

Ariane Launch Site
The construction of the Ariane Launch Site ('Ensemble de Lancement Ariane' – ELA) which started in mid-1975 with the civil engineering work, has continued through 1976 and 1977, during which time nearly all the equipment has been supplied and installed. The early months of 1978 saw the installation of the last items of hardware (cryogenic arm and vehicle release system).

The vehicle checkout system, which arrived in Kourou in December 1977, was immediately installed in the Launch Centre and the checkout of interfaces was initiated.

Individual acceptance tests of the ELA subsystems (phase-1 tests) started early in 1978; they will be followed by checkout system tests on dynamic simulators, and subsequently, from May to July 1978, with the ground facilities (phase-2 tests). The completion of the phase-1 tests in late June 1978 will mark the taking over by the site team of all the ELA facilities.

In the first months of 1978, the various propellants and fluids needed for the vehicle were despatched to Guiana, including the liquid hydrogen, the sea transport of which was a World 'first'.

The three stages and the various vehicle elements that constitute the propellant mock-up will leave Europe by ship in late June and arrive in Guiana in mid-July. The unloading of the stages and their despatch by road to the ELA will allow the launch-vehicle transport and handling procedures in Guiana to be validated.

The preparatory activity in Guiana will culminate with the vehicle erection tests and the propellant mock-up tests intended to qualify the procedures and the ground and onboard equipment needed for fill operations (phase-3 tests). These operations are scheduled for the period August to November.

The Base validation tests will be concluded by a launch rehearsal, scheduled for the end of 1978 and involving all the elements of the ELA, the CSG facilities, and the down-range stations.

Thus, by the beginning of 1979, the ELA will be ready for the first development launch (L01) of the Ariane vehicle.

Additional Ariane facilities
The preparation and completion of the Ariane additional facilities (Moyens Complémentaires Ariane – MCA), which relate to the necessary adaptation of the CSG and the down-range stations, are proceeding normally. The electronics of the CSG radars have been renewed and the new E-band telemetry stations have now been set up at Montagne des Pères (near Kourou) and Montabo (near Cayenne). The last tests at these stations are nearing completion.

The installation of a telemetry reception station with a configuration similar to that of the CSG stations is proceeding actively at Natal (Brazil) within the Brazilian launch base CLFBI. All the necessary steps have been taken to set up a mobile telemetry station in the Bélem region (Salinopolis). Technical arguments relating to the development launches have in fact recently shown the usefulness of having telemetry reception facilities in an intermediate zone between the Cayenne-Montabo and Natal stations. Despite the short time available, the Salinopolis station will be ready early in 1979 to participate with the other telemetry stations in the operational qualification of the Launch Base system.

The NASA and DOD tracking and telemetry stations on Ascension Island are ready to participate with the other Base facilities in carrying out global testing of the tracking and telemetry network, which will take place from late October until late January 1979. Operational qualification of the complete network will take place from February to mid-April 1979, including the communication and data transmission facilities. The main instrument for this campaign will be the American GEOS III satellite; it will be tracked for this purpose when visible successively from Kourou, Salinopolis, Natal and Ascension. □

La Base de Lancement d'Ariane en Guyane française.

The Ariane Launch Base in French Guiana.

en décembre 1977 à Kourou, a été aussitôt installé dans le Centre de Lancement et le contrôle des interfaces a commencé.

Les essais de recette individuelle des sous-ensembles de l'ELA (essais phase 1) ont commencé depuis début 1978; ils seront suivis par les essais du banc de contrôle sur simulateurs dynamiques, puis avec les installations sol de mai à juillet (essais phase 2). L'achèvement des essais phase 1 à fin juin marquera la prise en charge par les exploitants (équipe site) de toutes les installations de l'ELA.

Au cours des premiers mois de l'année, les différents ergols et fluides nécessaires pour le lanceur ont été acheminés vers la Guyane, y compris l'hydrogène liquide, dont le transport maritime constitue une première mondiale en son genre.

Les trois étages et les différents éléments du lanceur qui constituent la maquette ergols doivent quitter l'Europe par bateau vers la fin juin et arriver en Guyane vers la mi-juillet. Les opérations de déchargement des étages et de transport par route jusqu'à l'ELA doivent permettre de valider les procédures de transport et de manutention du lanceur en Guyane.

Le niveau culminant des activités préparatoires en Guyane sera atteint lors des essais d'érection du lanceur et des essais de la maquette ergols destinés à qualifier les procédures ainsi que les matériels sol et bord nécessaires aux opérations de remplissage (essais phase 3). Ces opérations sont prévues depuis août jusqu'à novembre.

Les essais de validation de la base se concluront par un lancement fictif, prévu à la fin de l'année, mettant en oeuvre tous les éléments de l'ELA, les moyens du CSG et les stations aval.

Ainsi, début 1979, l'ELA sera prêt à recevoir Ariane pour le premier lancement de développement L01.

Moyens Complémentaires Ariane (MCA)

La préparation et la mise au point des Moyens Complémentaires Ariane, qui désignent les adaptations nécessaires du CSG et les stations aval, se poursuit normalement. L'électronique des radars du CSG a été rénovée et les nouvelles stations de télémesure bande E sont maintenant en place à la Montagne des Pères (près de Kourou) et au Montabo (près de Cayenne). Les derniers essais de ces stations sont en voie d'achèvement.

L'installation d'une station de réception de télémesure de configuration semblable à celles du CSG se poursuit activement à Natal (Brésil) à l'intérieur de la base de lancement brésilienne de CLFBI. Toutes les dispositions ont été prises pour l'installation d'une station mobile de télémesure dans la région de Bélem (Salinopolis). Des raisons techniques liées aux lancements de développement ont en fait démontré récemment l'utilité de disposer de moyens de réception de télémesure dans une zone intermédiaire entre les stations de Cayenne-Montabo et de Natal. Malgré le peu de temps disponible, la station de Salinopolis sera prête début 1979 pour participer avec les autres stations de télémesure à la qualification opérationnelle du système Base de Lancement.

Les stations NASA et DOD de poursuite et de télémesure de l'Ile d'Ascension sont prêtes pour se joindre aux autres moyens de la Base pour l'exécution des essais globaux du réseau de poursuite et télémesure qui se dérouleront de fin octobre 1978 à fin janvier 79. De février à mi-avril 79 aura lieu la qualification opérationnelle du réseau complet, y compris les moyens de communication et de transmission de données. L'outil principal de cette campagne sera le satellite GEOS III; des poursuites seront à cet effet effectuées quand son orbite sera visible successivement depuis Kourou, Salinopolis, Natal et Ascension. □

Integration Testing of the Propulsion System of Ariane's First Stage

A. Souchier, Société Européenne de Propulsion (SEP), Vernon

SEP, which is responsible for developing and testing the Ariane launcher's Drakkar propulsion system, has carried out separate development tests on the subsystems forming the propulsion bay. The second phase of testing, begun on 17 November 1976 with the first propulsion-bay firing, was designed to study the functioning of the integrated subsystems. Called 'cluster', or for brevity 'G', tests ('essais de groupement'), their purpose was to highlight mechanical, thermal or vibratory problems that might result from interaction between the various systems in configurations and under conditions similar to those to be expected during Ariane's flight.

TEST PROCEDURES

The propulsion bay, held in place by the same attachment points that will be used to mount it in the launcher, was supplied with propellants from two thick-walled tanks containing N_2O_4 and UDMH, respectively, and pressurised by hot gas provided by the bay's own pressurisation system. The pipework was similar to that adopted for flight. This propulsion system only allowed firings lasting a maximum of 87 s because of the limited tank capacity, as against 147 s in flight, but the shorter duration was nevertheless adequate for obtaining thermal equilibria.

The hardware was integrated progressively during the tests, the heavy thrust frame (5 t) used for the first bay being replaced by a light, flight-standard one (1.6 t) for the second bay. The servomotors for swivelling the engines for flight-control purposes were introduced as from the third bay, which was once more mounted on a heavy thrust frame.

The last bay, tested with a light thrust frame and Pogo-correction system, was of flight standard. The other subsystems – water tank, hot-gas pressurisation device, tank-bottom connections for propellants and pneumatic services, filling, draining and overflow valves for the tanks, command units, Viking-II engines with conical nozzles (as opposed to the bell-shaped Viking-V nozzles to be used in flight) – were mounted on each bay, together with the hardware encasing the bay and the cowlings and heat shield.

Originally, it was intended to use five bays for the cluster or G tests, each one being fired twice. The aim was firstly to study the re-light that might be necessary in the event of an aborted launch, and secondly to gain a better span of test conditions (ullage spaces and pressurisations in the tanks at the start of firing, burnout on propellant depletion, cut-off when closing the valves, etc.). After a first test without re-light, the tests on bays 2, 3 and 4 were finally conducted three times, and although only four bays were tested because of slippages in schedule, all test objectives were achieved.

TEST FACILITIES

A special test stand (PF 20) was built between 1974 and 1976 for the Drakkar propulsion-system, tests, twenty thousand tons of concrete being needed for its construction. In each case, the propulsion system under test is secured on a concrete slab 3 m thick with a 5.5 mm square aperture through which the engine jets pass (Fig. 1). The latter are deflected 26 m below by the jet deflector, a buried flue with 800 t of uncooled protective lining.

The 100 t securing device on the slab allows the flatness, parallelism/perpendicularity and spacing of the retaining jaws to be maintained to within 0.1 mm, to avoid setting up stresses in the thrust frame. The two removable 36 500 l tanks, weighing a total of 52 t, are supported above the bay on four legs. The bay and tanks are protected by a metallic structure fitted with a travelling crane, which can handle the tanks, the bay, or the complete propulsion system with flight-standard tanks. This brings the total height of the structure above ground to 52 m. The associated propellant systems comprise two 125 m³ tanks for nitrogen tetroxide and UDMH, respectively, together with: the pumping systems needed for filling the tanks; nitrogen storage facilities with appropriate means for supplying at various pressures; safety facilities for injecting water, foam (intended to limit the evaporation of propellants in the event of an accidental leak) and products for neutralising propellant vapour or

Figure 1 – Propulsion system under test, mounted on the special concrete slab.

possibly dealing with polluted water; and facilities for decontaminating the propulsion system, which enable it to be moved and dismantled in complete safety.

The measurement and control facilities are located together in an underground command post capable of withstanding an overpressure of 2 bar in the event of an explosion. In the course of a test, 500 parameters are processed there by a Mitra-15 computer, and a second such computer is used for conducting the test itself. Automatic, majority-logic monitoring of the main parameters enables the firing to be stopped if anything goes wrong. Fifty thousand digital measurements are made per second, and 52 parameters are recorded by means of a wideband tape recorder.

MAIN RESULTS

The first results revealed considerable noise at the bottom of the tank, between the four engines. Studies by SEP (modelling), and tests by ONERA on the mock-up, revealed resonance of the aft cavity of the bay, between the heat shield and the cowlings, when excited by the engine jets. They also showed that the phenomena would not recur in flight with the bell-shaped Viking-V nozzles. Between tests G3-2 and G3-3 (test sequence and firing durations shown in Table 1), the Viking-II nozzles mounted on the bay were shortened by pyrotechnic cutting, and measurements during the latter test confirmed the influence of nozzle length on the noise, as predicted by ONERA mock-up tests.

The considerable noise and the simultaneous operation of the four engines led to a high vibration level which caused UDMH leaks during the first two firings. The propellant caught fire and the tests had to be stopped. Improved methods of locking the joints have obviated a recurrence of these incidents and two 87 s firings have since been carried out successfully. The G4 bay functioned for a total of 170.4 s without any problem.

Leaks at the sliding joints between the engines and the UDMH valves occurred because of the vibratory environment, and as from the third bay these joints were replaced by flexible connections, which have been proved satisfactory in use.

An oil leak in this same third bay due to a pipework rupture in one servomotor (a weak point already earmarked for modification) and the failure of a speed regulator in another were also due to the vibratory environment. After modification, the servomotors behaved entirely satisfactorily during the G4 bay's 170 s of running.

During each test, the high acoustic level between the engines caused the flexible connections between the engines and the heat shield to deteriorate. This problem was only resolved during the first propulsion-system firing with the flight-standard tank in December 1977. Some of the cowlings also suffered from the acoustic environment, but a new model was successfully tested during the G4 test.

Origins of hardware used during the 'cluster' or 'G' tests

Hardware elements	Suppliers
Viking-II combustion chambers	SEP and VOLVO – France and Sweden
Viking-II turbopumps	SEP and MAN – France and Germany
Viking-II gas generators	SEP and MAN – France and Germany
Viking-II main valves	FN – Belgium
Flameproofing	SEP and STEINER – France
Hot-gas pressurisation system	SEP – France
Filling, draining and overflow valves	SEP – France
Tank-bottom connectors for pneumatic services	SEP – France
Thrust frames	MAN – Germany
Pogo assembly plate	SEP and HSD – France and UK
Pogo correction systems	CASA – Spain
Pipework for filling, draining, overflow, pressurisation and feed	SNIAS – France
Collectors	SNIAS – France
Cowling supports	SNIAS – France
Heat shield	SNIAS – France
Cowlings	SNIAS and SABCA – France and Belgium
Tail fins	SNIAS and SABCA – France and Belgium
Flexible connections (gaiters)	HSD – UK
Electrical cabling	SEP and SNIAS – France
Command unit	FN, INDUSTRIA and SEP – Belgium and France
Water tanks	MAN – Germany
Actuator electronics	ROVSING – Denmark

TABLE 1

Test	Date	Duration (s)
G 1	17 November 1976	57.4
G 2-1	26 January 1977	41.9
G 2-2	4 February 1977	11.4
G 2-3	11 February 1977	11.0
G 3-1	5 May 1977	19.2
G 3-2	12 May 1977	85.5
G 3-3	1 June 1977	10.6
G 4-1	1 September 1977	53.4
G 4-2	22 September 1977	87.0
G 4-3	29 September 1977	30.0
	TOTAL	470.4

The first test had also revealed considerable oscillation of the chamber pressure on light-up, and this problem was resolved as from the G2-3 firing by staggering the times at which the tanks were initially pressurised.

During the last G4 test series (Fig. 2), the hot-gas system for pressurising the tanks functioned unstably (without affecting the conduct of the firing), owing to a modification of the adjustments and the small ullage spaces in the tanks simulating the launch conditions in Guiana. Remedies that had been partially tried out as from the

Figure 2 – Drakkar propulsion system test (G4-2) in progress.

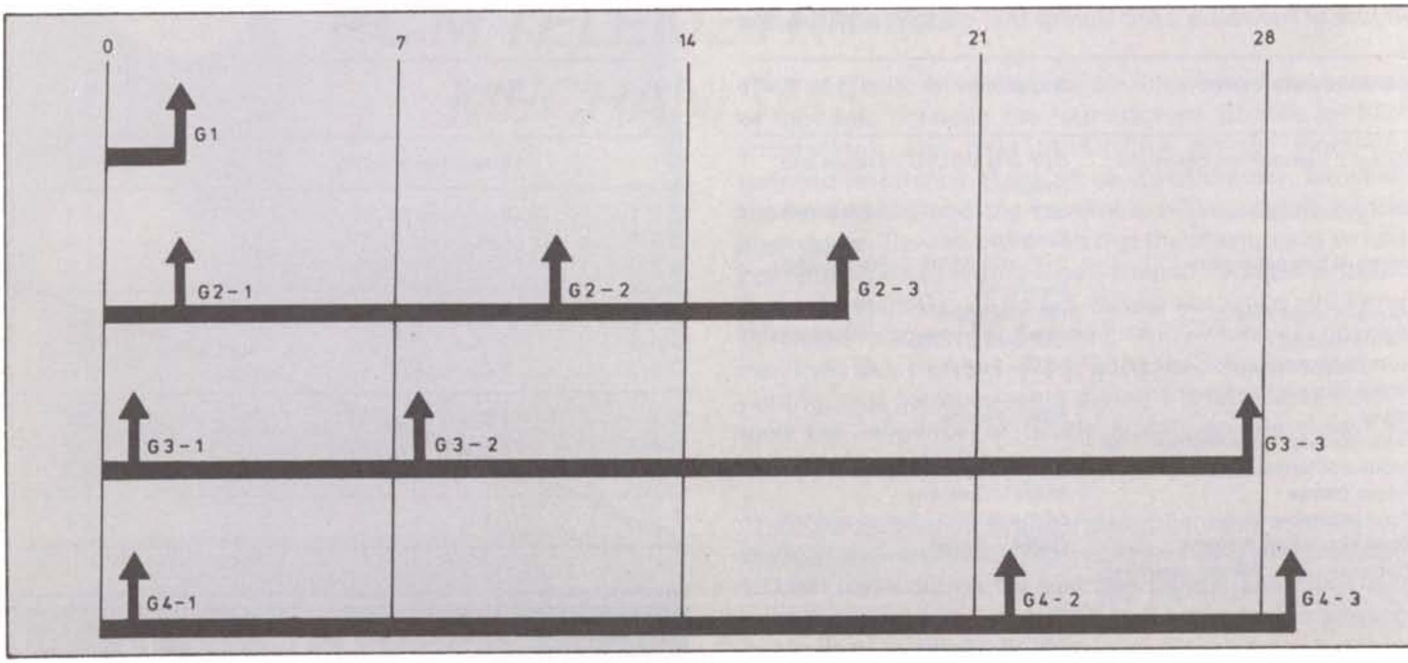


Figure 3 – Timing of 'cluster' or 'G' tests after N_2O_4 loading (scale in days).

second G4 firing were successfully applied to the first propulsion-system firing with flight-standard tanks.

The G3-2 test, which ended on propellant (N_2O_4) depletion, revealed a corrosion phenomenon in the tank-bottom collector (flight-standard hardware) after the firing. This was found to be due to pollution of the propellants by water in the pressurisation gases and the tank bottom has since been modified to solve this problem which, of course, does not arise in flight.

The G2 firing revealed a relatively large amount of unburned propellant (150 kg) on the N_2O_4 side. An anti-residual device was fitted as from test G3 and, by reducing the residual propellant mass to 30 kg, this has led to a 5 kg improvement in Ariane's performance in transfer orbit.

Failures of the valves of the bay's filling and draining system on the N_2O_4 side occurred one week after a first firing because of corrosion. This phenomenon does not occur after a short firing and is therefore not typical of the conditions in which the flight stages will operate, even in the case of an aborted firing. Generally speaking, the resistance of the hardware to propellants exceeded expectations (Fig. 3): the G4-2 firing (87 s) was carried out 21 days after the G4-1 firing (53 s), and G4-3 28 days after G4-1, compared with the 7 day maximum specified.

The preparatory operations of filling, pressurisation and countdown were conducted satisfactorily in every case.

CONCLUSION

To sum up, the cluster or G test firings have served to demonstrate the correct behaviour of the Ariane hardware which has been produced by a large number of European firms. The 10 tests have allowed any weak points to be determined and corrected and have allowed adjustments to be made that have resulted in vehicle performance improvements in a number of cases. Consequently, it has been possible to embark with confidence on the series of propulsion-system tests with flight-standard tanks, which should lead to final qualification in 1979. □

Stage-Separation Testing for Ariane

P. Gauge, Ariane Project Team, CNES, Evry, France

An essential element in the development of the Ariane vehicle has been the demonstration of correct functioning of the pyrotechnic devices that will be responsible for first/second and second/third stage separation during the launch sequence, and satisfactory resistance of these devices to the harsh environment in which they will be called upon to operate. The pyrotechnics for Ariane have been flight-qualified on the basis of both 'component tests' and the testing of complete pyrotechnic chains or 'integration tests'. It is the latter integration tests that form the basis for this particular article.

THE COMPOSITION OF THE PYROTECHNIC CHAINS

The functions to be performed during first/second and second/third stage separations are identical in as far as both involve:
- ignition of acceleration rockets on the upper composite
- ignition of retro-rockets on the lower composite and simultaneous cutting of the flange between the stages
- jettisoning after burnout of the acceleration rockets and their support structures.

The sequence of events in the separation chain begins with the sending of an electrical command signal (duplicated) to an 'arming unit', the purpose of which is to convert this current into a detonation, which then travels along confined detonating fuses (CDFs) to the linear shaped charges responsible for structural cutting, and the devices that ignite the separation rockets.

These chains are all fitted to the outside of the launcher on structures that also carry other, e.g. hydraulic, pneumatic or electric, functional systems equipment. As the latter equipment is located very close to the pyrotechnic elements, which produce very high-level shocks (150 000 g) when the structure is cut, integration testing must assume the double role of:
- demonstrating on mock-up structures that the pyrotechnic functions are correctly performed ('Category-I' testing)
- demonstrating, using real structures fully equipped to flight-standard (functional units, systems, etc.), that the pyrotechnic environment will not damage the units, systems, etc. ('Category-II' testing).

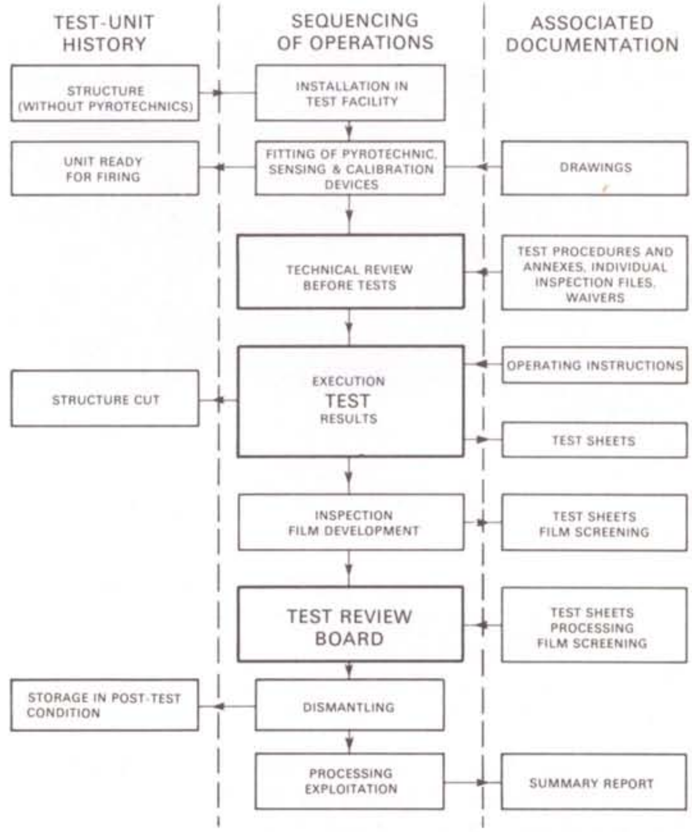
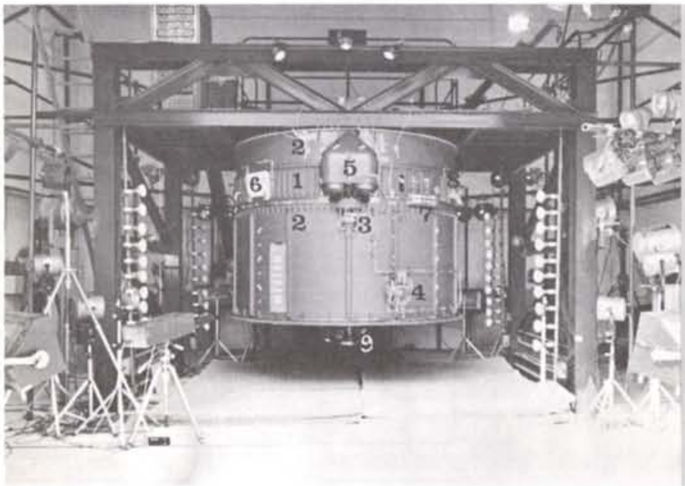


Figure 1 – Planning and documentation for stage-separation integration tests.

THE INTEGRATION TESTS

Four integration tests have been carried out to qualify the separation of Ariane's three stages, and each was planned and executed on the basis of the flow diagram shown in Figure 1.

The sequence shown has been applied as a standard



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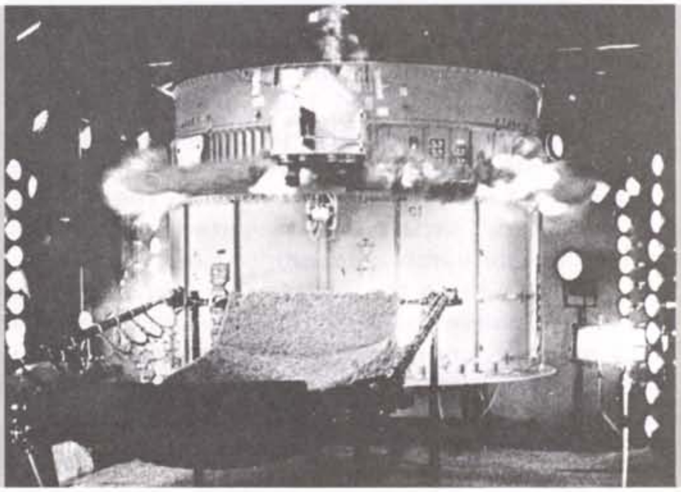


(b)

procedure in all the major Ariane tests, with the aim of providing maximum visibility as to:

- exact configuration tested
- conduct of the test itself
- results obtained.

It can be seen from the diagram that there was provision for a technical review before the test itself, as well as a final check on test procedures, including

- operating instructions for the test
- means by which the various parameters were to be measured
- test result sheets, for both instrument readings and observations.

As soon as each test was completed, the first visual observations were noted on the test sheets, the acquisition of measurements verified, and the camera films processed. An indication of the amount of preparation and subsequent effort needed for the separation tests can be gained from the fact that a test sequence lasting only 25 s involved a full seven-hour day by the team, all operations being manual except for the final firing test proper, for which an automatic sequencer was used.

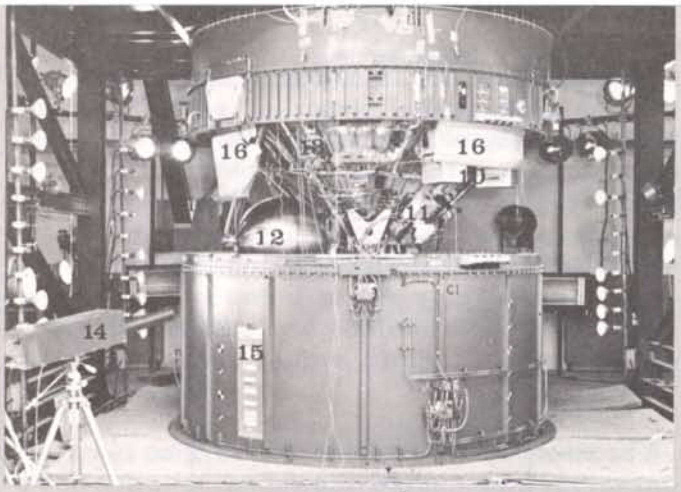
A Test Review Board ('Commission de Revue des Essais') was convened after each test to ensure that the documentation used for the test was that approved or amended during the technical review, that the first results agreed with predictions, and that the measurements acquired would make it possible to process the data successfully and exploit the test results. Provided these criteria had been satisfied, the Board authorised the test set-up to be dismantled.

INTEGRATION TESTING FOR SECOND/THIRD STAGE SEPARATION

The third-stage thrust frame used for these tests had previously undergone the requisite separation and subsystem vibration tests. It was completed by a mock-up skirt representing the second stage in order to accommodate all the pyrotechnic elements fitted to that stage; only the rockets were dummy units. Both the building up of the fully equipped thrust frame and the test proper were carried out in the main hall of the SNIAS pyrotechnic laboratory at Les Mureaux.

A total of 74 parameters were measured during the tests (28 time measurements, 33 shock measurements, 9 movement measurements, 2 pressure measurements and 2 temperature measurements).

Three stages of the separation test are illustrated in Figure 2. The accompanying legend traces the sequence of events from activation of the arming unit until the achievement of stage separation.



(c)

1. FULLY EQUIPPED STRUCTURE (H8 REAR BULKHEAD)
2. MOCK-UP SKIRTS
3. ARMING UNITS FOR ACCELERATION ROCKET CHAIN
4. ARMING UNIT FOR RETRO-ROCKET CHAIN
5. ACCELERATION ROCKETS
6. LIQUID OXYGEN UMBILICAL PLATE
7. ELECTRICAL SEPARATION PLUG BRACKET
8. DESTRUCT ARMING UNIT
9. EXTREMITY OF HM-7 ENGINE CHAMBER
10. Ag-Zn BATTERIES
11. SERVO-MOTOR HYDRAULIC UNIT
12. HELIUM STORAGE BOTTLE
13. ELECTRO-VALVE UNIT
14. LASER CAMERA
15. AIMING POINT FOR LASER CAMERA
16. SCREEN FOR ARRESTING FRAGMENTS

Figure 2 – Fully equipped third-stage structure, with mock-up skirt to represent the second stage (a) readied for test (note the need for intense illumination for the high-speed photography) (b) at the moment of separation and (c) after completion of the test (note the absence of substantial inward scattering, though many lamps on the outside have been broken).

Main Phases in a Separation Sequence

T=0.000 s	ARRIVAL OF COMMAND CURRENT AT THE INITIATORS IN THE ARMING UNIT OF THE ACCELERATION-ROCKET CHAIN
T=0.0028 s	CUT-OFF OF PRINTED CIRCUIT DETONATION LEAVES ARMING UNIT
T=0.0029 s	DETONATION ARRIVES AT THE THROUGH-BULKHEAD INITIATORS (TBIs) OF THE ACCELERATION ROCKETS; TIME DELAYS HAVE STORED THE COMMAND
T=3.694 s	ARRIVAL OF COMMAND CURRENT AT INITIATORS IN THE ARMING UNIT OF THE RETRO-ROCKET/SEPARATION CHAIN
T=3.697 s	CUT-OFF OF PRINTED CIRCUIT, DETONATION LEAVES ARMING UNIT
T=3.698 s	DETONATION ARRIVES AT THE TBIs OF THE RETRO-ROCKETS AND THE LINEAR SHAPED CHARGE – LOWER PART BEGINS TO FALL AWAY
T=4.100 s	LOWER PART HITS THE GROUND
T=16.000 s	BURN-OUT OF ACCELERATION ROCKETS
T=18.800 s	TIME DELAYS RECONSTITUTE AND TRANSMIT DETONATION TO LINEAR SHAPED CHARGES, THUS JETTISONING THE THRUSTERS; LAST PYROTECHNIC FUNCTION
	SEQUENCE COMPLETED

MEASUREMENT OF SHOCK SUSTAINED BY EQUIPMENT

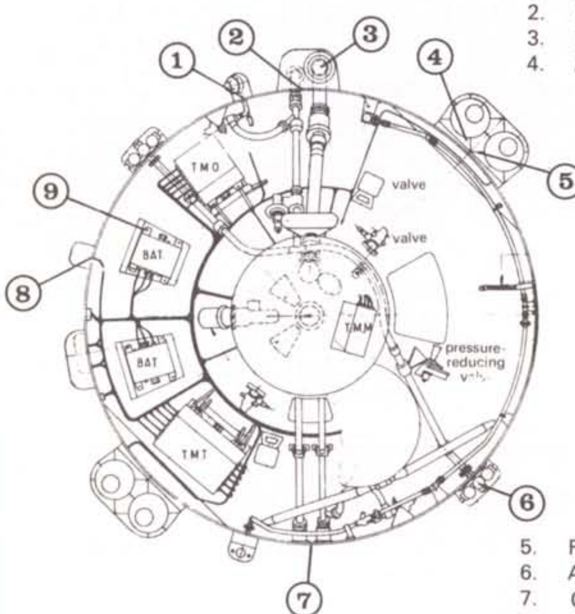


Figure 3

Item of equipment	Shock (g)/ Damping time (ms)		Distance from cut (mm)
1. H_2 vent	13 000 (2)	47 500 (1.1)	146
2. H_2 umbilical plate	50 000 (0.7)	20 000 (0.4)	152
3. H_2 feed valve	–	6 000 (3.5)	150
4. Acceleration rocket	12 000 (0.1)	71 000 (0.3)	150
5. Pyrotechnic time delay	18 000 (0.3)	–	250
6. Attitude & roll control system	51 000 (0.3)	31 000 (0.3)	150
7. O_2 umbilical plate	34 000 (0.6)	30 000 (0.7)	152
8. Destruct arming unit	10 000 (1)	24 000 (1.4)	120
9. Ag-Zn battery	–	3 000 -	900

TEST RESULTS

One of the test objectives was to determine the impulse per metre of the linear shaped charge used for structural cutting. The value recorded did, in fact, considerably exceed specifications, and there proved to be a good measure of agreement between the various tests and the various methods of measurement.

As far as the prediction of the trajectories of thrusters and their supporting structures were concerned, the test results agreed well with calculations and it is therefore possible to predict the in-flight trajectories during separation with confidence.

Shock-attenuation measurements were also made during the test and a clear correlation was apparent between damping-out time and distance from the linear shaped charge.

The levels of shock sustained by various items of third-stage equipment in the course of the separation are listed by way of example in Figure 3 (duration of the shock shown in brackets).

CONCLUSIONS

Four successful Ariane stage separation tests were carried out in 1977 and they have demonstrated both proper functioning of the sequences and pyrotechnic devices and satisfactory resistance of the equipment units subject to shock. The scope of the tests – size of structures and volume of information processed – has served to endorse the merits of laying down precise test procedures beforehand and shown just how much information can be obtained from movement and shock measurements of the sort described. □

The HM-7 Engine of Ariane's Third Stage

J. Borromée & Ph. Lesage, Ariane Project Team, CNES, Evry, France

The HM-7 engine, which is the first cryogenic engine developed in Europe, was designed specifically to meet the propulsion requirements of Ariane's third stage. It consists of a thrust unit fed with liquid hydrogen and liquid oxygen under pressure by a turbopump, and devices to monitor, control and condition the propellants. The whole assembly is mounted to the stage thrust frame (Fig. 1) by means of a gimbal and electro-hydraulic actuators, which allow pitch and yaw to be controlled.

The main contract for the HM-7 was awarded by CNES to SEP (France), and the subcontract for the thrust unit to MBB (Germany).

The engine's main characteristics are listed in Figure 2 and its operating cycle is shown schematically in Figure 3. It has a conventional gas-generator cycle, in that the turbine gases exit through an exhaust independent of the main nozzle.

The liquid hydrogen from the tank enters a centrifugal pump from which it passes to a chamber inlet manifold where some 6% of the flow is used to cool the upstream portion of the nozzle before being ejected level with the nozzle exit, a principle known as 'dump cooling'. The main flow, which is used for combustion, is fed back to the injector through a regenerative circuit made up of slots milled in the chamber body. The latter is cooled by hydrogen circulating in the opposite direction to the combustion gases.

The hydrogen exits from the regenerative circuit in gaseous form. A small amount is tapped in order to pressurise the hydrogen tank and to supply the attitude and roll-control system as and when required.

The liquid oxygen is injected directly into the chamber as it leaves the pump.

A pyrotechnic igniter fires the chamber gases.

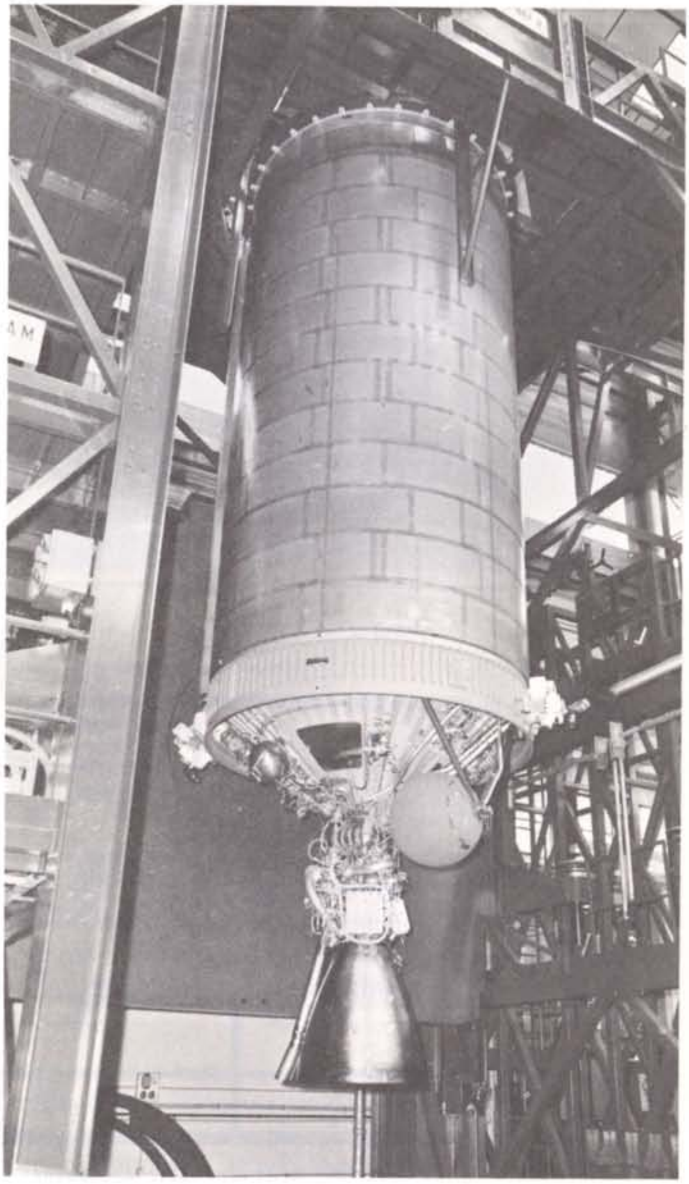


Figure 1 – The HM-7 engine mounted on the third-stage thrust frame.

The turbine driving the two pumps is fed by a gas generator, which is itself fed by the hydrogen and oxygen tapped at the pump outlets. The gas flow to the generator represents 1.8% of that to the chamber. The exhaust gases

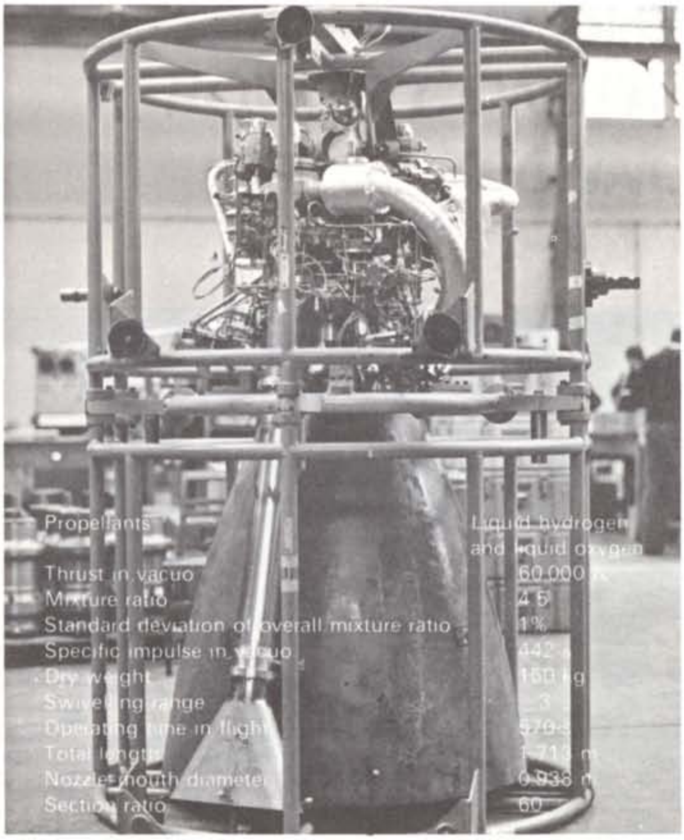


Figure 2 – An HM-7 engine assembled for test and, superimposed, its main operating characteristics.

from the turbine produce a slight additional thrust, but its specific impulse is less than that of the chamber.

In order to reduce the possible effects of interaction between the jets from the main chamber and the turbine exhaust, the two streams are kept in the same plane and at similar pressures.

A starter cartridge is used for starting the turbine and igniting the gas generator.

Regulation and adjustment
The thrust is regulated by the open-loop method: the turbopump's speed is stabilised by adjusting the feeds to the gas generator. The engine torque is kept practically constant when the turbine rotation speed exceeds 90% of its nominal value, the oxygen flow to the generator being

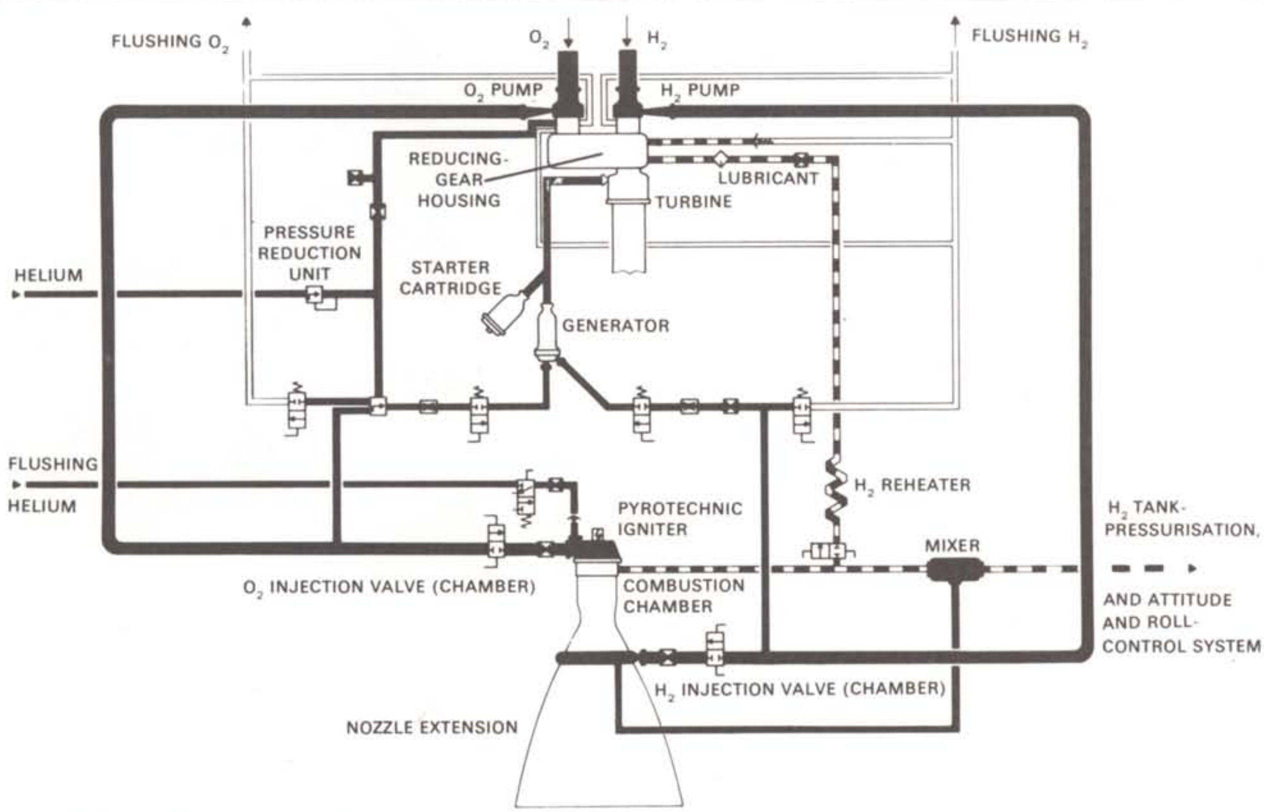
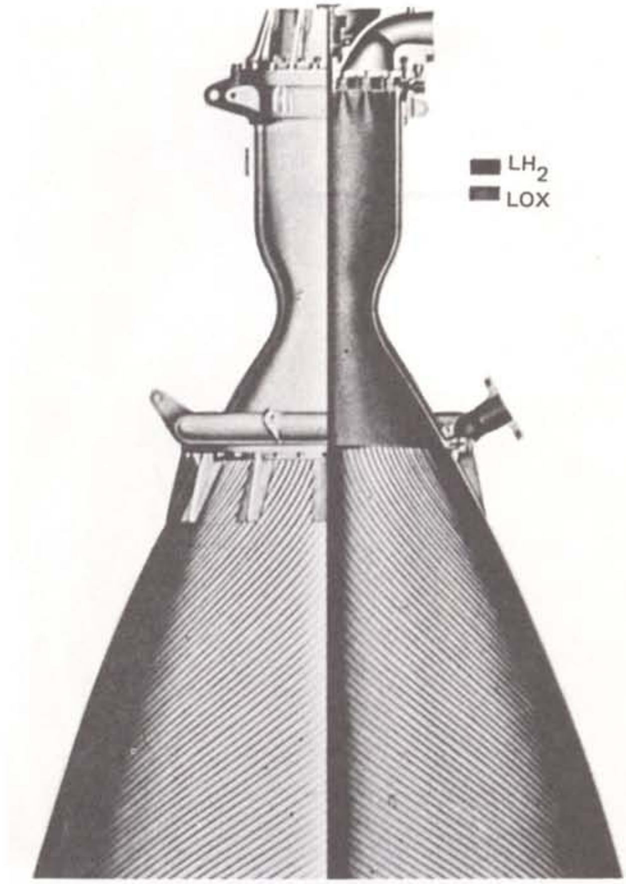


Figure 3 – Schematic of the operating cycle of the HM-7.

Figure 4 – Chamber configuration of the HM-7 thrust unit.



stabilised by a pressure regulator and a cavitating venturi. A similar venturi in the hydrogen circuit makes the flow of that gas independent of the generator's operation.

It was not thought necessary to regulate the mixture ratio, because it can be adjusted to within $\pm 1\%$ during acceptance testing by carefully selecting the calibrated orifices immediately upstream of the valves that inject hydrogen and oxygen into the chamber.

The engine start-up sequence has three main phases:

(i) Before lift-off and during launcher preparation
- Conditioning of all circuits by flushing with helium and successive compression and expansion.
- Commencement of cooling of propellant feed lines.

(ii) During flight of the first two stages
- Keeping feed lines cold by venting small quantities of propellant through the flushing circuits.

(iii) During third-stage flight
- On second/third-stage separation, precooling the chamber regenerative circuit for 2.5 s by opening the hydrogen-injection valve and flushing the oxygen injectors with helium.
- Initiating the igniter.
- Igniting the starter and opening the oxygen-injection valve.
- Opening the generator's injection valves.

THE THRUST UNIT

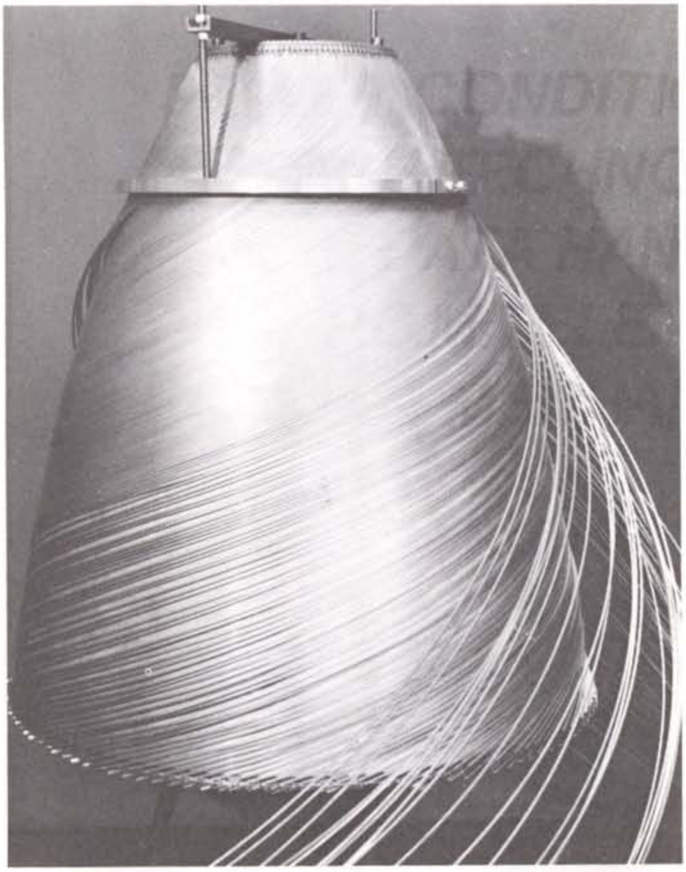
This unit is made up of three subassemblies: an injector, a combustion chamber, and a nozzle.

The injector is made from 90 identical coaxial elements equally spaced around five concentric circles. The face plate between injection elements is made of Siperm, a porous material through which a small fraction of the hydrogen flow is able to pass, thus ensuring cooling. Each injection element gives a twist to the liquid-oxygen jet and surrounds it with an annular layer of hydrogen. A high injection-velocity ratio and a 'swirler' ensure good homogeneity of the mixture and help to improve combustion efficiency.

The combustion chamber itself (Fig. 4) is cooled by 100 slots of varying cross-section milled in the copper chamber body and closed on the outside by successive layers of electro-deposited copper and nickel.

The configuration of the slots and the thickness of the chamber's inner wall were the subject of complex mathematical modelling to determine the thermal constraints and temperatures in the various areas, particularly in the neighbourhood of the throat where the figures are highest.

A detachable nozzle extension (Fig. 5) has been used to adapt the engine to sea-level test conditions by extending the combustion chamber outlet (beyond point where section ratio=7). It was made from 242 Inconel tubes arranged spirally around a mandrel and argon-welded on the outer periphery. Four hundred and eighty-four small nozzles were brazed into its lower end, enabling part of the impulse from the cooling flow to be recovered. This arrangement has the advantage of separating the nozzle from the combustion chamber when carrying out development tests under sea-level conditions, without danger of jet separation or modification of the engine's operational parameters.



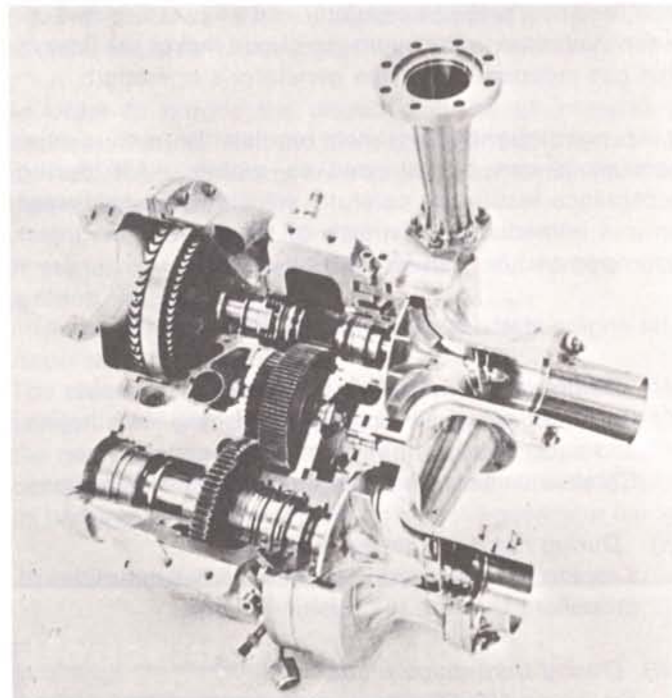


Figure 5 – Detachable nozzle extension used for testing under normal atmospheric conditions.

Figure 6 – The turbopump of the HM-7 engine. ▶

THE TURBOPUMP

A general view of the turbopump is shown in Figure 6. An axial turbine with two pressure stages drives both pumps. Eighty-two percent of the turbine power is used by the hydrogen pump, which is mounted on a common shaft with the turbine, the remainder being transmitted to the oxygen pump through a reduction gear.

The turbine rotors are made of Inconel and are machined by electrode erosion. The stators are cast.

Each pump wheel comprises an axial inducer, whose vanes are sharpened to improve cavitation performance, and a radial-vane impeller equipped with counter-vanes for balancing the axial thrusts.

The generator is of the non-uniform-mixture type. The injector unit is made up of three oxygen injectors converging at 45° surrounded by 12 axial hydrogen injectors.

The starter produces a gas flow at 2000 K for 1 s which first serves to spin up the turbopump and then, after opening the generator's injection valves, to ignite the latter.

The propellant-feed circuits have been designed so as to reduce the dead volume between the injectors and the injection valves.

DEVELOPMENT TESTING

The milestones in the development testing of the engine (Fig. 7) have been as follows:

– July 1973	Start of project
– July 1974	First turbopump test
– August 1974	First sea-level thrust-unit test
– May 1975	First sea-level engine test
– November 1976	First long-duration sea-level engine test
– April 1977	Turbopump qualification
– May 1977	First engine test with altitude simulation

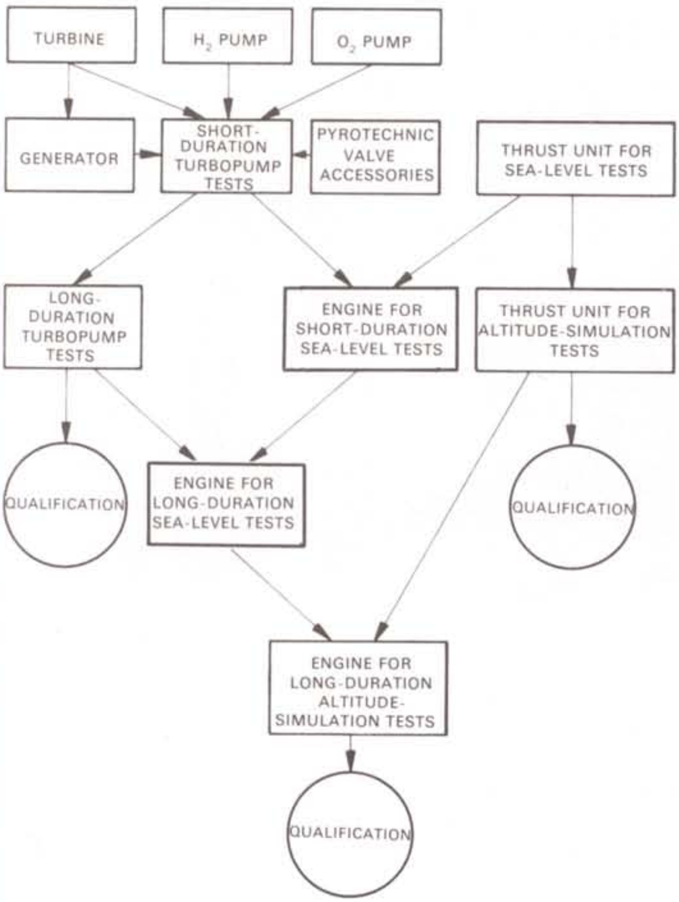


Figure 7 – Scheme for the main engine development tests.

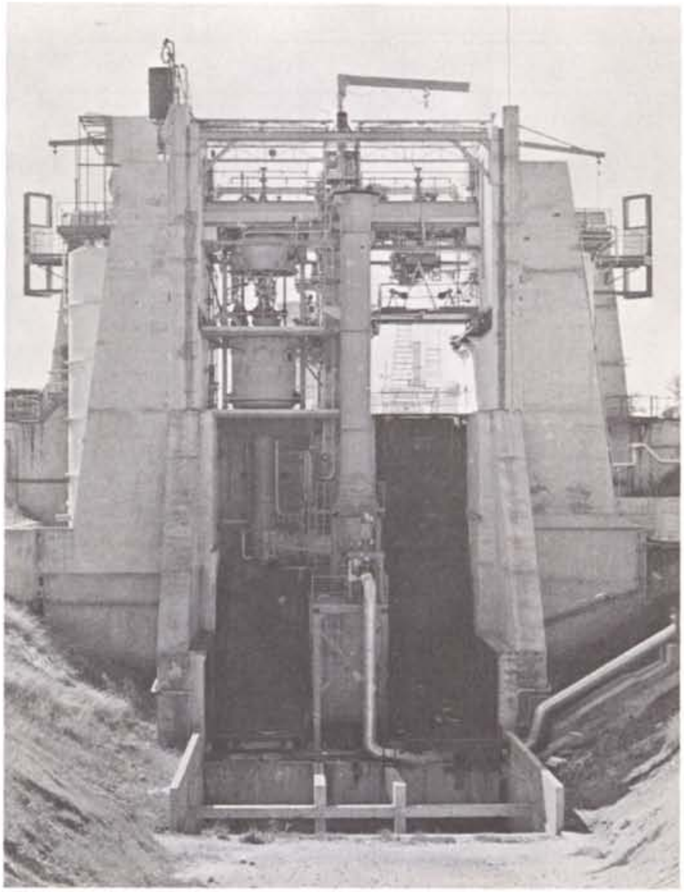


Figure 8 – The PF41 test stand at Vernon in France.

- June 1977 Thrust-unit qualification
- September 1977 First long-duration engine test with altitude simulation
- August 1978 Start of engine qualification

The main test facilities used are listed in Table 1.

Test stand PF 41 (Fig. 8) is the largest facility, consisting of two test cells with common services. The steam-extraction device, with a flow of 110 kg/s, creates a 50 mbar vacuum to simulate the conditions under which the chamber is pre-cooled and ignited.

The thrust-unit test stand (Fig. 9) also comprises two test cells. Altitude simulation is achieved by passing the chamber flow through a supersonic diffuser.

The results of the tests conducted up until 1 May 1978 are summarised in Table 2, including those conducted at propulsion-system level.

In view of the large number of tests, a computerised management system for their results has been set up. The data are stored on magnetic tapes and a set of interrogation procedures gives automatic access to the

TABLE 1

	Location	Type
Engine	Vernon (SEP) PF 41	Two vertical test cells for long-duration (750 s) tests, under both sea-level and simulated-altitude conditions
	Villaroche (SEP)	Horizontal test stand for short-duration (200 s) tests
Thrust Unit	Ottobrunn (MBB)	Two horizontal cells for short-duration (50 s) tests, under both sea-level and simulated-altitude conditions
Turbopump	Vernon (SEP) PF 41	Tests lasting >1000 s by converting the altitude-simulation test cell
	Villaroche (SEP)	Short-duration (20 s) test
Components	Villaroche (SEP)	Pumps, turbines, generator and accessories

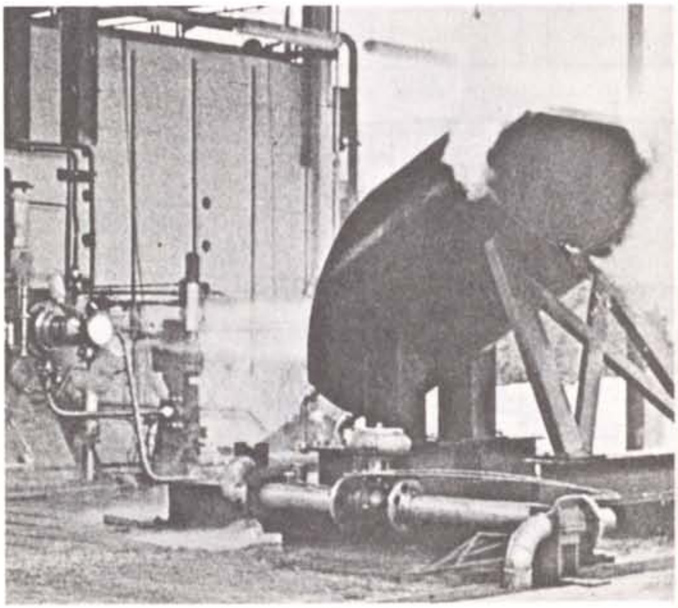


Figure 9 – Thrust-unit test stand.

TABLE 2

	Number of models tested		Number of tests and duration	
Turbopump	4 for development		67 firings, 6150 s	
	12 for acceptance		45 firings, 575 s	
Thrust Unit			**Sea-level**	**Simulation**
	14 combustion chambers 7 injectors 3 nozzles		110 firings, 3800 s	130 firings, 5000 s
Engine			**Sea-level**	**Simulation**
	4 ground engines 3 flight engines	for development tests	70 firings, 7400 s	22 firings, 1300 s
	5 ground engines	for acceptance tests and tests at propulsion-system level	12 + 8* 550 s + 1400 s*	

* Tests carried out at propulsion-system level.

** Qualification testing on two models has still to be carried out.

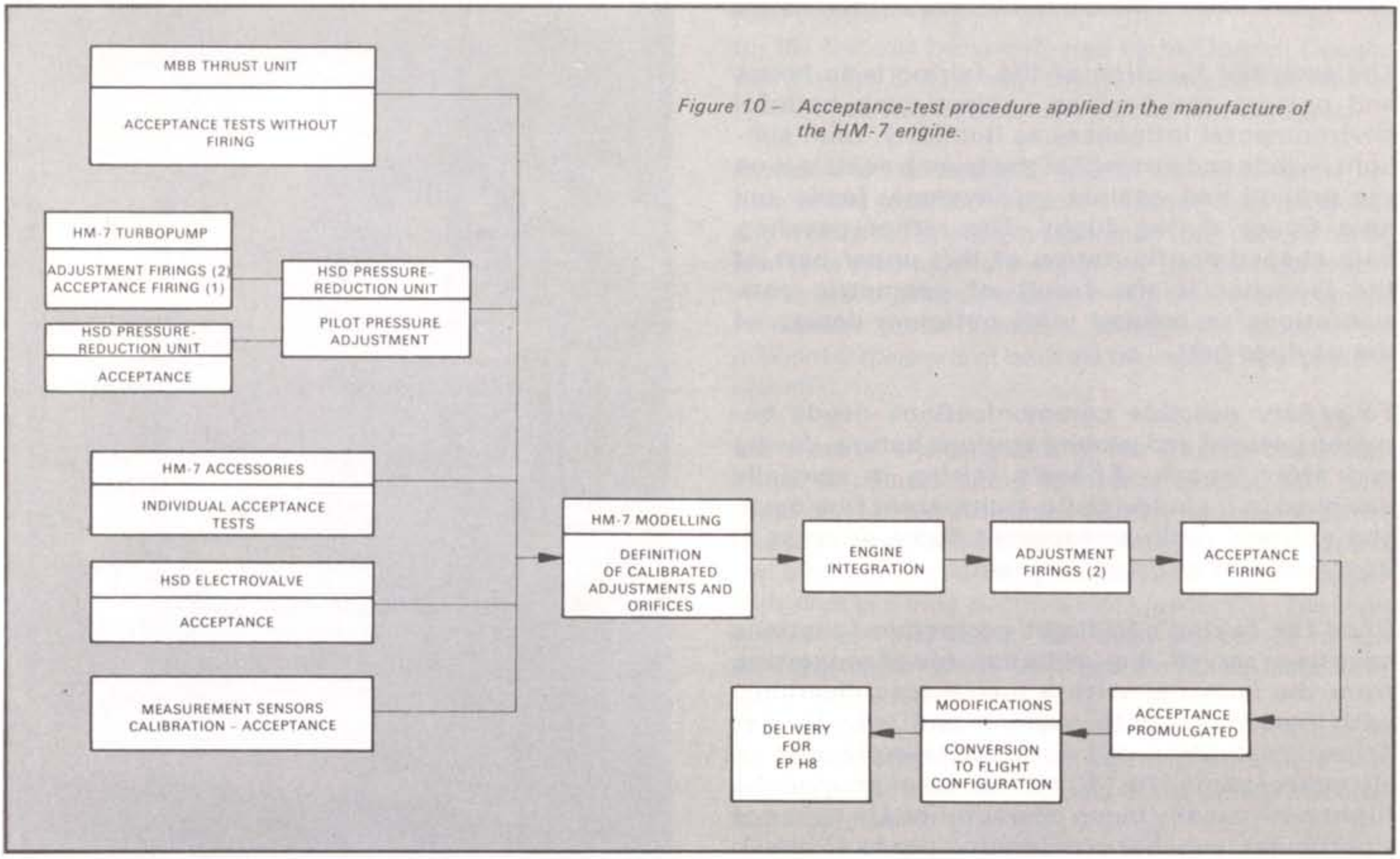


Figure 10 – Acceptance-test procedure applied in the manufacture of the HM-7 engine.

information on the basis of well-defined criteria. This system constitutes a propulsion data bank, which has been used for working out mathematical models for predicting performance and for dynamic studies, as well as for exploiting and summarising test series.

Each HM-7 engine undergoes acceptance testing on the basis of the procedure summarised in Figure 10. Initial adjustments are derived from a mathematical model of the engine, and measurements are made to an accuracy of 0.5%.

POSSIBLE PERFORMANCE INCREASE

The margins within which the engine can be adjusted allow its thrust to be increased and its mixture ratio to be altered without any technological modification. The development tests have already allowed the HM-7's upper operating limits to be explored (±10%), and a number of improvements have been proposed with a view to increasing launcher performance. They relate mainly to increased specific impulse, by increasing combustion pressure and expansion ratio, and to the lifetime of the chamber. A new chamber configuration with a reduced throat diameter and increased pressure has already been tested, and it leads to a gain of 2.5 s in specific impulse.

A new configuration for the chamber cooling slots has been drawn up to allow increased operating time. It involves decreasing the depths of the slots and increasing their number from 100 to 130. This modification allows the wall temperature to be reduced by 100 K and leads to a considerable increase in creep limit. □

The Ariane Fairing and its Separation Systems

R.W. Jaeger, Ariane Project Team, CNES, Evry, France

The essential function of the fairing is to house and protect the payload against such harmful environmental influences as humidity, rain, sunlight, winds and dirt whilst the launch vehicle is on the ground and against aerodynamic loads and heat fluxes during flight. The rather peculiar, bulb-shaped configuration of this upper part of the launcher is the result of geometric considerations associated with optimum design of the payload bay.

To satisfy possible communications needs between payload and ground stations before, during and after launch, Ariane's fairing is specially designed to include a radio-transparent rear cone, and optional radio-transparent doors or areas in its cylindrical or upper elements.

Once the fairing's in-flight protective functions have been served, it must be capable of separating from the launcher with a guaranteed clearance with respect to both payload and vehicle. For Ariane, separation will normally take place at an altitude of some 110-140 km, the exact point in the flight path usually being characterised in terms of a particular launcher acceleration (up to 45 m/s^2).

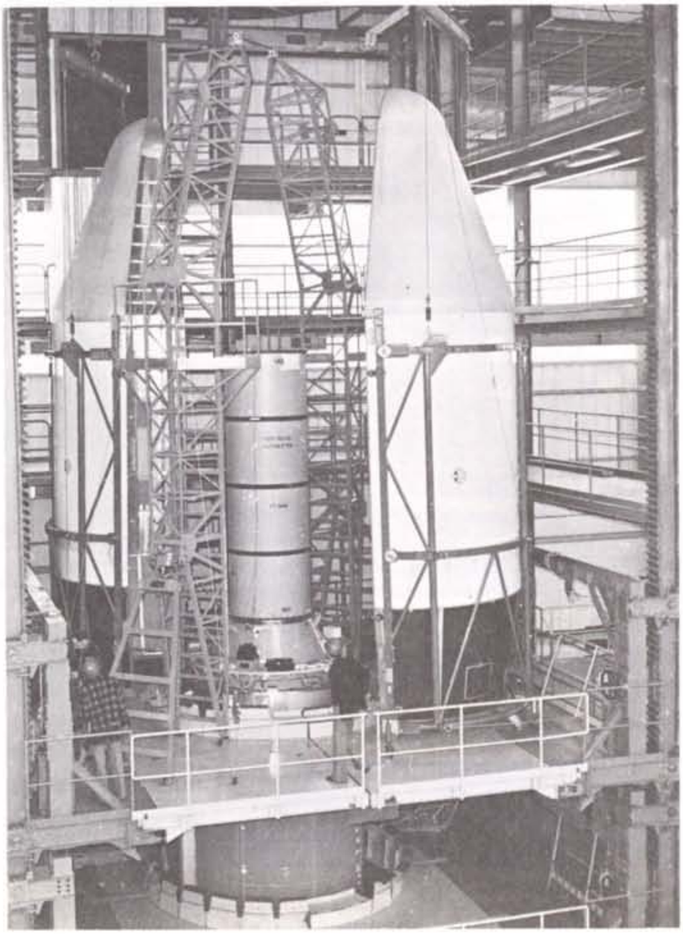


Figure 1 – Ariane fairing during integration for dynamic test.

The general composition of the Ariane fairing (Fig. 1) is as follows. An aft cone with an interface diameter to the equipment bay of 2.6 m opens to 3.2 m maximum diameter and is followed by a cylindrical section 4 m high that terminates in a front-cone section with a spherical nose. The overall height of the fairing is 8.6 m. As can be seen in Figure 2, the fairing can accommodate a maximum payload diameter of 3.0 m and the useful payload volume amounts to approximately 40 m^3.

The cylindrical section and front cone are of classical metallic-frame/stringer construction; the aft cone, for reasons of radio-frequency transparency, is a kevlar-glassfibre sandwich. Access to the payload is provided by four 450 × 450 mm doors in the cylindrical section. The positions of these doors can be adjusted within a specified zone to suit the particular payload carried. Access to certain Vehicle Equipment Bay (VEB) items is possible via doors in the rear cone. Standard payload connectors on a variable-length support, to cope with a large variety of satellite sizes and connector types, are available. A second such device can be provided for dual-launch purposes.

The fairing can be delivered with acoustic protection for those payloads susceptible to lift-off and aerodynamic noise.

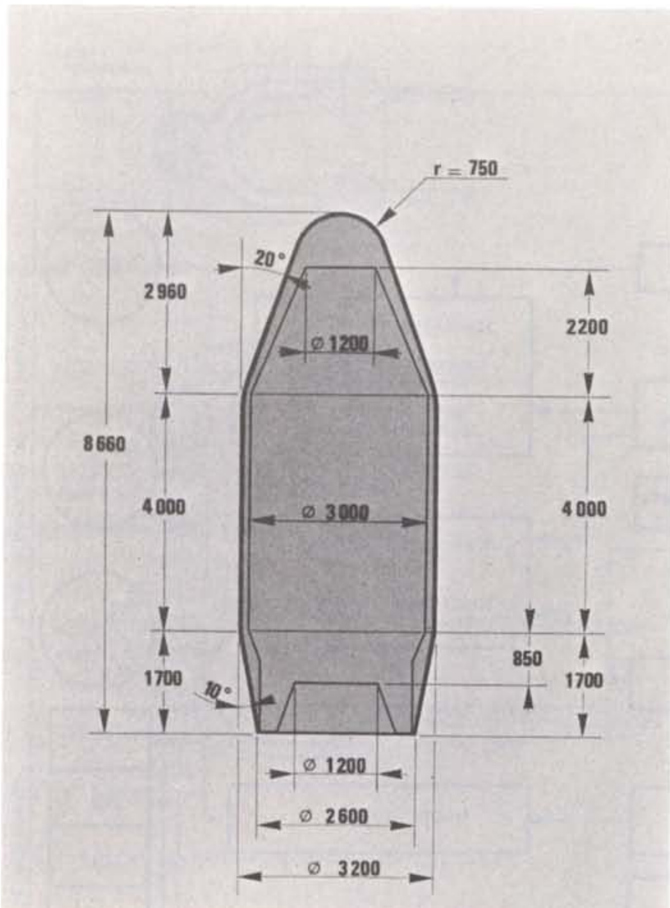


Figure 2 – Overall design and 'free volume' of the Ariane fairing.

DEVELOPMENT PHILOSOPHY

The development philosophy for the Ariane fairings (Fig. 3) foresaw the use of three units for development and qualification on the ground (DMU, SM1 and SM2), and the delivery of four flight units (L01, L02, L03 and L04). The static and dynamic qualifications were to be realised using two complete structures (models SM1 and SM2).

Three separation tests have been conducted using SM1 in the large vacuum chamber (DTC) at ESTEC, the fairing unit being refurbished after each test. A linear thrusting joint system is used for fairing separation (vertical), that for the first test being delivered by McDonnell Douglas Astronautics Company (MDAC). A European-developed system was employed for the second and third tests.

A mathematical model to predict fairing dynamic behaviour and separation trajectory has also been developed and it has been applied in separation tests using a fairing rear cone prior to fairing-separation qualification proper. A dispersion analysis allows in-flight fairing-separation trajectories to be predicted taking into account the inherent dispersions of both the fairing and its separation system.

The material characteristics of the structure were subjected to manufacturing tests prior to prototype construction. A dynamical model (DMU) has been provided for use in overall vehicle checks. This model will also serve for electromagnetic-compatibility and radio-compatibility checks during electrical mock-up testing. The static qualification unit (SM2) has been refurbished for use during propellant mock-up tests at the Guiana launch site.

The electrical system has already been subjected to breadboard testing, and two electrical simulators have been manufactured, also for use in the vehicle electrical mock-up tests.

The acoustic protection system will be employed in the fairing to be used on the second test flight (L02) to provide in-flight qualification.

Radio-frequency tests have been conducted and a 1/5 th scale-model will be permanently available to verify the suitability of particular antenna configurations.

Lanyards, umbilicals, venting and cooling have also been the subject of development and functional qualification testing, the SM2 static model being used in the majority of cases.

Fairing development has been entrusted via SNIAS to Contraves, leading representative of the Swiss Aerospace Consortium, which has the Swiss Federal Aircraft Factory, Pilatus and FFA as partners.

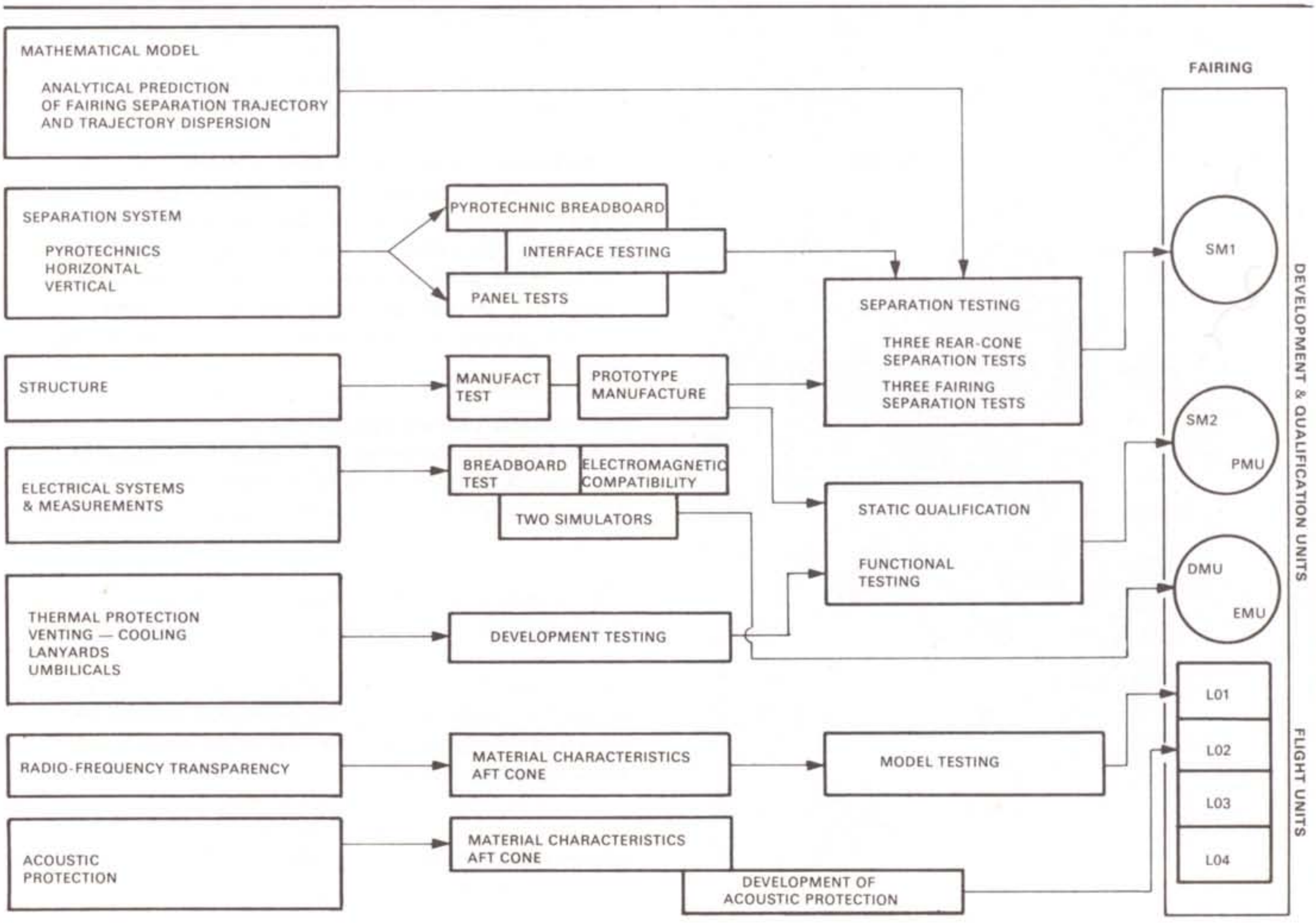


Figure 3 – Development logic for the Ariane fairing. (PMU = Propellant Mock-Up; DMU = Dynamic Mock-Up; EMU = Electrical Mock-Up).

FUNCTIONING OF THE FAIRING-SEPARATION SYSTEMS

Fairing separation is produced by the contaminant-free action of the linear thrust-joint system mentioned above, relying on a horizontal separation system to free the fairing sections from the adjacent VEB. Both separation systems are activated by a pyrotechnic system.

The vertical separation system consists of a linear energy source which forces a piston, connected to one half of the fairing, out of a linear cylinder, connected to the other fairing element. The relative motion of piston and cylinder produces a lateral separation of the two halves of the fairing (Fig. 4). The energy source consists of strands of mild detonating fuse (MDF), the number of strands determining the total energy available and influencing fairing deployment velocity. Surrounding the MDF is a temperature and shock attenuator assembly, in the form of two eccentrically mounted steel tubes, each containing a row of holes through which the hot gases must flow before exerting a force on the piston. The attenuator

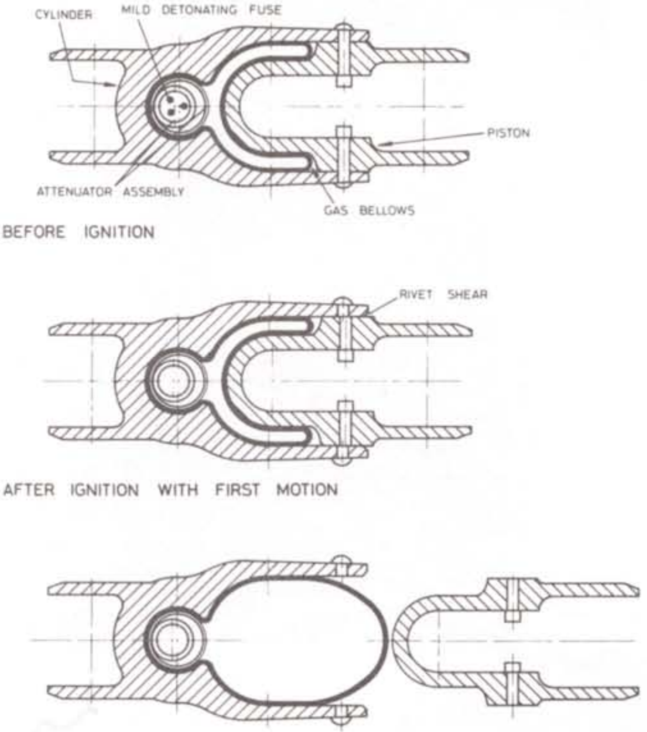


Figure 4 – Fairing vertical separation system (VSS).

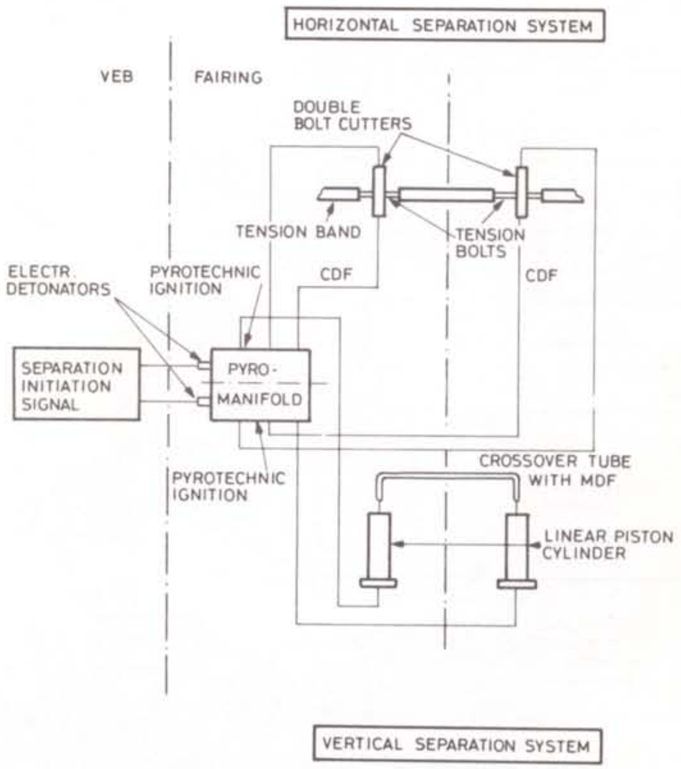


Figure 5 – Schematic of overall fairing separation system (VSS and HSS).

assembly is surrounded by a flexible bellows which contains the hot gas and propels the piston.

The vertical separation system also helps to hold the two fairing halves together up to the time of deployment, the piston being held in place within the cylinder by shear rivets. It is a closed, continuous system extending from the aft flange of the rear cone, forward to the area of the interface between the forward cone and the nose cap, around the inside of the nose cap near the separation plane, and then down the opposite side to the aft flange of the rear cone. The system is normally ignited at both ends in the fairing rear cone.

The horizontal separation system consists of a steel band manufactured in two pieces, held together in tension by two adjustable bolts, and wrapped around the aft flange of the rear cone. To release this system for fairing deployment, four guillotines (from two double bolt cutters) are fired to shear the two tension bolts. This breaks the tension band and, as this band is secured to the rear flange of the rear cone, serves to pull the rear flange away from the VEB.

Near-simultaneous functioning of the vertical and horizontal separation systems (VSS and HSS) is achieved by using a central pyrotechnic manifold unit to ignite the confined detonating fuses (CDF).

Because the fuses have a high propagation velocity and they are all of near-equal length, the vertical and horizontal systems are activated within approximately 300 μs of each other. The separation system is shown schematically in Figure 5.

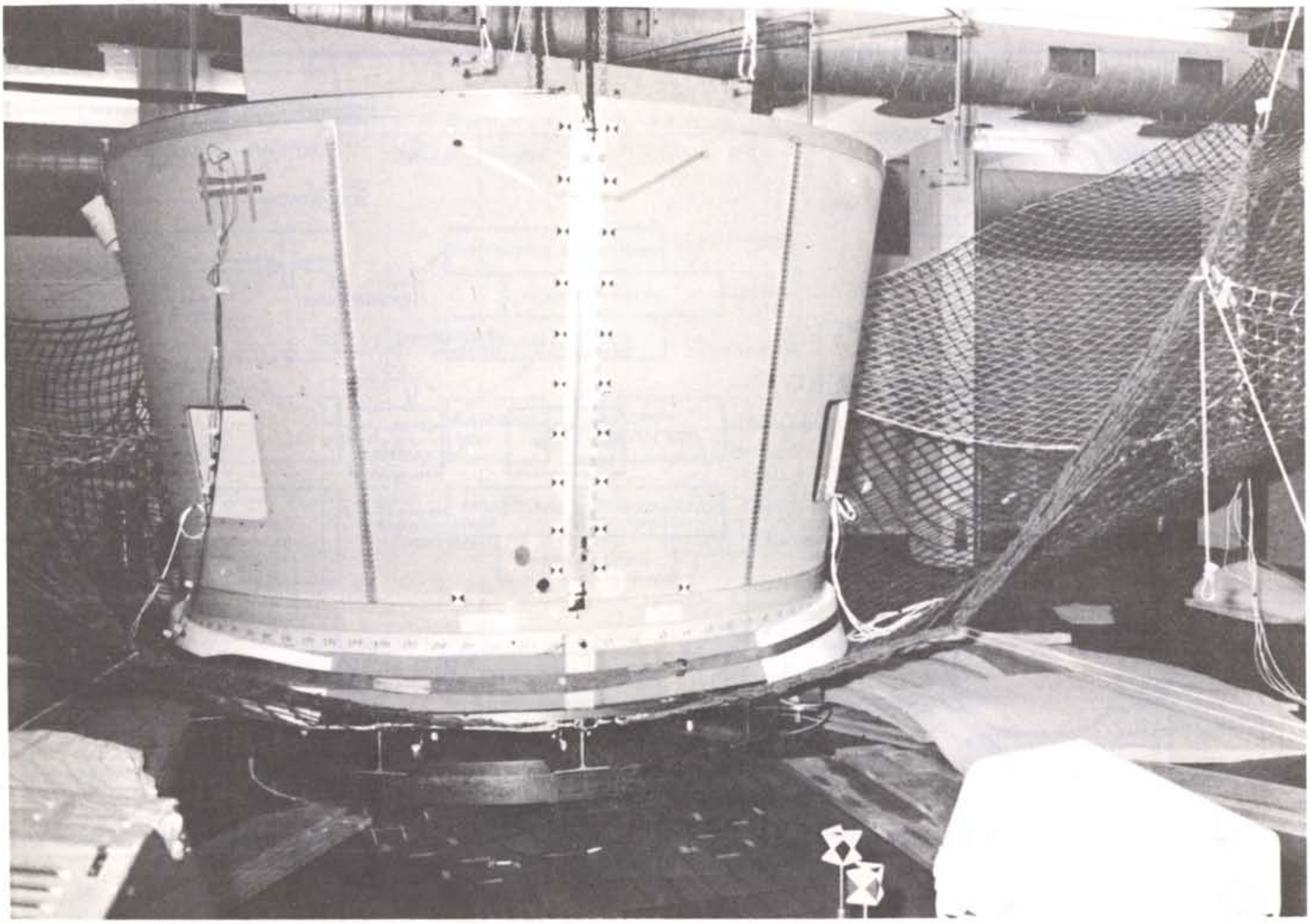


Figure 6 – Rear fairing cone installed on VEB, ready for separation test.

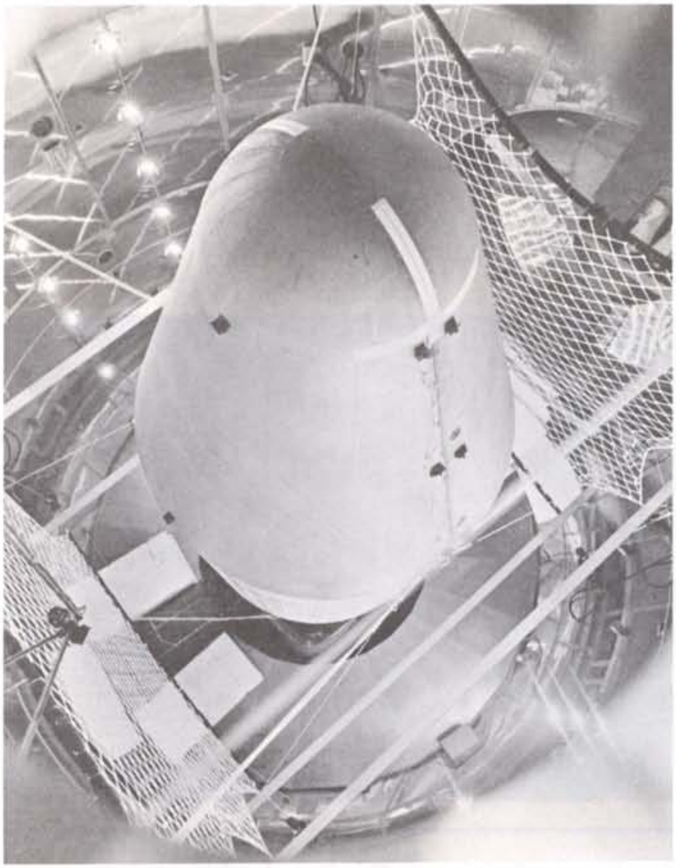
DEVELOPMENT OF THE EUROPEAN SEPARATION SYSTEM

The first step in deriving the European separation system was to determine the number of detonating strands needed for the vertical separation system. This turned out to be three, rather than two as used for the Thor-Delta fairing.

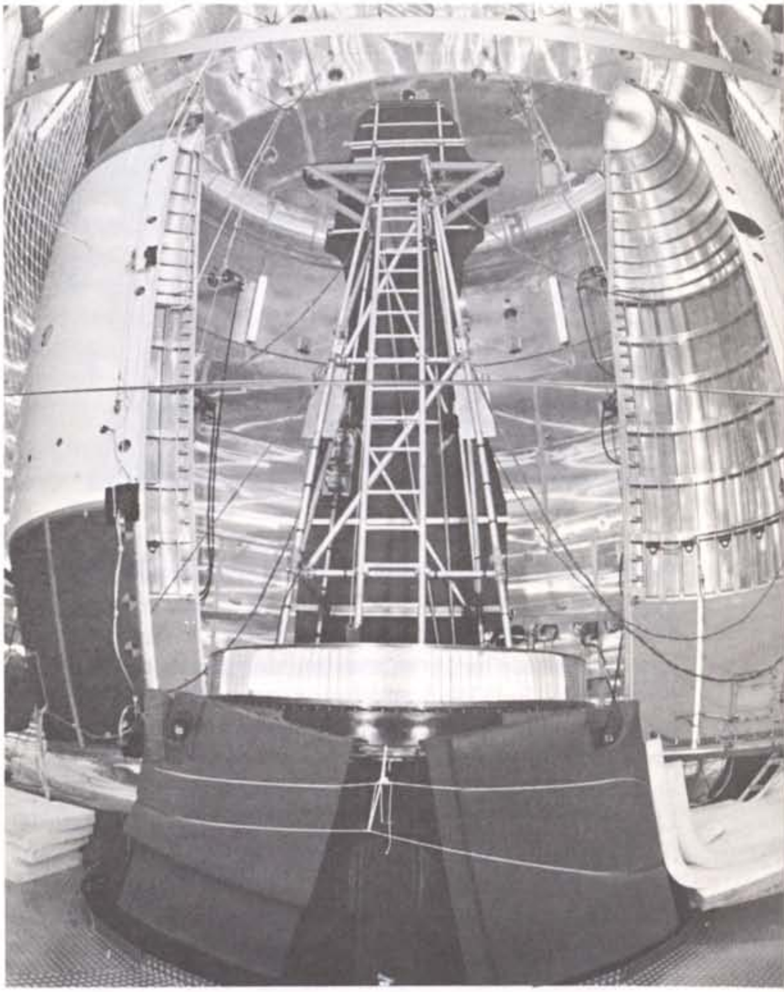
A series of tests was then made using 1 m VSS-rail on panels to study its functioning, to establish the best attenuator-tube pattern, and to derive the energy per unit length available. This series of tests was initially conducted with the assistance of Ensign-Bickford and later, after installation of the test stand in Europe, with the help of Contraves.

These tests allowed the final VSS configuration to be validated. Qualification testing was completed with five 1 m panel test-firings in early 1977.

As fairing clearance had given rise to considerable



▲ *Figure 7 – First fairing separation test (SM1A) in the Dynamic Test Chamber (DTC) at ESTEC.* ▶



concern during 1976, a fairing rear cone (Fig. 6) was prepared for a series of three tests at the end of that year to verify separation behaviour, to verify the mathematical model for prediction of fairing trajectory, and to demonstrate the concept of improving clearance with respect to the launcher by attaching the tension band of the HSS to the rear-cone bottom flanges.

The successful outcome of this series of tests resulted in increased confidence in the development of the vertical separation system, particularly as the European system had been used.

The first large-scale separation test took place on 18 June 1977 in the ESTEC test chamber with the SM1 fairing model (Fig. 7). The main objectives were to study separation behaviour, to validate test procedures, to learn how to handle a complex structured measurement system, and to run through a process of complete data evaluation. The VSS used on this occasion was provided by MDAC. The fairing separated successfully, all systems functioned correctly, and clearance was greater than predicted, giving rise to subsequent modification of the mathematical model.

There followed two more successful qualification tests using the European-developed VSS, the first on 20 October 1977, the second on 7 April 1978. The second of these tests had the supplementary objective of proving that one-sided initiation of the VSS would still result in trouble-free separation.

The separation system can therefore now be considered as 'qualified', and the formal qualification procedure for the Ariane fairing itself can be initiated. □

Inauguration of ESA's Villafranca Station

The Villafranca ground station, designed to serve the Agency's IUE, OTS-2 and future maritime satellites, was officially inaugurated on 12 May by His Majesty Juan Carlos, King of Spain.

The station, 30 km west of Madrid, has been built under the terms of an Agreement signed in 1974 between the Spanish Government and ESA. Like the other stations in the ESA ground network – Redu in Belgium, Michelstadt in Germany and Fucino in Italy, the Villafranca station is linked with the European Space Operations Centre (ESOC) at Darmstadt (Germany), which houses the control and computer facilities for the exploitation of the European satellites.

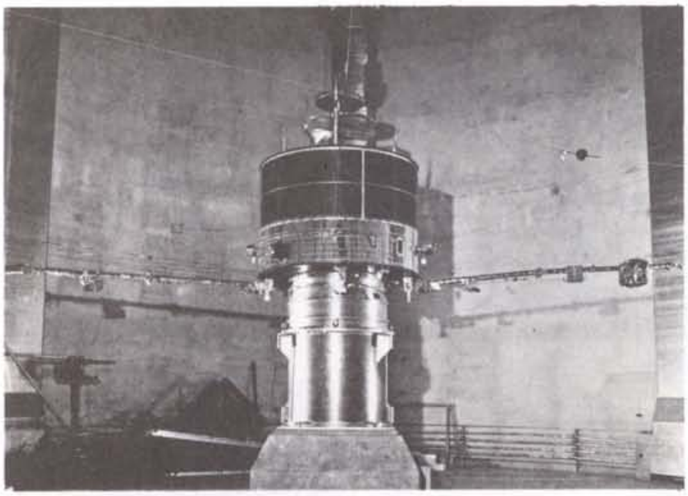
Villafranca is equipped with three antennas, one of 15 m diameter for the IUE satellite, one of 12 m for maritime satellites and one of 3 m (support function, ranging, etc.) for OTS-2, and accommodates various facilities specific to the individual programmes (those for IUE were outlined in Bulletin No. 13). From the end of 1978 onwards, the station will also be used for the control of the American meteorological satellite GOES which, like Meteosat, is taking part in the World Meteorological Organisation's Global Atmospheric Research Programme (GARP). □

Indian Space Research Organisation and ESA sign new space-co-operation agreement

The Indian Space Research Organisation (ISRO) and ESA have signed a new Agreement to strengthen their existing friendly relations and to establish mechanisms that would facilitate the development of co-operation between the two agencies in the peaceful uses of outer space. The Agreement was signed by Prof. S. Dhawan, Chairman of ISRO, and ESA's Director General, Mr. Roy Gibson, at Bangalore on 14 April.

The new Agreement defines the areas of co-operation and lays the groundwork for periodic consultations on matters of mutual interest, co-ordination of efforts made towards the definition and realisation of common objectives, information-exchange visits by scientists, award of fellowships to scientific and technical personnel, mutual use of available test facilities, and tracking and telemetry support for each other's satellites.

The Agreement, which includes satellites, sounding rockets and balloons for space research and applications such as communications and remote sensing, is the outcome of growing co-operation between the two agencies since 1971. □



Geos-2 launched

The Agency's geostationary scientific satellite Geos-2 was launched successfully by an American Delta-2914 vehicle from Eastern Test Range, Florida, on 14 July. This satellite is designed to carry out the mission originally conceived for Geos-1 (see ESA Bulletin No. 9, May 1977), which was injected into too low a transfer orbit to allow geostationary orbit to be achieved, due to a malfunction of the Delta-2914 launcher. The satellite's apogee boost motor was used to inject Geos-1 into a 12-hour elliptical orbit and the mission was modified, but not abandoned. After a year's operation in this orbit, Geos-1 has in fact already made a significant contribution to the International Magnetospheric Study (IMS).

Built as the qualification model at the same time as Geos-1, the second spacecraft has since been converted into a high-quality flight model, with only minor modifications to certain spacecraft subsystems being made in the course of refurbishment, based on Geos-1 experience. The payload of Geos-2 is identical to that of Geos-1.

Geos-2 will study the Earth's magnetosphere, and in particular that region of the magnetosphere in which many of the dynamic processes responsible for magnetic and ionospheric disturbances are believed to develop.

The satellite has been developed under ESA management by industry in ten European countries (Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Sweden, Switzerland and the United Kingdom), through the STAR Consortium, led by British Aerospace Dynamics Group as Prime Contractor. □

Changes in the ESA Executive

At its Session of 26 April, the ESA Council took a number of decisions concerning the structure of the Agency's Directorate.

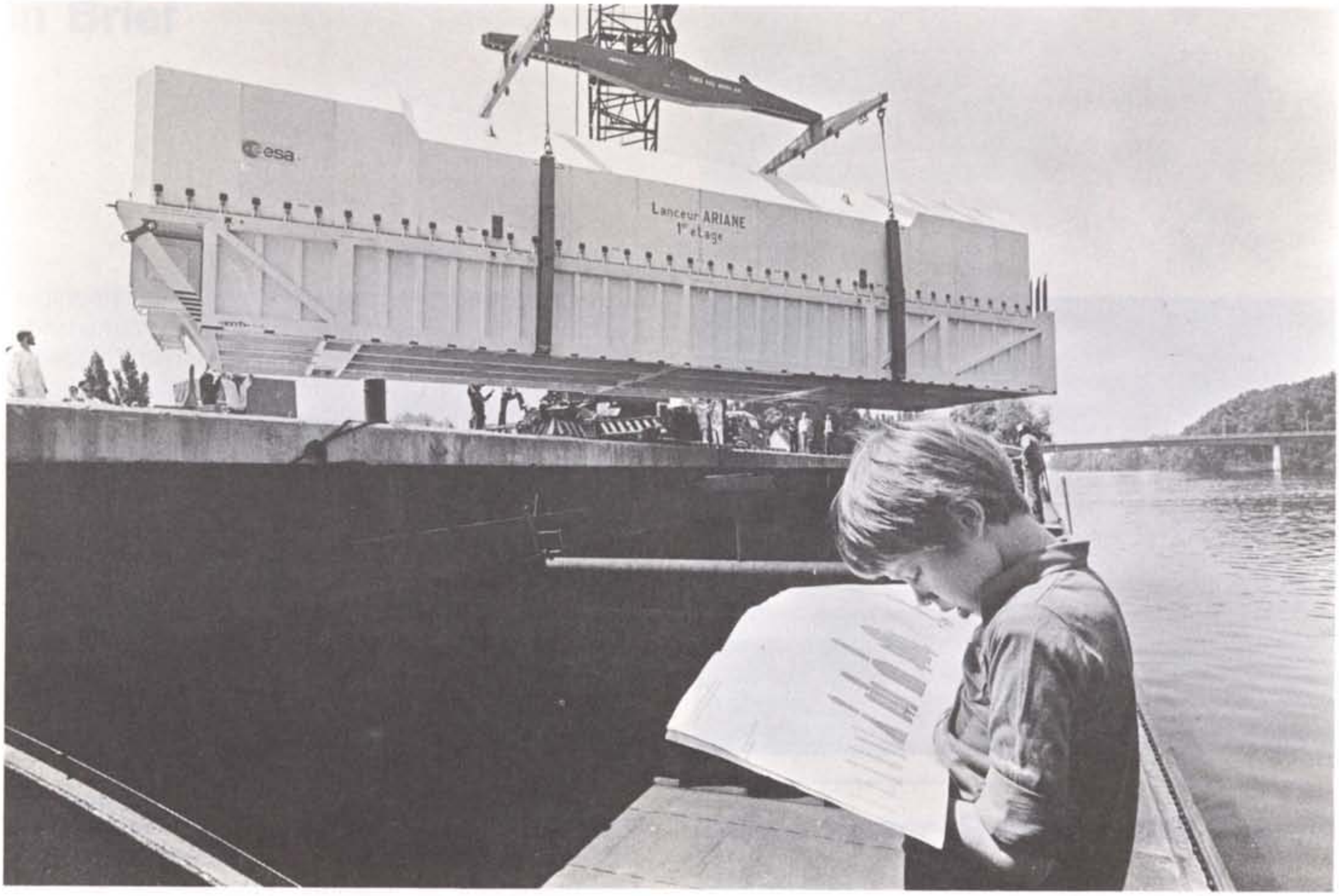
As a consequence, with effect from 1 June:

(i) Responsibility for future studies related to the Scientific Programme, previously the responsibility of the Directorate of Planning and Future Programmes (D/PFP), is transferred to the Directorate of Scientific Programmes, with the exception of studies related to life and material sciences. The latter remain under the authority of D/PFP. The Director of Scientific Programmes thus becomes the principal interlocutor of the Science Programme Board, the Science Advisory Committee and the relevant Working Groups.

(ii) Responsibility for future studies related to other programmes will be transferred from D/PFP to the appropriate programme directorate as and when these studies are approved for Phase-A (study phase).

(iii) The Directorate of Communications is transformed into a Directorate of Applications Programmes, which takes responsibility for all approved telecommunications and earth-observation programmes, including the Meteosat programme.

At the same time, the Director General has reorganised the services attached to him through the Head of Cabinet, who becomes responsible for all external relations, both international affairs and public relations, in addition to the services directly concerned with the serving of Council and the Director General's office. □



First Ariane Launcher leaves for French Guiana

A major new phase in the Ariane test programme began in June when the full-scale propellant mock-up (47 m high with a maximum diameter of 3.8 m) left the Launcher Integration Site at Les Mureaux near Paris for the Ariane Launch Base in French Guiana.

Three pressurised containers (one for each stage) were transported by barge to Le Havre, where they were loaded onto a freighter bound for Cayenne. Early in July the stages, the fairing and the other elements of the launcher were transported by road from the port of Cayenne to the Ariane Launch Site at the Guiana Space Centre.

In August, the launcher will be erected for the first time on the launch table and the propellant-mock-up tests, which will last for three months, will begin. These tests are designed to check:

- the general conditions for launcher assembly and compatibility with the vehicle of the ground facilities (platform, tower, etc.);

- the technical functioning of the fuelling and draining facilities and systems, both on the ground and on the vehicle, and the satisfactory working of the relevant procedures.

The transport, assembly and test operations will be carried out by Centre National d'Etudes Spatiales (CNES). The system integrator, Aérospatiale, will be responsible for evaluating the dynamic and thermal behaviour of the launcher in ambient climatic conditions (wind, temperature) and when subjected to vibrations simulating those at lift-off. □

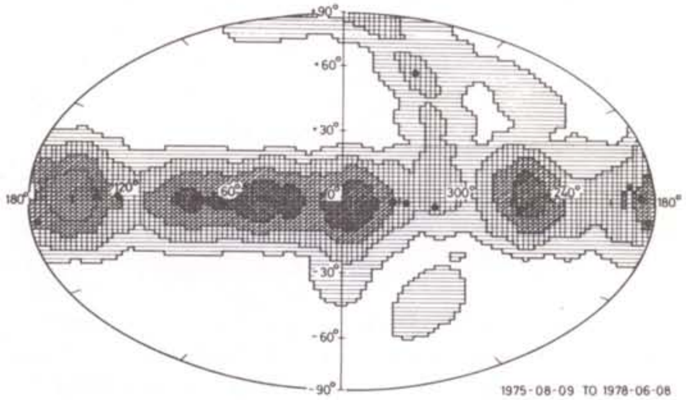
Boost to Gamma-Ray Astronomy from Cos-B

ESA's gamma-ray astronomy satellite Cos-B completes its third year of successful operations on 9 August. The mission was originally foreseen to last two years, but the scientific results from analysis of the first year's data were considered sufficiently important that in May 1977 Council approved an extension of operations to the end of 1978. This extension was possible because of the high level of technical performance of both experiment and spacecraft.

The scientific payload consists of a single instrument provided by a Collaboration of six European institutes (see ESA Bulletin No. 2, August 1975). As one member of this collaboration, the Space Science Department of ESA contributed the detector's triggering telescope and is playing a full role in the analysis of the data.

The Cos-B instrument is able to measure the arrival direction and energies of cosmic gamma rays with energies greater than about 30 MeV, more accurately than any experiment previously flown. The broad aim of these measurements is to study sources of extraterrestrial gamma radiation in detail, with special emphasis on investigation of the spatial structure and energy spectrum of the emission from our Galaxy and on the examination of known or postulated localised sources.

Cos-B has made a comprehensive scan of the part of the sky along the plane of the Milky Way, with a series of one-month observations, each covering a circular field of about 25° radius. Because of the need to provide some overlap between these regions, a total of 15 such observations were devoted to this work. Meanwhile some of the more interesting observations were repeated and a few areas at high galactic latitudes were studied to investigate the possible existence of sources of gamma rays outside the Galaxy. The galactic scan was thus completed in about 22 months. Since then, more time has been devoted to the higher latitudes, while additional repeat investigations have been scheduled on the basis of results from the data being analysed. A number of recent observations have been directed at specific objects of general interest, such as radio pulsars, quasars and Seyfert galaxies. The sky coverage achieved in 34 months is shown in the accompanying figure.



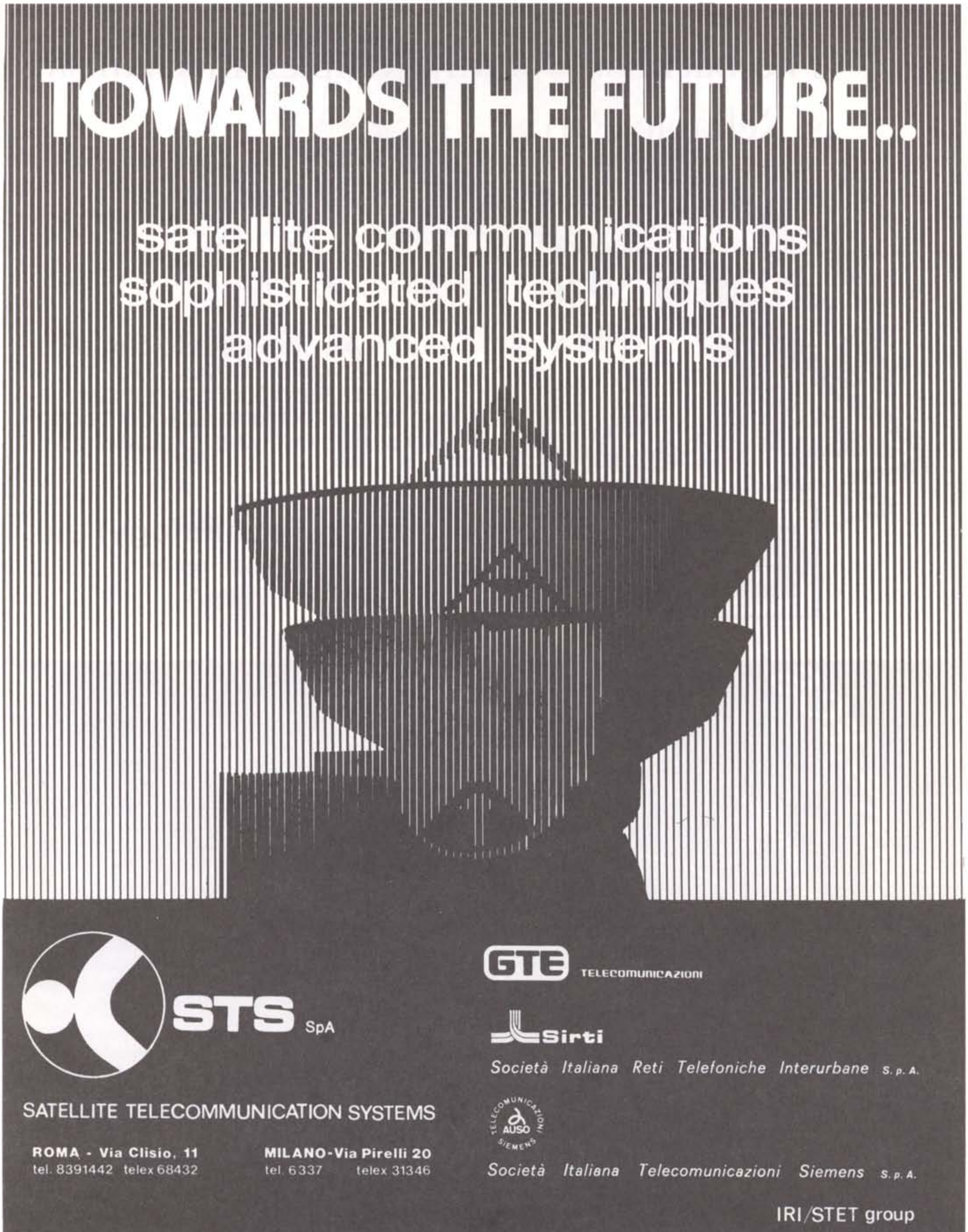
Relative sky coverage (galactic co-ordinates) of Cos-B observations up to 8 June 1978. The intervals between contours correspond to the equivalent of about 18 days axial exposure. The positions of the 14 gamma-ray sources are indicated by solid circles.

First analysis efforts were concentrated on the data from the observations near the galactic equator. In the longitude range $305° < l^{II} < 40°$, the latitude profile of the radiation was found to be consistent with the angular resolution of the detector, placing a limit of about 2° on the width of the emitting region in these central parts of the Galaxy. At greater angular separations from the galactic centre the emission intensity profile becomes broader (and weaker) and in the anti-centre region (after subtracting the contributions from the two well-established localised sources) there is no evidence for any emission from the galactic disc. This variation of the intensity with longitude is in good agreement with the picture derived from the results of NASA's SAS-2 satellite, but the better angular resolution of Cos-B has highlighted many regions of intense localised emission. From the energy spectrum of the galactic radiation derived from Cos-B observations, it seems that, in addition to the expected gamma-ray production in collisions of cosmic-ray protons with interstellar matter, there must be a significant contribution from radiation processes of the electron component of the cosmic radiation.

The existence of 13 point-like gamma-ray sources has also been revealed, two being readily identifiable with the pulsars PSR 0531 + 21 and PSR 0833-45. The other 11 could not be easily identified with objects radiating at other wavelengths and only one of them had been previously reported. These sources are concentrated toward the galactic equator, suggesting that most of them have a galactic nature with typical distances in excess of 3000 light-years. It has been proposed that such sources may make a significant contribution to the total gamma-ray luminosity of the Galaxy.

Very recently, analysis of data from one of the high-latitude observations has revealed the existence of the first gamma-ray source to be identified with an object outside our own Galaxy. This is the quasar 3C273, whose distance from the solar system is estimated to be about 2×10^9 light-years. This discovery lends support to a hypothesis that one of the other Cos-B sources (known as CG 135 + 1) may also be identified with a quasar. An object of this type was recently discovered by radio and optical astronomers following a precise measurement by SAS-3 of the position of the nearest known X-ray source to CG 135 + 1. Whether or not this identification is confirmed, there is no doubt that the discovery of this new quasar (the nearest one known at the present time – only about 6×10^8 light-years distant!) has been a direct consequence of the Cos-B measurement.

These results, and others from Cos-B, have aroused world-wide interest amongst astronomers working at other wavelengths and have provided useful new material for astrophysics theoreticians. It is anticipated that more new discoveriès will be made when further data have been analysed. □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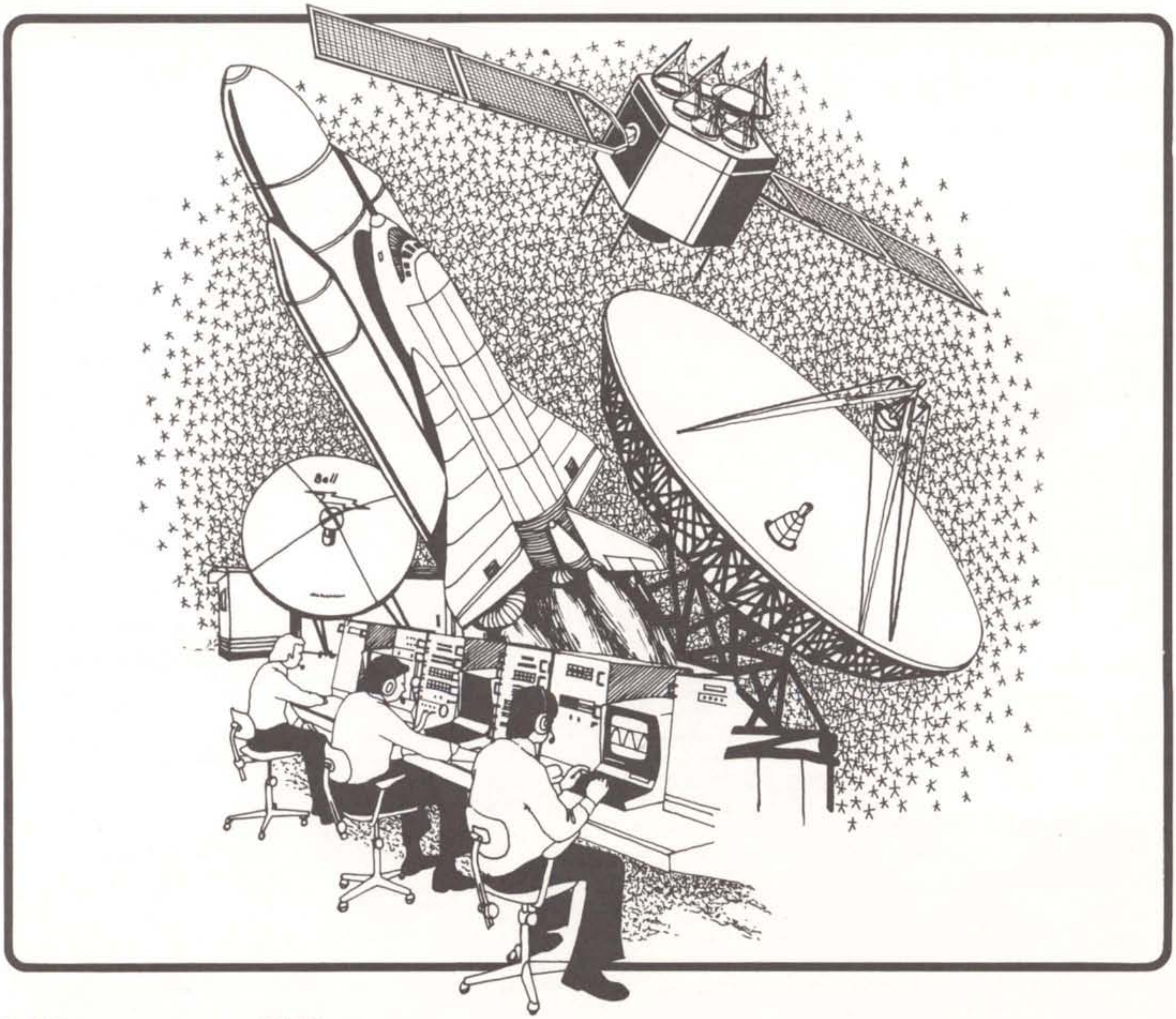
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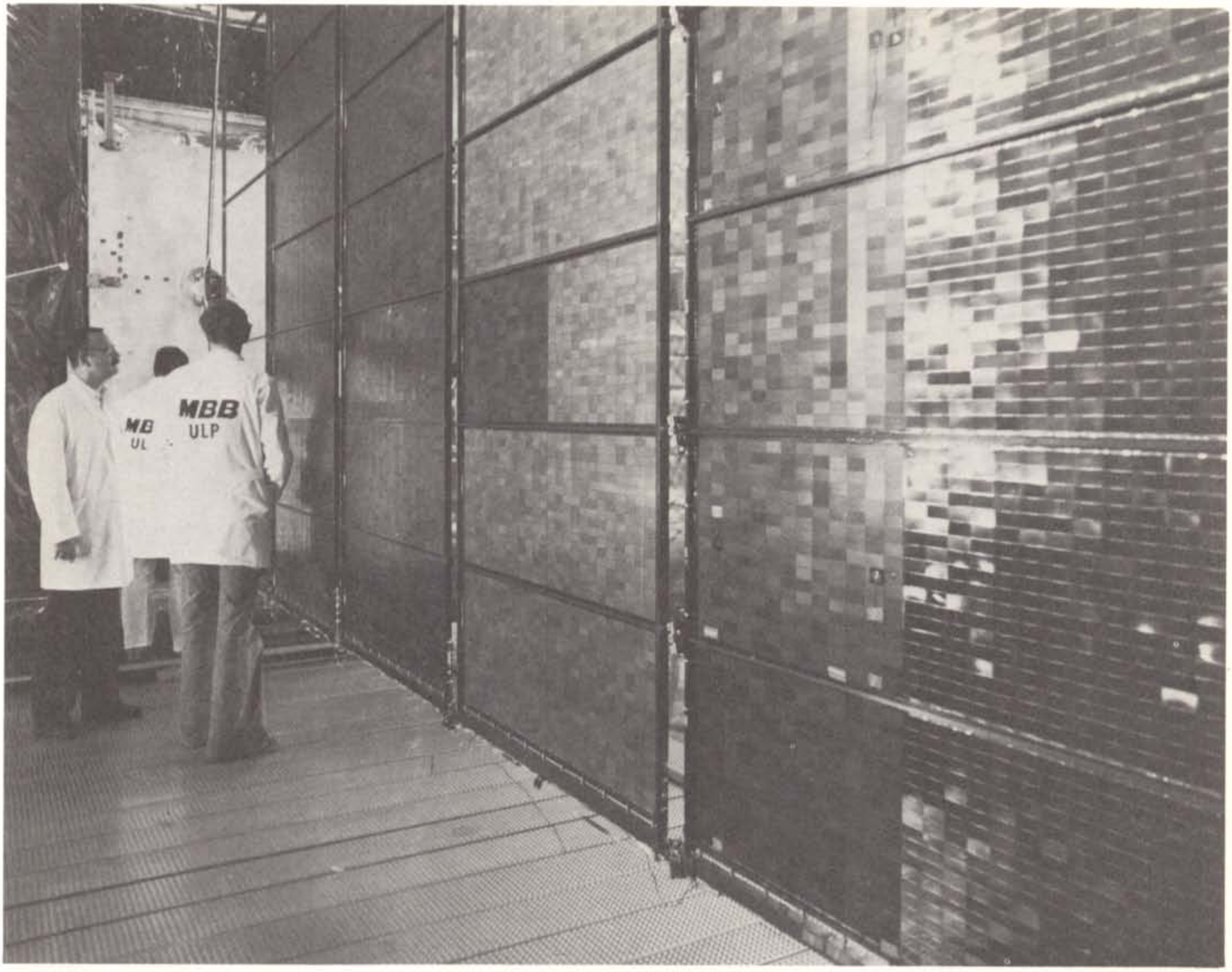
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