# esa bulletin

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1977

EUROPEAN SPACE AGENCY
AGENCE SPATIALE EUROPEENNE

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(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:
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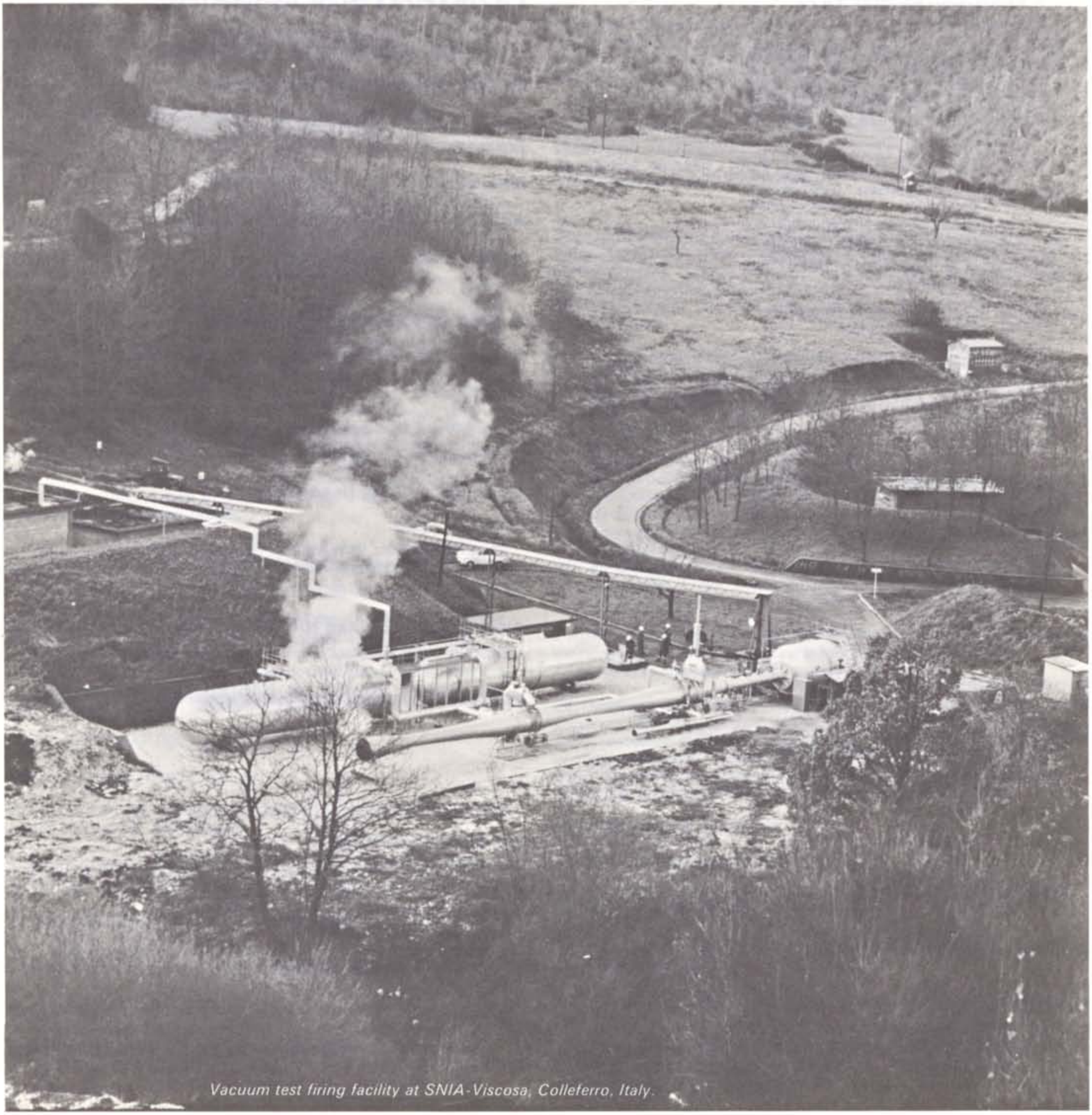
COVER/COUVERTURE:

The cover shows the Agency's Geos satellite, to be launched in April this year, undergoing spin boom-deployment tests in the Large Dynamic Test Chamber at ESTEC.
The next Bulletin (No. 9 May 1977) will include a detailed account of the Geos project and the mission objectives of this, Europe's first geostationary scientific satellite.

*La couverture montre le satellite Geos, dont le lancement est prévu pour le mois d'avril, au cours des essais de déploiement des bras en rotation dans la Grande Chambre d'Essais Dynamiques de l'ESTEC. Le prochain Bulletin (No. 9, Mai 1977) décrira en détail le projet et les missions de ce premier satellite scientifique géostationnaire de l'Europe.*

PHOTOGRAPHS/PHOTOGRAPHIES:
Giancarlo Martelli (page 2); Meudon (pages 25, 26); NASA (page 32); Marc Riboud, Magnum (page 38); SEP (page 40); DFVLR (page 42); ERNO (page 44); Selenia (page 49); SNIAS (page 51); MBB/SNIAS (page 52); Bill Muncke (page 61, 62, 63), and ESTEC Photographic Services.



Vacuum test firing facility at SNIA-Viscosa, Colleferro, Italy.

# A European Apogee Boost Motor for Geos

*J.A. Steinz, Geos Division, ESTEC, Noordwijk, The Netherlands*

**Europe's first solid-propellant apogee boost motor has been formally accepted by the Agency for its geostationary scientific satellite Geos to be launched this April. It forms an integral part of the satellite and will be used to inject it into geostationary orbit from the initial elliptical transfer orbit provided by the Thor-Delta launch vehicle. The motor's design, development and qualification programme has spanned a period of three years and a total of 10 successful ground test firings in air and in vacuum have served to demonstrate its reproducible and reliable performance.**

**Developed, manufactured and tested for ESA by SNIA-Viscosa (Italy) in collaboration with SEP (France), the 306 kg Geos motor produces $2.3 \times 10^4$ Newtons of thrust and accounts for more than half the satellite's total weight.**

As the reference satellite for the International Magnetospheric Study (IMS) Programme, Geos is the first scientific satellite to rely on an apogee motor to achieve geostationary orbit (ESA Bulletin No. 4, February 1976). The seven very sensitive field, wave and particle experiments that it carries place stringent magnetic and chemical cleanliness requirements on all satellite subsystems, including the apogee boost motor.

Geos will be launched by a Thor-Delta 2914 vehicle from Eastern Test Range, Cape Canaveral, Florida. Figure 1 shows the sequence of events following lift-off until the satellite achieves operational status. The apogee motor will inject the satellite from the transfer orbit provided by the launch vehicle, into near-synchronous orbit. It is planned to fire the motor at the fourth apogee of the transfer orbit by controlled time-delay telecommand from the European Space Operations Centre at Darmstadt (Germany).

The apogee motor chosen for Geos is a solid propellant rocket motor developed by SNIA-Viscosa, Colleferro, in collaboration with SEP, Bordeaux. This particular choice

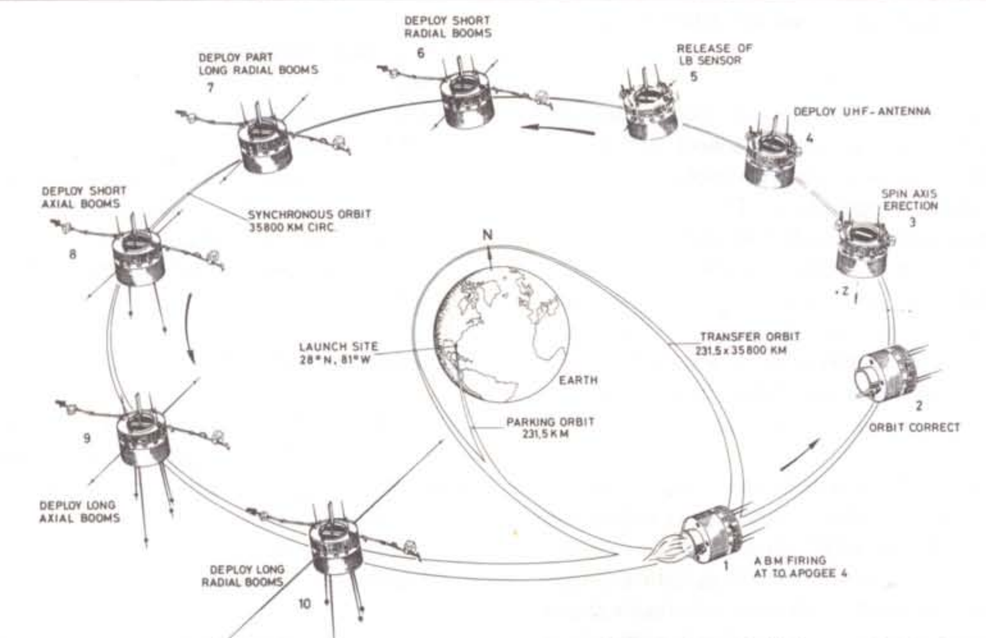



*Figure 1 – Initial events in the Geos mission sequence*

was consistent with ESA policy to buy European but without significantly increasing the risk to an already committed satellite project. A solid-propellant type was chosen for its relative simplicity and inherent high reliability. The motor that has subsequently been developed makes best use of and represents a controlled advance on the well-established technologies of the two supplier companies.

## MOTOR DESIGN

The motor consists of a case, propellant grain, nozzle, igniter/safe-arm device combination, and a number of thermal-control and performance monitoring items (Figure 2). An attach flange is used to mount it to a rigid central thrust bearing cylinder inside the spacecraft. Figure 3 shows a full-scale inert (noncombustible) model of the motor being installed in the flight-model spacecraft.

The *motor case* is made of high-strength titanium alloy (Ti 6Al 4V). The two ellipsoidal domes, the cylindrical section and the spacecraft attach flange are machined down to a thickness of only 1.4 mm from heavy forgings, which are then electron-beam welded. The interior wall of the motor case is lined with thermal insulation to protect it against the hot combustion gases, which attain temperatures of 3100°C.

The *propellant grain* is a mixture of polybutadiene synthetic rubber, ammonium perchlorate and aluminium powder. The propellant is cast into the motor case and then cured at elevated temperature. The grain has a cylindrical central bore and is bonded to the motor-case thermal insulation at all points except along the dome at the igniter end. The resulting free surface relieves the grain of expansion-contraction stresses. It is covered with an inhibitor layer of the same material as the case liner, to ensure that the propellant grain only burns radially outwards.

The *nozzle* is partially recessed into the motor case in order to minimise the overall length. It is mainly made of a highly heat resistant carbon-cloth/phenolic-resin composite material. It also has a high-density graphite throat to preclude excessive erosion, and an aluminium burst disc to seal the motor's interior from the surrounding environment before firing.

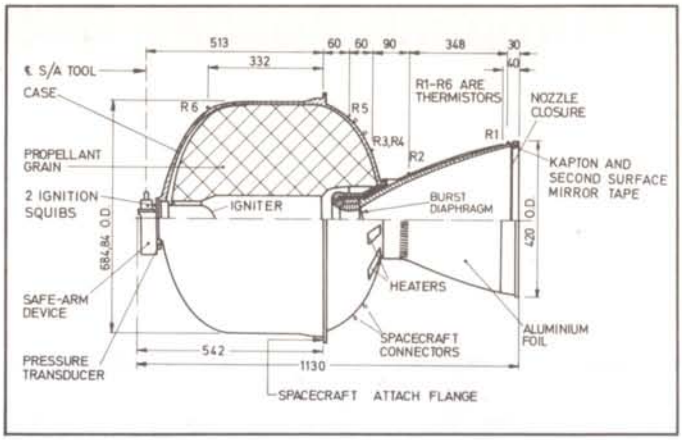



*Figure 2 – Apogee boost motor configuration*

The *igniter and safe-arm device* form an integral unit (Figure 4). The safe-arm device has been introduced for reasons of personnel safety and it ensures that accidental firing of the two pyrotechnic ignition squibs will not start the motor or the igniter. It is armed by a remote-controlled DC electric motor a few minutes before launch. The DC motor itself has been specially developed and is fitted with a compensating magnet to minimise interference with a sensitive magnetometer on board the spacecraft.

The *thermal control items* fitted to the motor include:
- heaters on the dome of the motor case at the nozzle end and a kapton-sheet thermal closure in the nozzle exit plane to reduce heat losses to space
- aluminium foil wrapped around the nozzle and thermal washers between motor and spacecraft attach flanges to reduce heat input to the spacecraft when the motor is fired.

*Performance monitoring items* comprise;
- six thermistors (R1 to R6) to monitor motor temperature before and after firing. Two thermistors (R3 and R4) have a small range ( $-5°$ to $+45°C$) and high accuracy ( $\pm 2°C$) to provide accurate temperature control before the motor is fired
- a pressure transducer to monitor combustion-chamber pressure during firing.

## MOTOR CHARACTERISTICS

The motor must deliver a velocity increment of 1775 m/s, with less than 1% ($3\sigma$) dispersion, to the total satellite mass of 575 kg (including motor mass before firing) in order to put the satellite into its planned near-synchronous orbit. Other important design criteria are summarised in Table 1.

The firing time is of the order of 50s and depends on the pre-fire temperature of the motor. While the motor burns

*Figure 3 – Installation of inert motor model in spacecraft.*

faster when the temperature is higher, the total impulse (or velocity increment) delivered remains constant, as it depends only on the amount of propellant consumed.

The test programme that will be outlined has shown that the SNIA/SEP motor complies with these specifications in every respect. The most important flight motor

TABLE 1

| | | |
|---|---|---|
| Total motor mass | $<307.2$ kg | |
| Temperature before firing | $-10$°to $+40$°C | |
| Spin speed | $90 \pm 10$ rpm | |
| Thrust misalignment | $>0.1$° | |
| Thrust offset | $<1.0$ mm | |
| Thrust | $<2.9 \times 10^4$ N | |
| Spacecraft acceleration | $<10.5$ g | |
| Magnetic moment | $<8.0$ Gauss cm$^3$ | |
| Reliability | $>0.99$ (60% confidence) | |
| Balance | *Static* | *Dynamic* |
| – before firing | $<3.0$ kg cm | $<50$ kg cm$^2$ |
| – after firing | $<2.0$ kg cm | $<60$ kg cm$^2$ |

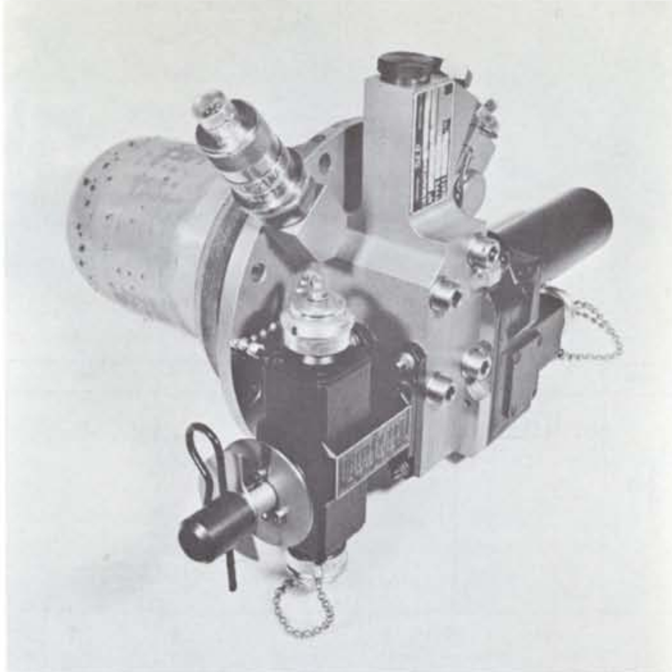


*Figure 4 – Igniter/safe-arm device combination*

performance parameters yielded by the programme are:

| | |
|---|---|
| Propellant specific impulse in vacuum | = 285.8 s |
| Mass ratio (propellant/total mass) | = 0.8808 |
| Total motor mass | = 305.9 kg |

## PROGRAMME ORGANISATION AND SCHEDULE

The motor programme was carried out under the auspices of the European Space Agency by SNIA-Viscosa (prime contractor) and SEP (subcontractor). The breakdown of responsibility for successful conduct of the programme was as follows:

| | |
|---|---|
| SNIA-Viscosa | Day-to-day management of the motor programme, overall design, thermal insulation and propellant manufacturing, motor assembly and testing. |
| SEP | Design, manufacture and testing of component parts, i.e. the igniter, safe-arm device, motor case and nozzle. |
| ESA | Programme supervision and co-ordination of motor/spacecraft interfaces and compatibility tests with the STAR Consortium, responsible for the spacecraft. |

The apogee-boost-motor programme was conducted over a period of three years, starting in May 1973 and ending in July 1976. The overall schedule shown in Figure 5 was separated into six phases, each terminating in a formal ESA review of results achieved and detailed future plans and procedures. The specific aims of each of these reviews were as follows:

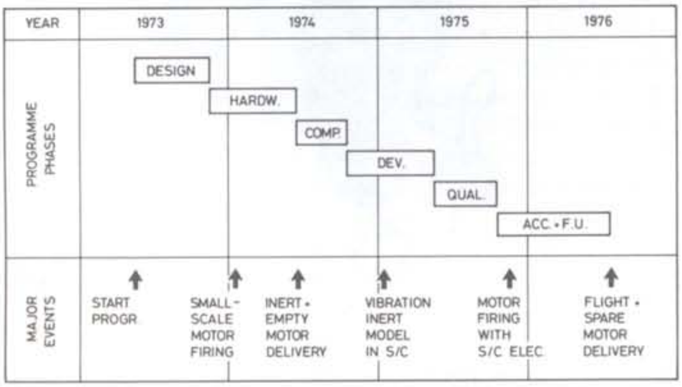



*Figure 5 – Motor programme schedule*

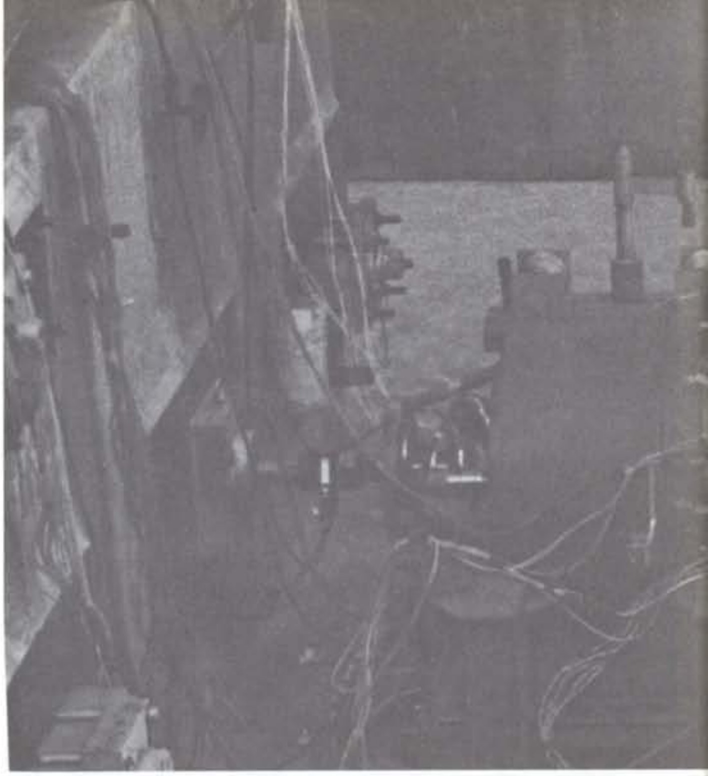


*Figure 6 – Motor firing in air*

- Initial Design Review, to finalise motor design, interfaces with satellite and all fabrication, test and quality control procedures (releases manufacturing lines). November 1973.
- Hardware Design Review, to verify ability to construct full-scale empty motor and its compatibility with the satellite (gives reassurance that the component fabrication already under way is in order). June 1974.
- Component Qualification Review, to evaluate qualification results for all components (releases development test activity). October 1974.
- Development Test Review, to evaluate results of development test firings at atmospheric pressure and in vacuum (releases qualification test activity). May 1975.
- Qualification Test Review, to evaluate results of qualification test firings in vacuum (releases activity for loading of flight motors and acceptance test motors). October 1975.
- Acceptance Test Review, to evaluate results of acceptance test firings (releases flight units for delivery). Programme completed in July 1976 and reviewed in September 1976.

## TEST PROGRAMME

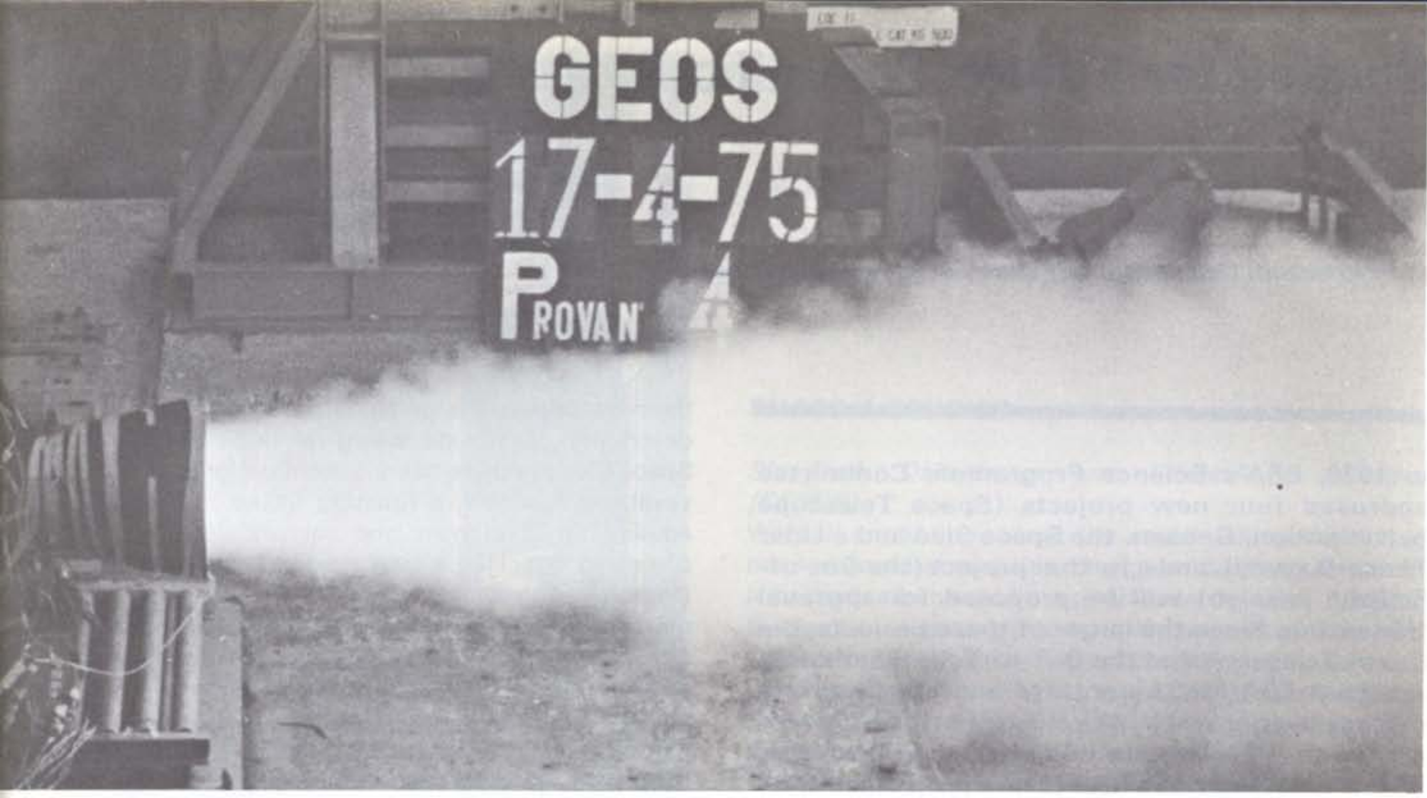
Three main categories of test were carried out during the course of the Geos apogee boost motor programme: motor component tests, full-scale motor tests and compatibility tests with the spacecraft. Two special full-scale motor models, one empty and one filled with an inert (noncombustible) propellant, were built for compatibility testing with the spacecraft.

*Component Tests*

- hydraulic burst testing of three motor cases
- hot firing tests in vacuum with two nozzles
- acoustic test with one nozzle
- depressurisation (venting) tests on nozzle fitted with exit plane closure and wrapped in aluminium foil
- ignition tests on 13 separate igniters
- propellant-grain ignition tests with three simulated full-scale motors
- magnetic tests on a large number of development safe-arm actuator devices.

TABLE 2

| | Development | Qualification | Acceptance |
|---|---|---|---|
| With short nozzle | XXX | | |
| With long nozzle | X | XXXX | XX |
| Environmental tests | XX | XXXX | XX |
| Firing tests | | | |
| At 1 atm | XXX | | |
| In vacuum | X | XXXX | XX |
| Spinning | | XXXX | XX |




*Full-Scale Motor Tests*

A total of 10 full-scale motors were tested in the course of the programme, under the test conditions summarised in Table 2. The environmental tests covered the full set of vibration, acceleration and thermal exposures.

Figure 6 shows a motor being fired in air. All vacuum firing tests were performed in a special facility relying on a large-capacity steam ejector system to maintain vacuum despite the large quantity of exhaust gas produced (about 5 kg/s). This facility is shown in operation on page 2.

*Motor/Spacecraft Compatibility Tests*

A particularly important test carried out early in the programme was a small-scale motor firing in vacuum to measure the spacecraft heating caused by the exhaust gases and motor outgassing. The results confirmed, early in the overall Geos programme, that the motor would not have to be ejected from the spacecraft to avoid experiment measurements being disturbed by contamination effects.

Other compatibility tests carried out during the programme have included:

- vibration tests with the full-scale inert motor in the spacecraft structural model to obtain early data on motor resonances and vibration qualification test levels
- standard compatibility tests during spacecraft system thermal, vibration, electrical and magnetic tests using the inert and empty full-scale motors
- motor and ignition squib initiation tests using an electrical pulse generated by spacecraft on-board electronics.

All such tests have demonstrated satisfactory performance and have shown that the motor is fully compatible with the satellite. The motor has been shown to be a reproducible and reliable propulsion system and its performance complies with its specifications in all respects. Its performance in space remains to be demonstrated soon after Geos's launch in April 1977!

## CONCLUSIONS

The timely and successful completion of the apogee-boost-motor programme within the initial cost-estimate envelope represents a significant advance in European space technology. The experience gained should form an important base for future European projects employing solid-propellant rocket technology, including the ESA-sponsored Common European Apogee Boost Motor (MAGE - Moteur d'Apogée Géostationnaire Européen) project, which has already started and which has more ambitious aims for future European technology. □

# Studies for Future Scientific Projects

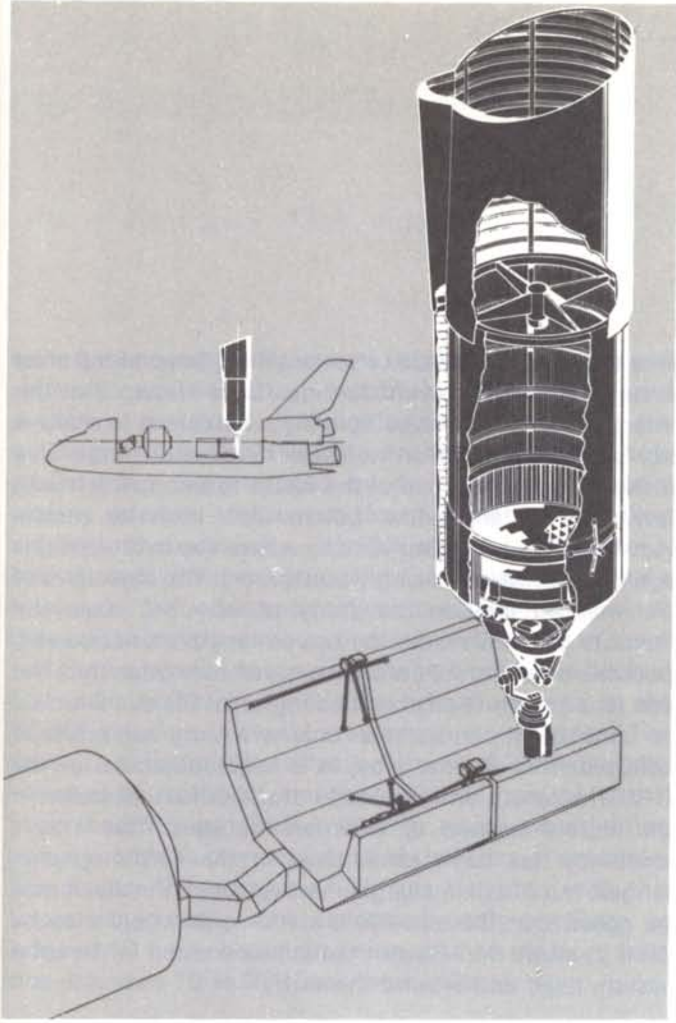
*E. Peytremann, Department of Future Scientific Programmes, ESA, Paris*

**In 1976, ESA's Science Programme Committee approved four new projects (Space Telescope participation, Geosari, the Space Sled and a Lidar Phase-B study), and a further project (the Out-of-Ecliptic mission) will be proposed for approval this spring. Since the larger of these projects, the Space Telescope and the Out-of-Ecliptic mission, are joint ESA/NASA ventures and are therefore subject to approval by the US authorities, there is a need to plan for possible alternative projects. This article describes four future projects, one of which could be selected for a new start early in 1978; these are a Sun-Earth Observatory and Climatology Satellite (SEOCS), a Grazing-Incidence Solar Telescope for Spacelab (GRIST), an Extreme Ultraviolet and X-Ray Survey Satellite (EXUV), and a Space Astrometry mission. In addition, several smaller studies will be conducted to complement past studies and to prepare the ground for later missions.**

The new projects approved in 1976 by the Agency's Science Programme Committee were: a contribution to NASA's Space Telescope, described elsewhere in this Bulletin; Geosari; a Space Sled for vestibular studies, and a Lidar (Phase-B study only). Geosari, which is a mission employing a spare Geos spacecraft, the so-called 'qualification model', will be launched by ESA's Ariane launcher on its second qualification flight. Whereas the scientific payload will be the same as that of Geos, the new spacecraft's orbit will be elliptical and geo-synchronous, so that its period of revolution will be the same as that of the earth and, when viewed from the earth, it will appear to move in 'figures of eight' about one fixed point. Geosari will be launched in December 1979, and since the next Bulletin will be devoted to Geos, on the occasion of its launch in April 1977, nothing further will be said here about Geosari's scientific payload. The Lidar (contraction from LIght and raDAR) is a Spacelab-borne device that will allow the earth's atmosphere to be studied by means of powerful laser beams. A feasibility study (Phase-A) was completed in 1976 and so far the Science Programme Committee has decided to fund only the next detailed design study phase (Phase-B). A brief description of the Lidar was given in Bulletin No. 3. The Space Sled is a piece of equipment designed to study the vestibular function, a function linked to the sense of equilibrium of humans and animals. This Sled, to be carried in Spacelab's long module, will be accelerated (together with its passenger) at well-defined rates. By measuring the effect of these accelerations on the subject (e.g. by observing eye movements), it is hoped to achieve a better understanding of the vestibular function. In this respect, besides increasing our basic knowledge of one particular aspect of physiology, there is a definite attempt to solve the problem of space sickness, which is of course of great relevance for the efficient use of Spacelab and the manned space stations that will succeed it. The Sled will be developed with the view to its inclusion in the First Spacelab Mission in 1980 and several groups of scientists, from both Europe and the United States, have recently been selected to carry out the experiments.

In addition to the above, two further projects have been strongly recommended by ESA's scientific advisers; they are the Out-of-Ecliptic mission and a Large Infrared Telescope for Spacelab. The first of these, planned as a joint ESA/NASA venture, has been described in a previous Bulletin ('Exploratory Journey Out of the Ecliptic Plane' by Edgar Page, Bulletin No. 6). A decision regarding this mission will be sought from the Science Programme Committee this spring. As regards the Large Infrared Telescope, a major problem is the total cost of the programme, which will certainly be high because several Shuttle-Spacelab missions will be required to achieve worthwhile scientific objectives and because the size of LIRTS means that almost the full cost of each mission is borne by it. Nevertheless, it is felt useful to start at least the next stage in the development of this project (Phase-B), during which detailed design studies will be carried out. In preparation for this, it is intended to conduct a few studies on instruments (photometer, spectrometer, etc.) with which LIRTS could be equipped.

After this brief introduction, we should perhaps ask ourselves whether it is worthwhile undertaking these new studies since the above programme, if completely approved, will consume the Scientific Programme's resources for many years to come (until about 1982). The hitch is that both major undertakings, the Space



*The Large Infrared Telescope for Spacelab (LIRTS)*

Telescope and the Out-of-Ecliptic mission, are planned jointly by NASA and ESA (ESA contributes only about 15% to the Space Telescope, whereas for the Out-of-Ecliptic the division of contributions is about fifty-fifty) and no final decisions have yet been taken by the US authorities on either project. Prudence therefore demands that other missions be planned to replace either or both of these co-operative projects.

The remainder of this article will be devoted mainly to the four projects that have been recommended for feasibility studies and cost assessment (Phase-A studies) and which will therefore constitute the next set of candidates for decisions to be taken in 1978. These four new missions have been chosen from eight contenders, and a brief description will also be given of the four missions that were investigated in 1976 but could not be recommended for Phase-A studies at the present time. Some advanced work will, however, be carried out on certain of these, as well as on other missions, in order to prepare the ground for still later missions: an overview of such study work will be given in the closing paragraphs.

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## PHASE-A STUDIES

*Sun-Earth Observatory and Climatology Satellite (SEOCS)*

We still know little about the earth's climate and the mechanisms that cause it to change, and yet we know that it has indeed changed many times in the past. Besides trying to ascertain the natural causes of climatic variations, a better knowledge of the phenomena involved would allow the biological and climatological effects resulting from human activities, such as possible reductions in stratospheric ozone levels, to be assessed. Consequently, it is necessary to achieve a better understanding, on a global scale, of the earth's atmosphere, its surface and its oceans. One important aspect of this search, the primary goal of the SEOCS mission, is to make precise measurements of the earth's radiation budget, or the difference between the incoming solar radiation and the radiation emitted by the earth itself, the latter consisting of solar light reflected by clouds, and the earth's surface, and infrared radiation emitted by the atmosphere and the surface. Although measurements of this kind have already been made, the SEOCS mission is needed to produce high-precision results for the whole globe at various times of day. Another set of observations, aimed at measuring the solar ultraviolet radiation and the chemical properties of the stratosphere, is expected to improve our understanding of the physics and chemistry of this region, and to help us to study its interaction with other layers of the atmosphere and with the earth's surface.

For carrying out the SEOCS mission, three options have so far been identified, one involving a single spacecraft in a high-inclination orbit, and two involving two spacecraft each. In the latter case, various types of orbits are envisaged, mostly with high inclinations. All of these orbits are near-earth (about 800 to 1300 km), and the masses of the spacecraft needed have been estimated to be in the 200–350 kg range (20 to 50 kg of scientific instruments). Hence, the launch requirements of the SEOCS mission are considerably less than Ariane can provide, and it will therefore be necessary to study the possibility of multi-satellite launches, or possibly use of a reduced, two-stage version of Ariane. The SEOCS mission is planned to last three years, but continuous observations over five years, that is during about half a solar cycle, would be preferable.

*Grazing-Incidence Solar Telescope for Spacelab (GRIST)*

Moving away from the earth itself, the sun obviously exerts much influence on our planet and its environment and therefore merits an unravelling of the secrets of even its most detailed behaviour, so that we may learn how it influences terrestrial life. At the same time, and from quite a different perspective, the sun is the closest star, and the only one which can be studied in great detail. It therefore provides a powerful testbed for many astrophysical theories, including such phenomena as nuclear fusion, which is so common in the universe but which has yet to be mastered on earth.

Although the sun has been well studied so far, even from space, the above introduction points towards the need to provide European solar physicists with a facility of their own (so far they have been active from non-European space observatories only). The one to be considered here is a large telescope (4-5 m long, mass about 1500 kg) for Spacelab to operate in the ultraviolet part of the spectrum (100–1700 Å). The characteristics of this telescope and its associated instruments (e.g. spectrographs) will allow high spectral resolution (i.e. the spectral lines can be studied in sufficient detail to infer such physical parameters as the velocity of the gas in the sun's atmosphere), high spatial resolution (i.e. relatively small features can be studied) and high time resolution (the causes of several fast, short-lived or otherwise variable phenomena that occur on the sun's surface are not yet well understood).

The GRIST will need a high-precision pointing system (accurate to about one arc second) and it could ideally operate as part of a cluster of solar telescopes, the others presently being planned by NASA.

*Extreme Ultraviolet and X-Ray Survey Satellite (EXUV)*

Changing our perspective once more from the sun and its planetary system, this mission will allow us to observe relatively near stars and the regions between them, known as the interstellar medium. However, we probably do not see much beyond our own galaxy because the 'landscape' is seen in the light of extreme ultraviolet radiation. Indeed, in the spectral region just below 912 Å, radiation is very much absorbed by the hydrogen gas so abundant in the interstellar medium, so much so that until recently it was thought impossible to see anything beyond the solar system. However, recent findings have shown that the interstellar medium is sufficiently transparent to make a sky-survey mission worthwhile in this spectral range. This is the primary objective of the EXUV mission which will, however, by the same token, also look at shorter wavelengths, including X-rays, where the hydrogen gas again becomes increasingly transparent. The objectives of the mission include the study of very hot stars, the majority of whose radiation has so far gone unobserved, possible detection of coronae around stars other than the sun (the corona is an extended region of the sun which is so faint that it can be seen only when the sun's disc is eclipsed: this, by the way, is a major objective of the GRIST project), and the study of the diffuse emission in the regions around or between the stars. The latter's existence has been established in the EXUV spectral ranges, but it remains largely unexplained. Finally, it may be noted that the satellite's instruments could also be used to study the relevant radiations emitted in the solar system itself and around the earth.

The spacecraft, carrying two telescopes in addition to the usual service equipment, would be fairly small, weighing approximately 150 kg. A 500 km, equatorial orbit would be suitable, and thus only a very small fraction of Ariane's capability would be needed for this mission.

*Space Astrometry*

Again we are looking beyond the solar system with this mission, but instead of using such esoteric instruments as grazing-incidence X-ray and ultraviolet telescopes, we observe the sky in the same light as our, and one might add our ancestors', eyes, since we are dealing here undoubtedly and rather paradoxically with the most ancient discipline of astronomy – careful measurement of the positions of celestial objects. Astrometry involves measuring the positions of stars (planets will not be considered here) with maximum accuracy, to far better than a second of arc – as an illustration, one second of arc can be represented approximately as the apparent size of a coin seen at a distance of 2000 to 4000 km. Sufficiently accurate measurements of position, combined with the motion of the earth around the sun, allow the distances to stars to be determined (parallaxes). Repeated positional measurements over several years allow their velocities (proper motions) to be derived. All these quantities are quite fundamental to astronomy in general: distances and velocities are needed to establish the structure and dynamical properties of the galaxy and, beyond, of the whole universe. Distances are needed to find out how much energy is produced by the numerous celestial objects (stars in various stages of evolution including pulsars and supernovae, galaxies, quasars, etc.). Moreover, a set of precise positional measurements provides a framework (a fundamental reference system) in which to determine time, the movement of the earth's axis in space and the movement of the poles, which brings us back to our earlier and more earthly considerations, and to the SEOCS mission. But then, why astrometry in space? The answer: to eliminate the effects of the earth's atmosphere, which so blurs and deforms the images of stars that use of even modest sized instruments in space would bring about enormous progress, not only in terms of precision, but also in the number of objects detected with this improved accuracy: one expects, broadly speaking, to achieve 10 times better precision, and to measure with this precision 10 to 30 times more objects.

The spacecraft needed for the astrometry mission would be rather small, would weigh about 150 kg, and would carry a comparatively small telescope of about 20 cm diameter. Its orbit would be nearly polar, with an inclination adjusted to provide a complete survey of the sky every six months. A total mission duration of two and a half years is envisaged, for which a 500 km orbit would be suitable. Again, the capabilities of Ariane far exceed the launch requirements, and multi-satellite launches or reduced versions of the launcher must be investigated.

## OTHER STUDIES

As already mentioned, the four new projects were selected from eight candidates, and the four remaining ones and two other areas of study will now be briefly described, not least to illustrate the vitality and imagination of the European scientific community.

*Solar Probe*
In this mission, a spacecraft with proper shielding would be flown towards the sun, after swinging-by Jupiter. It would pass within only a few solar radii of the sun's surface, on a very eccentric orbit. The probe's main scientific objectives would be to study the solar quadrupole moment, parameters related to gravitational theory (general-relativity tests), and various physical properties of the sun's immediate surroundings. This mission was found to be of sufficient interest to warrant some advanced study work in specific areas, such as shielding against solar radiation and radio communications from solar orbit, the sun itself emitting radio waves.

*Dumb-bell*
This mission would consist of two spacecraft linked by a wire or tether and its prime purpose would be to measure the earth's gravitational field, emphasising those aspects that could improve our knowledge of plate tectonics or convective motions in our planet's interior. Another part of the mission would be devoted to magnetospheric and plasma studies, due advantage being taken of the special spacecraft configuration.

The Dumb-bell mission is a good example of how the requirements of purely scientific research have implications for broader applications. In this particular case, as well as in the case of subsatellites tethered to Spacelab (examined in the course of one of the Agency's Phase-A studies last year), the necessary technical competence has to be developed, and this will subsequently be of use for all sorts of applications, such as in the building of large space structures or in servicing or retrieving spacecraft by means of an easily manoeuvrable vehicle tethered to the heavier and less agile Shuttle. At present, a study is being carried out as part of ESA's Applied Research Programme on the technical aspects of deploying tethered spacecraft.

*Transient X-Ray Sources Satellite*
Another X-ray mission studied last year was aimed at detecting, observing and monitoring variable X-ray sources. A coherent package of experiments was planned with a view to observing the whole of the celestial sphere with moderate sensitivity, as well as to studying known or newly discovered variable sources in great detail. Only a small spacecraft would be needed for this mission, its orbit being low enough to remain below the radiation belts.

*IRSAT*
This satellite would carry a telescope cooled to liquid-

helium temperatures. The purpose of the mission would be to measure the spectrum and spatial distribution of the diffuse flux in the far infrared. The flux's properties have important implications for the theories of cosmology.

*Superconducting Magnet Facility*
Advanced work is also being done on a Spacelab facility that would be used to observe cosmic rays. This tool would be rendered particularly powerful by the use of superconducting magnets, which need to be cooled to liquid-helium temperatures (magnetic fields as high as 15 kilogauss are planned).

*Life Sciences*
Finally, we should not forget to mention another study in the life-science field, which concerns incubators to be carried on Spacelab for research into the effects of the space environment (weightlessness and hard radiation) on biological organisms. For conducting these investigations, the living organisms must be maintained in a closely controlled environment in which such physical parameters as temperature, humidity, illumination and atmospheric composition are measured and regulated. Various small facilities, or 'incubators', purpose-designed to carry cells or tissues, plants or low vertebrates (amphibia, fish) are being studied.

With the advent of Spacelab, the life-science disciplines are attracting considerable interest in Europe. With the exception of the Sled already mentioned, mainly small experiments are being planned, with the help of some general equipment developed by NASA (Minilab) or possibly the incubators mentioned above, which are not yet approved equipment. It might, however, be worth noting that, for studies related to human physiology, the main equipment is constituted by the Shuttle and Spacelab themselves, which provide the support systems for the subjects of the experiments.

## CONCLUSION

The obvious conclusion to be drawn is that the vitality and imagination of European scientists are amply demonstrated by the large number and great variety of the future space projects they would like to undertake.

As always, the brake on the progress that the scientific community might otherwise achieve, and on the service that the Agency itself can provide to this community, is imposed by the levels of funding that can be made available. □

# The 2.4 m Space Telescope and ESA Participation in the Programme

*V. Manno, Department of Future Scientific Programmes, ESA, Paris*

**NASA's 2.4 m Space Telescope is the most ambitious space astronomy project presently planned. It will dominate astronomical research for the rest of the century, will open up fields of research at present unattainable, and will contribute to cosmological studies and to our understanding of the geometry of our universe. It is expected that the project will be approved by the United States Congress in Autumn 1977, and that the telescope will be launched into orbit in 1983/4. Over the past two years, ESA and NASA have been discussing the possibility of European participation in the programme. These discussions are presently nearing a successful conclusion and ESA's Science Programme Committee has decided meanwhile to approve the participation of the Agency in such a programme.**

## SCIENTIFIC RATIONALE

The 2.4 m Space Telescope has capabilities that are unique: it will be able to concentrate light from a star in a fraction of a tenth of an arc second, provide near diffraction limited imagery, and observe celestial objects nearly 100 times fainter than those observable from the ground; it will have access to the vacuum ultraviolet region between 1000 and 3000 Å, which is unobservable from the earth, and to the optical and infrared regions. It will also be maintained in orbit for very long periods thanks to the Space Shuttle's revisit and refurbish capabilities, and hence will be available to the international astronomy community for observations of unprecedented sophistication. These will be particularly startling in respect of the evolution of galaxies and of the universe.

The high-resolution capability, pointing stability and long lifetime (15 years or more) of the Space Telescope will permit a great improvement in the direct measurement of basic astrometric data for celestial objects. In addition, the faint limiting magnitudes achievable will extend over larger distances the range over which present standard candles can be used. The combination of these two characteristics will permit a decisive advance in the determination of distance to other galaxies, a measurement which is fundamental to the study of the evolution of the galaxies and of the age of the universe.

The ten-fold increase in spatial resolution of the Space Telescope, coupled with spectroscopic capability, will allow study of star formation and stellar and chemical evolution in nearby galaxies.

Star formation can be studied with the greatest resolution in our own galaxy, and it may even be possible to detect large planets orbiting the nearest stars. The Space Telescope will probe objects at the end point of their evolution and possibly identify dark companions in binary systems and optical counterparts of pulsars.

The telescope's very high resolution, coupled with the limiting magnitude achievable, will be essential to the detailed morphological studies of distant galaxies and of their nuclei. Recently, there has been an enormous increase in interest in the problem of the violent phenomena taking place in the nuclei of some galaxies. Time-variation measurements indicate that some nuclei have structures of only a few parsecs. With a resolution better than 0.1″, these structures could be investigated up to distances of 10 Mpc, the distance of the Virgo Cluster. Quasars and the phenomena taking place within them, and their relation to galaxies, will be a subject of particular relevance to the Space Telescope because of the achievable faint limiting magnitude and space resolution.

Finally, the extension of the absolute distance scale 10 times farther out than is presently possible will allow the Space Telescope to be used to attack the classical cosmological problem of defining and tracking back in time the expansion of the universe, and to throw new light on its ultimate fate – expansion forever or eventual collapse into another primordial fireball followed by rebirth and eternal recycling?

## SCIENTIFIC PAYLOAD AND MISSION

The Space Telescope observatory consists of a 2.4 m Ritchey-Chrétien telescope designed to operate near its diffraction limit. The system focal ratio is f/24. The

*The NASA 2.4 m Space Telescope, to be put into orbit in 1983/4*

complement of focal-plane instruments is located aft of the primary mirror and modularised for ease of in-orbit replacement.

The scientific instruments currently being considered for the initial flight of the Space Telescope are:

- a *Focal Plane Camera*, imaging a 3 arc min square portion of the f/24 plane on a $50 \times 50\,mm^2$ SEC Vidicon tube operating in the 1200 to 6000 Å region. This camera is designed to reach a magnitude 26 star in one orbital night, i.e. half an hour, and will also be operated in conjunction with other instruments in 'serendipity mode'. This mode should produce a number of high-resolution images that may reveal very distant clusters of galaxies and new ultraviolet objects

- a *Faint Object Spectrograph* (FOS), for spectrographic studies with resolving powers of $10^2$ to $10^3$. When coupled to a photon counting detector, it will be capable of reaching down to magnitude 25 in 10 hours of exposure

- a *Faint Object Camera* (FOC), a high-resolution camera operating at about f/96 and imaging a field about 11 arc sec square on an Imaging Photon Counting System (IPCS). The camera has a spatial resolution of only 0.22 arc sec and hence utilises the full spatial resolution of the telescope. In addition, the use of a photon counting detector allows the stacking of repeated observations of a celestial object and reaches down to the faintest limiting magnitude of the Space Telescope, i.e. a magnitude 28 star, in 10 hours of observation

- an *Infrared Photometer*, covering the spectrum between 1 and 1000 $\mu$m. The detectors will be cooled to liquid-helium temperatures by a dewar designed to last one year in orbit.

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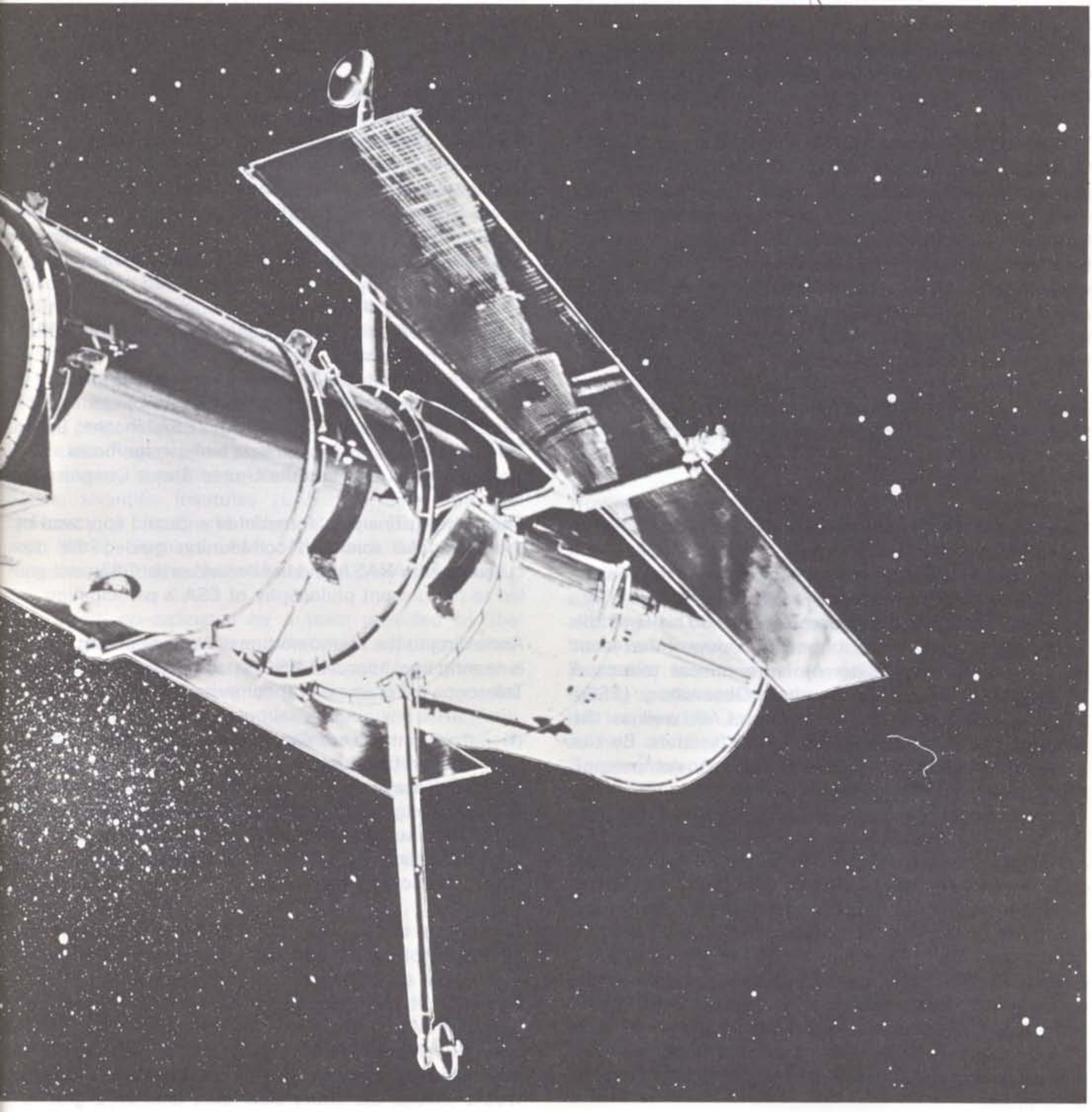


In addition, relative astrometric observations of stars can be performed using the fine guidance system of the spacecraft. This system will give a pointing accuracy of about 0.03" and a pointing stability of 0.007 arc sec (rms).

The Space Telescope will be launched by the Space Shuttle into a nominally circular orbit of 28.8° inclination and with an altitude of 520 km, in late 1983. The telescope is a long-term enterprise, with an operational lifetime of at least 15 years, an unusual feature that can only be realised by development of the Shuttle and of its reflight capabilities. It is foreseen that the telescope will in fact be refurbished in orbit via the Shuttle every 2.5 years and that it will be brought back to earth for major refurbishment at five-year intervals.

The Space Telescope Project will come before the United States Congress for approval as a NASA 'New Start' in fiscal year 1978.

## ESA PARTICIPATION IN THE PROGRAMME

Clearly, there is not an astronomer who would not wish to avail himself of the possibility of using such a 'far-reaching' facility as the Space Telescope. This is all the more true for European astronomers, in view of the recent (or imminent) completion of large optical telescope projects by the European Southern Observatory (ESO) and by individual European countries, as well as the setting up of new European infrared facilities. By the 1980's, there will be a high level of European competence and interest in fields where the new telescope offers unique opportunities.

Although it can be argued that European astronomers could have had access to the data from the Space Telescope via the guest observing programme, there were a number of reasons for ESA securing a well-defined fraction of the observing time for the European community. Not least, this should stimulate orderly and co-ordinated development of the European astronomy effort, leading ultimately to well-planned and optimal use of the telescope by Europe, as distinct from the more fragmented opportunities offered by the guest observing programme.

It was thus that the Agency under took to open discussions with NASA concerning direct participation in the Space Telescope programme.

The question then was what form such participation should take. There was a consensus within ESA, following discussions with its advisory bodies – the Astronomy Working Group and the Science Advisory Committee (formerly the Launching Programmes Advisory Committee) – that European astronomers should be directly involved in the production of the tools by which the science of the Space Telescope would be achieved, and they should also be afforded the possibility of participating directly in the running of the scientific operations of the telescope and in the planning of its scientific programme. Last but not least, the amount of observing time allocated to Europe should be sufficient to meet the requirements of European astronomers, and the related level of participation by ESA in the Space Telescope Programme such as to make it significant in the eyes of both NASA and the United States Congress.

These three principles, formulated with and approved by the European scientific community, guided the discussions with NASA and the American astronomers, and led to the present philosophy of ESA's participation.

According to the Memorandum of Understanding, which is nearing final approval, ESA's participation in the Space Telescope programme will comprise:

(i) the Faint Object Camera and associated Imaging Photon Counting System
(ii) the Solar Arrays and deployment mechanisms
(iii) support of the activities of the Scientific Centre which will be established to guide and perform the scientific programme of the Space Telescope in its operational phase.

In return for this participation, ESA would be guaranteed 15% of the observing time of the Space Telescope during 10 years of space operations. This figure does not seem very large at first sight, and in the context of the overall project the Agency's role would still be a relatively minor one. But even 15% of the observing time would be invaluable to Europe: in terms of hours per year, this share would exceed the entire clear dark time on a ground-based telescope, and it would give European astronomers the chance to share in the order-of-magnitude improvement offered by the Space Telescope.

The terms of the Memorandum of Understanding and the participation of ESA in the Space Telescope project have been repeatedly discussed and verified with the scientific advisory groups of the Agency and with the Science Programme Committee. These bodies have recently unanimously approved the inclusion of this programme in the scientific activities of the Agency, this being the first commitment in the world to the Space Telescope project.

## ESA'S ACTIVITIES AND THE TASKS AHEAD

To achieve improved definition of the elements to be contributed by ESA, as well as to attain the same degree of project preparedness as NASA, a number of studies have been carried out over the past two years, with the help of some twenty scientific consultants from ESA Member States, scientific institutes (LAS, Marseille, and the University of Liège) and industrial firms (Dornier, AEG and MBB, Germany; EMI, NIC and BAC, United Kingdom; TPD, The Netherlands; and SNIAS, France).

This effort, co-ordinated by a team provided by the Agency, has led to an advanced state of definition for all elements to be contributed and a confidence that the effort and commitment required of ESA can be forthcoming. The effort in industry continues, particularly as regards the production of some of the most critical components of the Imaging Photon Counting System, and detailed design (Phase B) studies are soon to be initiated with the aim of completely aligning ESA's schedule with that of NASA at the beginning of the development phase late in 1977, after congressional approval.

With the approval by the Science Programme Committee of such participation, and once the final points still under discussion on the Memorandum of Understanding have been mutually agreed, the first cycle of activity on the Space Telescope project will have been completed.

Besides the technical realisation of technologically advanced hardware, it is ESA's present concern to promote increased direct involvement of the European astronomy community in all future phases of the Space Telescope project. It is of paramount importance that astronomers should be closely associated with the design, development and testing of the Faint Object Camera and Imaging Photon Counting System from the earliest stage. This is typically one of the Agency's responsibilities, and it is in this connection that an ESA Instrument Science Team, to advise the Agency on the Faint Object Camera project, is being set up, following the widest solicitation and consultation within the European astronomy community.

However, of even greater importance ultimately is preparation of the European astronomy community for the utilisation of this exceptional facility and definition of the ways and means by which European astronomers will participate in the scientific operations and the method of allotting the observing time allocated to ESA. Progress here will require in-depth discussions within the European astronomy community and ultimately the setting up of proper schemes and a suitable framework. In this respect, ESA has taken the initiative by setting up an ad hoc advisory group, the Space Telescope Working Group, made up of qualified and experienced European astronomers. With the backing of this group and its Instrument Science Team, the Agency is now well placed to resolve the difficulties of the challenging project that lies ahead. □

# Infrared Astronomy – Why and How?

*J.E. Beckman, Space Science Department, ESTEC, Noordwijk, The Netherlands*

**What precisely is meant when we talk about infrared radiation? In contrast to visible light, the infrared covers three decades of the electromagnetic spectrum, between 1 μm and 1000 μm in wavelength. The 1 - 30 μm band is generally termed the near and middle infrared, 30 - 300 μm the far infrared, and 300 - 1000 μm the submillimetre region. Within this large range of the spectrum lies key information about various types of astronomical objects. For example, an object at 3000 K emits with maximum intensity around 1 μm wavelength and so the near-infrared region is used in observing late-type stars which have surface temperatures in this range. Similarly, the middle-infrared region is used for observation of dusty circumstellar shells and clouds of ionized hydrogen and dust around early-type stars, since these objects are typically at a temperature of a few hundred degrees kelvin and have their peak emission at about 10 μm. The huge molecular clouds, the cooler dusty ionized regions, and other proto-star bearing clouds of matter, all of which have emission temperatures of a few tens of degrees kelvin, are observed in the far infrared (a 30 K blackbody peaks near 100 μm). Coolest of all, the cosmic background radiation which appears to fill the whole of space, and is thought to be a remnant of the 'big bang' origin of the universe, shows a blackbody spectrum at 3 K, peaking close to 1000 μm (1 mm) wavelength. In addition, radiation from highly energetic active galaxies, such as Seyfert galaxies and quasars, peaks in the far infrared, and emission from normal galaxies at great distances is Doppler shifted into the infrared as a consequence of their relative velocity in the expansion of the universe.**

With so much information to be obtained, the question arises, why has infrared astronomy tended in the past to lag behind some other disciplines, notably UV and X-ray astronomy, in making use of rockets and satellites as observing platforms? There are two reasons. In the first place, while UV and X-ray observers had little choice but to place their telescopes above the atmosphere due to its absorption of incoming radiation in these ranges, in the IR there are a few poor atmospheric 'windows' through which at least some work can be done from high ground-based observatories. More recently this has been augmented by aircraft and balloon observing, examples of such systems being shown in Figures 1 and 2. Infrared astronomers have always been told 'at least *you* can work from the ground'. This is totally untrue in the far infrared, where absorption and re-emission by the rotational band of water vapour make observations impossible. Even in the near and middle IR, the atmospheric transmission at ground level, as illustrated in Figure 3, presents a formidable handicap and one which is becoming increasingly unacceptable as the sensitivity of IR observations is increased.

Another reason for slow progress in spaceborne IR has been cryogenic technology. Infrared detectors must respond to photons of low energy (i.e. 1 eV to $10^{-3}$ eV), and hence must be kept cold in order to reduce the thermal background noise. Typically, an astronomical object will be detected at a flux of only $10^{-14}$ to $10^{-15}$ W at the output of a telescope. Modern broadband IR systems therefore use liquid helium to cool the detectors to temperatures below 4 K and, although laboratory dewars for liquid helium are commonplace, a space qualified dewar of reasonable mass which is able to hold helium for periods of weeks or months is an expensive item and difficult to develop. The alternative scheme of using a closed-cycle helium refrigerator is not presently practicable on grounds of low thermodynamic efficiency and reliability. There is, in addition, the problem of controlling a boiling liquid under zero gravity so that the gas phase does not quickly blow the liquid away at the vent. Solutions to all of these technical problems are now well understood. Development of space dewars is under way in the United States and has started within ESA, while the Russians have already placed a simple helium cryostat in orbit. We seem to be on the verge of a new era in IR astronomy.

What are the likely patterns of observation for IR astronomy from space? First a comprehensive survey satellite is essential. The near- and middle-infrared sky has been partially surveyed by rocket, but in the far IR only a couple of hundred sources have been observed. These are

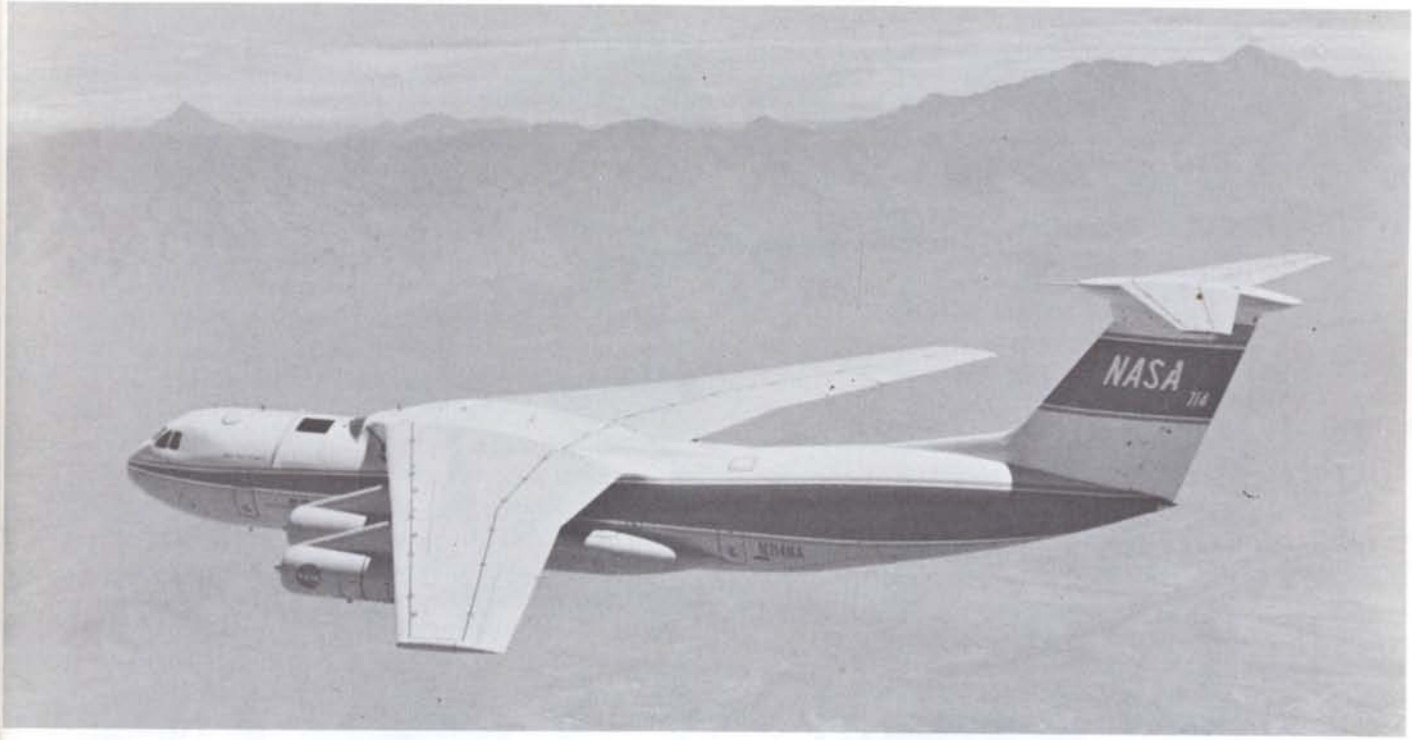



*Figure 1 — The NASA IR Airborne Observatory. A 91 cm diameter IR telescope and star tracker are accommodated in a sealed section of the fuselage of the C141 jet aircraft. Observations are made by astronomers on board (Fig. 4) from altitudes above 12 km to reduce atmospheric interference.*

virtually all galactic, and all are known radio sources. Such detections, and some maps with angular resolution in the 1 arc minute range, are being made currently and very slowly using aircraft and balloon-borne systems. A multiband photometric survey satellite needs to scan the sky at a sensitivity at least an order of magnitude better than is currently used in balloon observations, i.e. around $10^{-26}$ $Wm^{-2}Hz^{-1}$ at 100 $\mu$m. Such a performance implies all liquid-helium-cooled optics in order to remove the background thermal flux. This is totally impracticable using telescopes working within the atmosphere. A satellite of the type described would observe, on an arc minute scale, a large fraction of the highly ionized regions (H II regions) where a highly luminous new O or B star is heating up the surrounding interstellar medium, ionizing it and causing the associated dust shell to re-radiate in the infrared. It would also detect the much cooler, large molecular clouds, where new stars are beginning to form. A comprehensive IR map of the galactic plane would result. The galactic centre itself was first observed in the near IR at 5 $\mu$m. Observations by this type of satellite would provide new insight into macroscopic galactic structure, as well as detecting many individual sources. In addition, hundreds of new infrared galaxies, mainly quasars and Seyfert galaxies, can be surely predicted as observable targets. These galaxies together emit almost 50% of the total radiation from galaxies of all types, even though they constitute only 1% of the galaxy population. The role of active galaxies in a possible chain process of galactic evolution is a vital problem in cosmology, for which IR information is badly needed. A good candidate for carrying out this survey is IRAS, the proposed NASA-Dutch-UK satellite. This has a completely helium cooled telescope and detector system and is being considered for

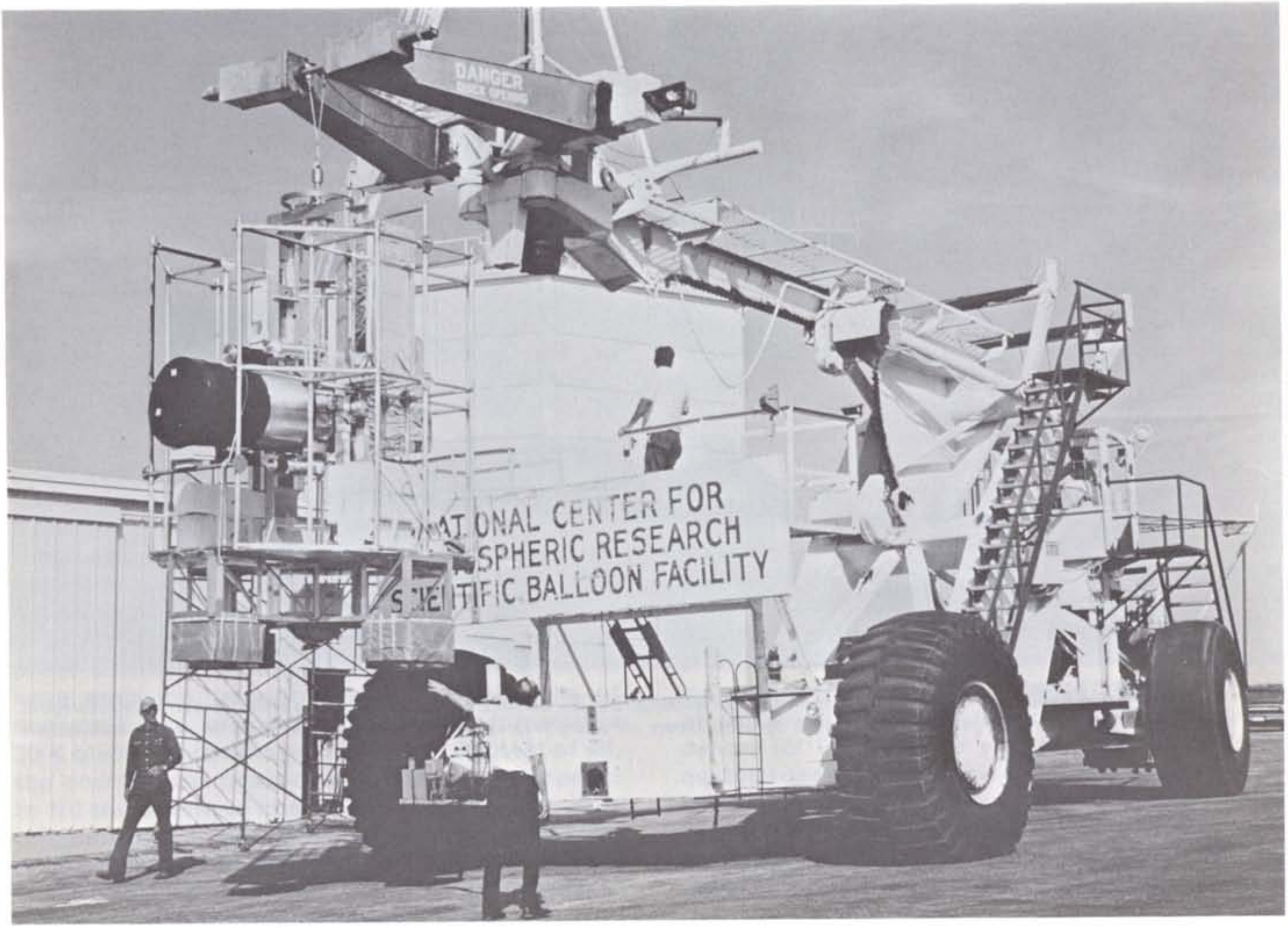



*Figure 2 – University College London's 60 cm diameter IR telescope gondola prior to launch.*

launch around 1981. If for some reason this project does not proceed, some perhaps more modest equivalent with bands in the near to far IR would certainly be needed in the early 1980's.

Extending from the survey work, there are clearly three routes the IR astronomy observations can then take. One rather specialised possibility is to carry out studies of the cosmic background radiation. This radiative remnant of the 'big bang' is our most direct clue to the origin of the universe that we can actually observe. To distinguish between theoretical models for the big bang origin itself, to acquire information on pre-galactic clouds and thereby on the process of galaxy formation, and to test Mach's principle against the most distant frame of reference observable, we need an accurate spectrum of the submillimetre portion of the background radiation, as well as a precise measure of its variation with direction. The feasibility of such a mission (Irsat) has already been studied by ESA. At present NASA has an Explorer mission study team working on a similar but more extensive proposal. The Irsat study showed, however, that this science can be performed from quite a small 'free-flyer', and a Shuttle-launched 'piggy back' experiment would be a very suitable means of conducting this fundamentally important piece of work.

Secondly, after a source survey, would come detailed investigations of the physics of the interstellar medium and of external galaxies, for which relatively high angular and spectral resolutions are needed. Whereas the survey and the background experiment both look at continuum radiation at a spectral resolution $\lambda/\Delta\lambda \simeq 10$, a resolution of $\geqslant 10^4$ is required if we want to tackle other problems such as determining electron densities, velocity distributions, and element and isotope abundances by the measurement of line radiation from ions, atoms and molecules. In the near, middle and far IR, the lines that would be observed are mainly due to forbidden ionic fine structure transitions of relatively abundant species such as $S^{++}$ (S III), $Ne^{+}$ (Ne II) and $O^{++}$ (O III). In the submillimetre range, rotational transitions of light molecules such as CO, HCN, DCN, CaH, SiO and HDS, which occur in cool clouds, supply the diagnostic information.

Some initial progress has been made in ionic line detections. A recent example is the ESTEC–Meudon Observatory – CNRS (LPSP) high-resolution Michelson interferometer experiment, using the 91 cm telescope aboard NASA's G.P. Kuiper flying IR observatory. The photograph in Figure 4 was taken during the course of observations with this instrument. An S III line at 18.7 $\mu$m and an O III line at 88.35 $\mu$m wavelength were detected in the Orion nebula for the first time. This system has also provided the best resolved terrestrial stratospheric spectra in the 18 and 88 $\mu$m ranges, setting new standards of wavelength precision for many molecular isotopic emission lines and, incidentally, showing that the atmosphere is still a strong and variable blocking agent, even at aircraft altitudes. What will be needed, however, in order to fully exploit this developing field of IR spectroscopy is a large telescope of the type shown in Figure 5. This LIRTS instrument, of about 3 m diameter, has been studied in detail by ESA for use on Spacelab. A telescope of this sort will permit observations of the many predicted ionic lines in the IR spectrum of H II regions. At the same time, LIRTS would allow us to map IR sources

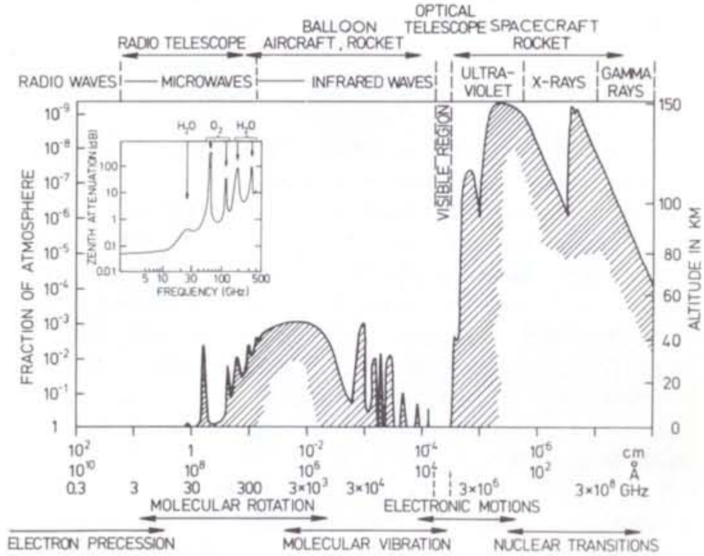



*Figure 3 – Attenuation of electromagnetic radiation in the earth's atmosphere for the different wavelength ranges. The solid curve indicates the altitude at which the intensity of incoming radiation is reduced by 50%, illustrating the importance of going to space observation platforms for IR astronomy.*

*Figure 4 – Science and sandwiches 12 km up! Star acquisition and spectroscopy by the ESTEC-Meudon-LPSP team on board the NASA IR Airborne Observatory. Typically about nine NASA personnel and five scientists are involved on an eight-hour astronomy flight.*

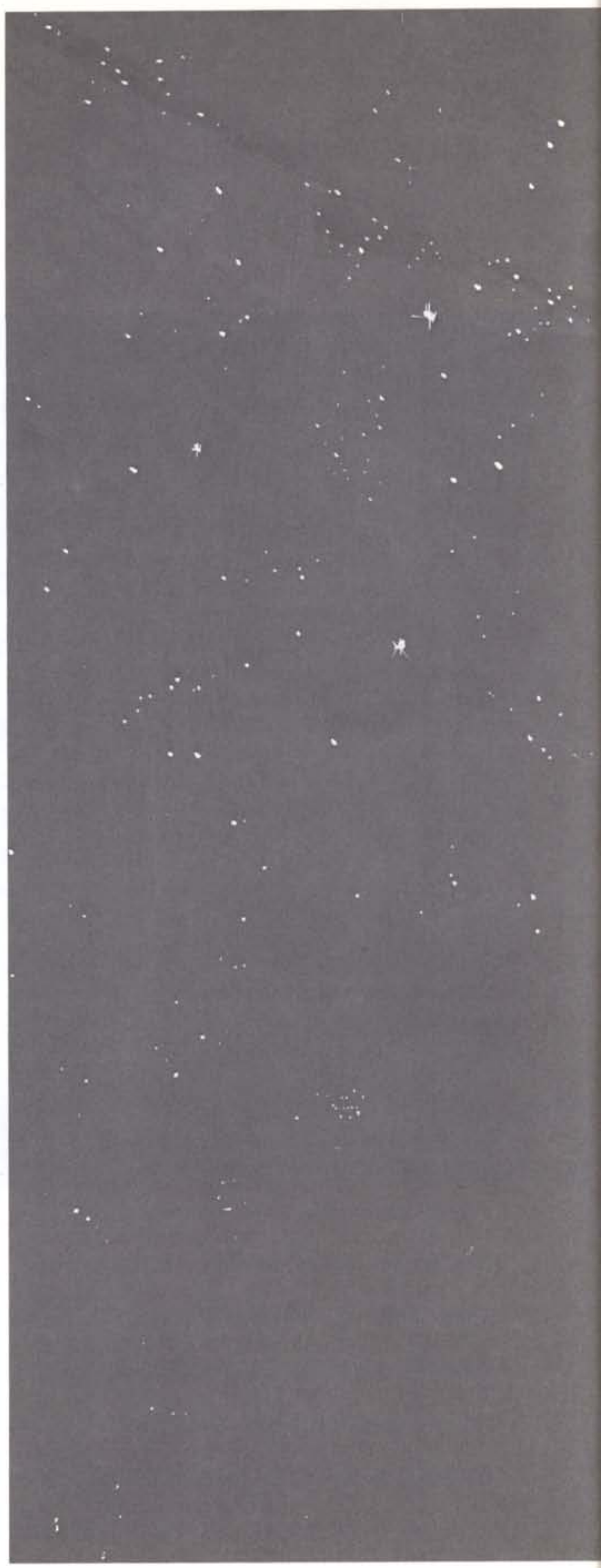
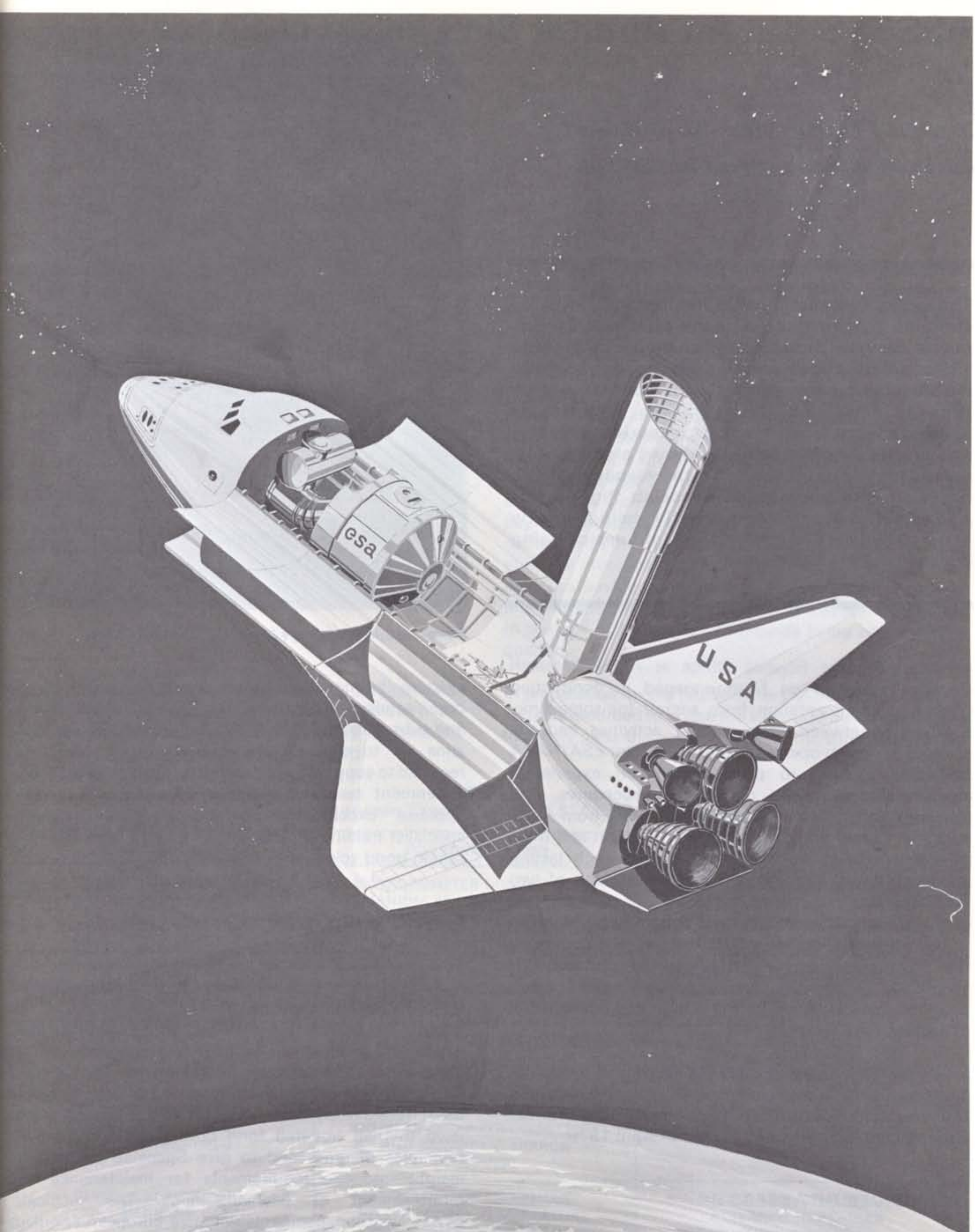


*Figure 5 – Artist's impression of ESA's proposed Large Infrared Telescope for Spacelab (LIRTS), in operational mode aboard the Shuttle.*

with the same angular resolution of a few arc seconds, as is now available to radio observers on the ground. For example, to understand star formation we need to know whether the same clouds and globules of interstellar matter are the same emitters in the optical, radio, and IR, or whether different portions of a cloud complex emit differently in the different wavelength regions. Only a large-diameter telescope in space can tackle this problem. An instrument of this type for the IR needs less optical quality but better thermal engineering than a UV/optical space telescope.

In the long term, the highest spectral and angular resolution in the IR will develop using heterodyne techniques, as is the case in radio astronomy. In the radio regime these methods are far advanced, but in the IR the technique is still in its infancy. Once developed, however, it will have a revolutionary impact. Technical developments such as solid-state oscillators and carcinotron high-powered valves in the 1000 $\mu$m and submillimetre ranges, the use of Schottky barrier mixers, and even Josephson junctions, will eventually make the IR akin to a branch of radio astronomy from the viewpoint of techniques. Already, the use of heterodyne techniques at wavelengths longer than 1000 $\mu$m has enabled emission from the CO molecules in cool clouds to be used to infer the distribution of nearby molecular $H_2$, which forms at least 10% of the mass of the galaxy. The possibility of using submillimetre lines to look at the sites of star formation, and the freedom from atmospheric emission lines to look at CO, $H_2O$ and OH in other galaxies, are just two of a wide variety of important observations that would accrue from the use of such space instruments in conjunction with the LIRTS.

Infrared astronomy is standing at the threshold of its own epoch of space observations. As I have tried to convey, IR work is concerned typically with birth: the birth of stars, of galaxies, and of the universe itself. Astronomers in this fascinating discipline look forward with keen anticipation to enhancing human understanding of some of the basic phenomena underlying our world and its origins. □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# ASSESS II – An Aircraft Simulation of Spacelab

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**The highly successful ASSESS I mission (ASSESS standing for Airborne Science Spacelab Experiments System Simulation), carried out in June 1975, provided such valuable results that ESA and NASA have agreed to carry out another similar mission, ASSESS II. Although the intention is again to simulate Spacelab experiment operations, the overall objective shows a slight shift away from design aspects to the managerial and organisational aspects of Spacelab flights. The ASSESS II mission is currently being jointly planned by ESA and NASA, the flight period being set for mid-May 1977.**


*Figure 1 – Living quarters for ASSESS II payload crew.*

NASA's Airborne Science Office at Ames Research Center, California has been engaged in conducting scientific experimentation from aircraft for some time. Similarities between these aircraft activities and the planned Spacelab operations led to the joint ESA/NASA ASSESS I mission to provide data on experiment equipment design and operational procedures. The Convair CV-990 flying laboratory operating from Ames Research Center and carrying three European and three American experiments made five flights, each lasting about six hours. The payload crew, consisting of two Europeans and two Americans, was confined to the area of the aircraft. This mission was fully reported in ESA Bulletin No. 4 in February 1976. In essence, it confirmed that low-cost experimentation can be performed if simplified management procedures are used, and it provided many pointers for the design and operation of experiment equipment.

In view of the interesting data obtained from the mission, and the recent advancement of Spacelab design and planning for its use, ASSESS II was conceived as a further joint mission, and planning started in April 1976.

## OBJECTIVES OF ASSESS II

The overall objective of the ASSESS II mission is to exercise the management and integration schemes and organisations proposed for the First Spacelab Payload and subsequent joint Spacelab flights. Equally important aims are to evaluate the ground-support equipment required to support Spacelab and its payloads, to develop experiment test and interface specifications, and to appraise experimenter participation and payload-specialist training. A final and important objective is to obtain good scientific results.

## ASSESS II PAYLOAD

To ensure that the last of the above objectives would be met, European experiments were selected from replies to an ESA announcement of flight opportunity. An important selection criterion used was the relevance of an experiment to Spacelab flights in terms of hardware and integration and operations requirements. The selected European experiments are summarised in Table 1; two of them have already been flown on ASSESS I and will be used in their updated form both to demonstrate the principles of reuse and to give Spacelab planners an insight into the requirements for maintenance and refurbishment of payload items. The medical/psychological experiments will give European scientists an excellent opportunity to evaluate the performance and

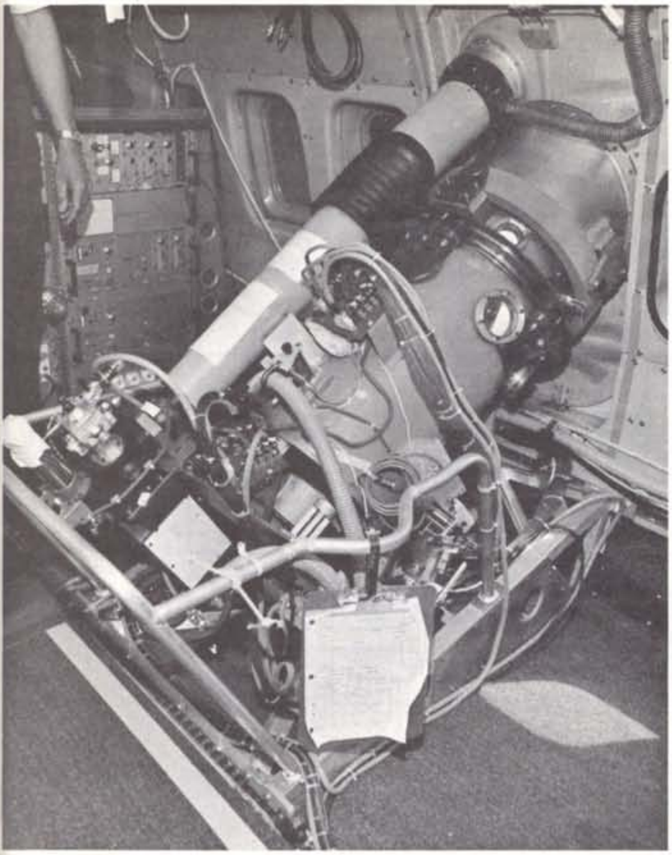


*Figure 2 – Meudon IR telescope attached to open port of aircraft.*

behaviour of scientists and engineers acting as payload specialists. With one exception (the isotropometer), all the experiments are regarded as preparatory versions of actual experiments to be flown on Spacelab.

The European experiments will be supplemented by four US experiments, so that an equitable ESA/NASA payload balance is maintained.

## ASSESS II MISSION

As in the case of ASSESS I, the flights comprising the ASSESS II mission will be made from Ames in California using a CV-990 aircraft. Starting on 15 May, some seven flights of six hours' duration are envisaged over a period of 10 days. During this time the mission specialist and payload specialists will be constrained so that their only contact with the outside world, and in particular with the principal investigators, will be via a television and voice link. The payload crew will spend their on-the-ground time in a special camper-van (Fig. 1) that can be brought to the rear of the aircraft to provide living and sleeping quarters.

In preparation for the mission, the CV-990 aircraft will be suitably modified to house the experiment equipment and to satisfy particular requirements of the sort illustrated by

TABLE 1
*European Experiments for ASSESS II*

| ORGANISATION | INSTRUMENTATION | MEASUREMENT |
|---|---|---|
| CAPODIMONTE ASTRONOMICAL OBSERVATORY, NAPLES | ISOTROPOMETER CONSISTING OF GERMANIUM BOLOMETER, MICHELSON INTERFEROMETER AND 45° SWITCH WITH TWO COLLECTING HORNS | TEMPERATURE OF THE UPPER SOLAR ATMOSPHERE IN THE FAR IR |
| OBSERVATORY OF MEUDON; UNIVERSITY OF GRONINGEN; MAX-PLANCK-INSTITUTE, GARCHING | 30 CM CASSEGRAIN TELESCOPE* WITH IR PHOTOMETER; COOLED GERMANIUM BOLOMETER | INFRARED OBSERVATIONS OF GALACTIC COLD CLOUDS AND H II REGIONS |
| UNIVERSITY OF SOUTHAMPTON | IMAGING ISOCON TV SYSTEM* | STUDY OF GRAVITY WAVES FROM TV OBSERVATIONS OF HYDROXYL AIRGLOW |
| DFVLR-INSTITUTE FOR ATMOSPHERIC PHYSICS, OBERPFAFFENHOFEN | LIDAR SYSTEM CONSISTING OF ND-GLAS LASER (TRANSMITTER) AND PARABOLIC MIRROR (RECEIVER) | MEASUREMENT OF THE AEROSOL MASS CONCENTRATION |
| DFVLR-INSTITUTE FOR FLIGHT MEDICINE, BONN | EEG AND ECG EQUIPMENT (ELECTRODES); TEMPERATURE PROBES, ETC. | MEDICAL-PSYCHOLOGICAL RESEARCH (CIRCADIAN RHYTHM, WORKLOAD) |

* ALSO FLOWN ON ASSESS I

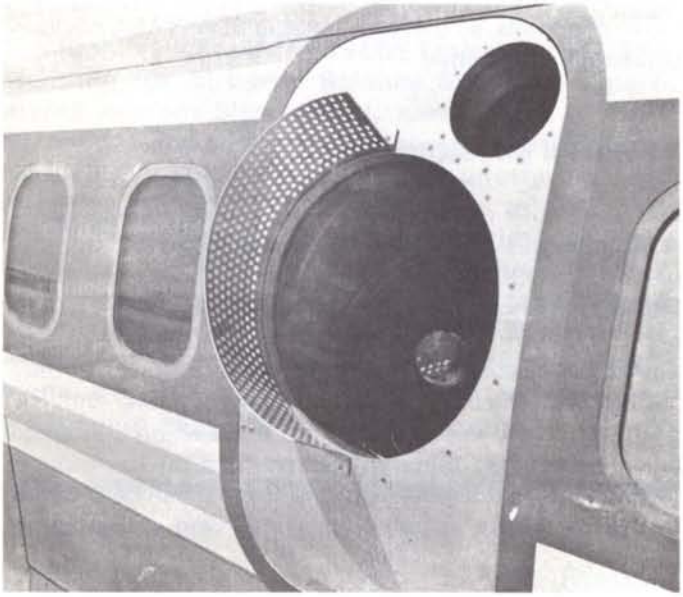


*Figure 3 – Telescope viewing port and aerodynamic fence.*

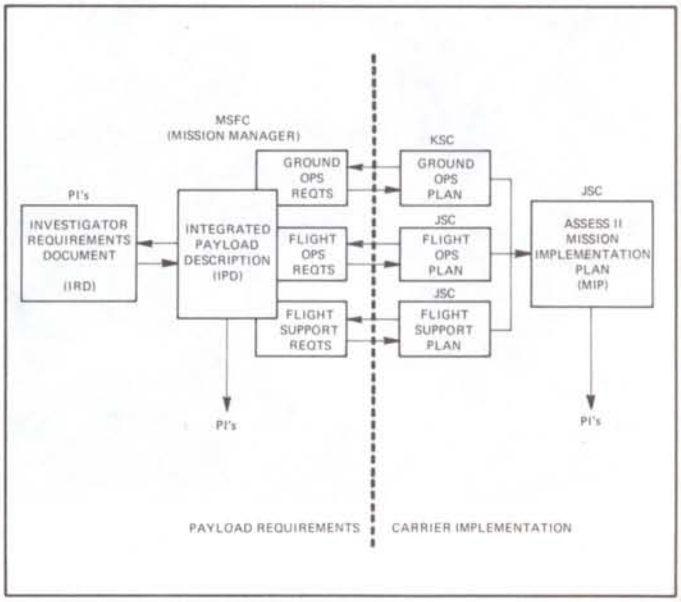



*Figure 4 – Documentation and information flow for ASSESS II.*

the photographs in Figures 2 and 3, taken during the ASSESS I mission. Similar arrangements will be implemented for ASSESS II. Figure 2 shows the Meudon telescope mounted inside the aircraft, and Figure 3 the viewing port and aerodynamic fence installed on the outside of the aircraft to avoid turbulent air flow over the telescope field of view.

It is planned to display the CV-990 aircraft, together with its complement of ASSESS II experiments, at the Paris Air Show in June 1977.

## MANAGEMENT

The ASSESS II mission is controlled by a Mission Steering Group (MSG) co-chaired by ESA and NASA. This Group consists of representatives of all the major organisations that will be concerned with integrating and operating Spacelab payloads, so that the lessons learned from ASSESS II can be applied directly to Spacelab. The Group will provide planning guidelines for the execution of the mission and serve as a forum for resolving interface problems. Overall responsibility for the mission rests with NASA's Marshall Space Flight Center and all European activities will be co-ordinated by ESA's SPICE team (SPICE standing for Spacelab Payload Integration and Co-ordination in Europe).

An Investigator Working Group has been formed, composed of one representative (principal investigator) per experiment, the tasks of which are to:

- optimise the payload requirements to assure maximum payload return within the established mission constraints
- recommend payload specialists to mission management, and
- act as scientific and technology advisory group to management.

## DOCUMENTATION

Over-documentation has been identified as a large cost contributor to past manned spaceflight programmes. It is an express aim of ESA and NASA that payload-related documentation for Spacelab should be kept to a workable minimum. Accordingly, the scheme shown in Figure 4

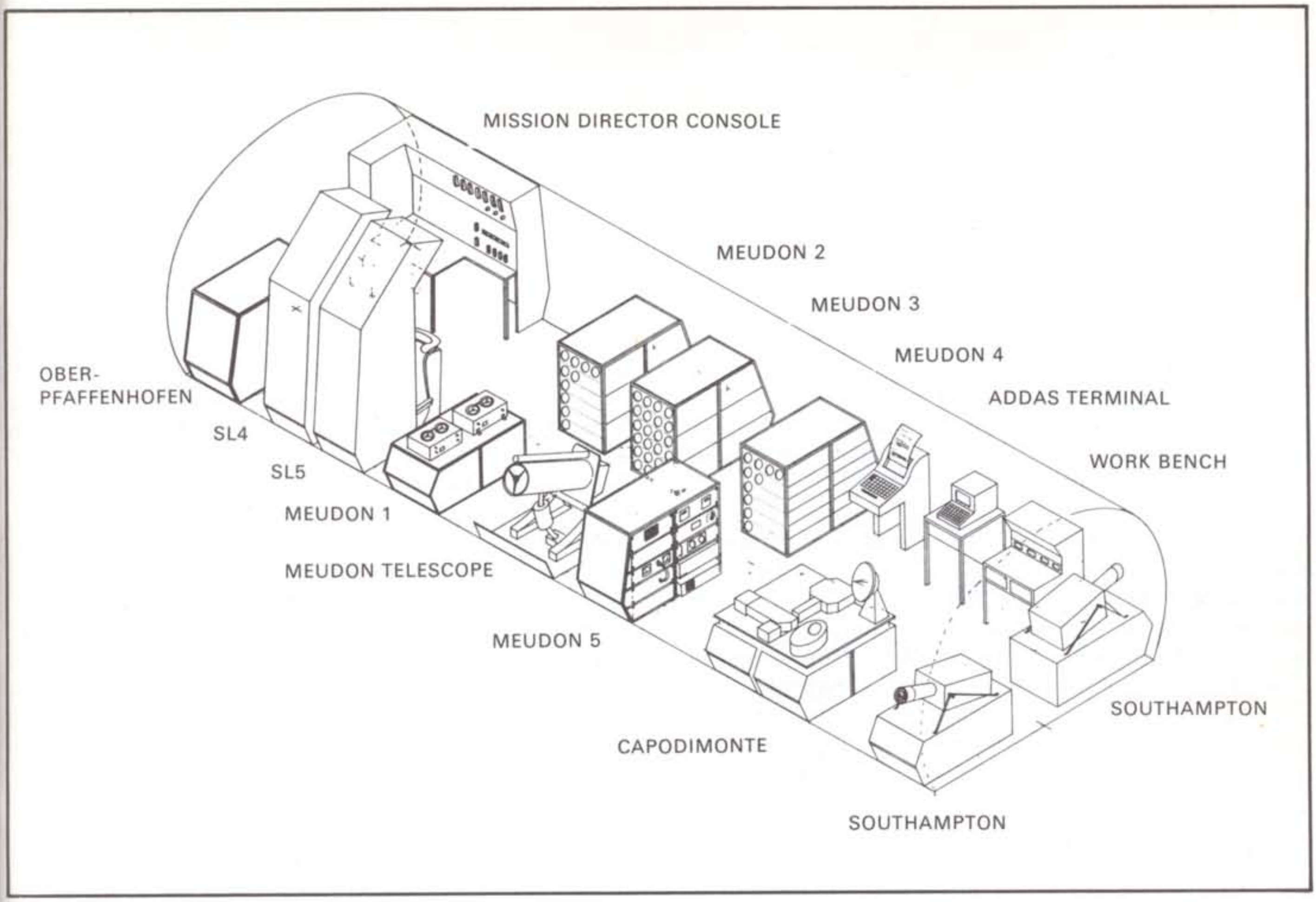



*Figure 5 – Layout of DFVLR's planned CV-990 mock-up for payload integration.*

will be operated during the ASSESS II mission to help in the identification of a low-cost, simplified documentation scheme for Spacelab payloads. It should be stressed that the only document prepared by the experimenter is the Investigator Requirements Document (IRD). His requirements are interpreted for execution by the mission management team and passed to the relevant operating centre, which gives its commitment to satisfy the experimenter's needs in the form of an applicable plan.

Already, the preparation of IRDs has provided some important lessons regarding the type and form of data provided by the experimenter to cover his requirements on the carrier and on implementation organisations for performing the experiment.

## GROUND OPERATIONS

The various ground operation levels defined for Spacelab can be adequately simulated during the ASSESS II programme. Firstly, the aircraft is equipped with standard racks which can be made available to the user well in advance of the mission. Some of these racks have been specially built and are identical to those to be used in Spacelab. This enables the investigator to perform a physical and functional integration at his home laboratory. Secondly, the aircraft is equipped with power-distribution, centralised-data-management and other subsystems which are not identical, but are certainly similar in function to the corresponding Spacelab subsystems. Ground versions of these aircraft subsystems will be available in Europe at the Porz-Wahn facilities to support the next higher level of integration. Under the direction of SPICE, the entire European payload complement will be integrated and functionally tested in an aircraft mock-up, equipped with the above-mentioned subsystem simulators, at DFVLR'S (Deutsche Forschungs-und Versuchsanstalt für Luft- und Raumfahrt) premises. A possible layout for this planned mock-up is shown in Figure 5.

In the United States, a similar activity will take place at the Ames centre where the US payload complement will be pre-integrated by the team from Marshall Space Flight Center. Only after both payload complements have been totally debugged will the integration of the total payload be initiated.

With the connection of the ASSESS II payload to the aircraft subsystems, the Spacelab equivalent of payload-to-Spacelab core module connection will be completed. The Spacelab-to-Orbiter integration cannot be simulated in ASSESS II, since the CV-990 plays the dual role of laboratory and carrier.

It must be noted here that, as in the case of Spacelab payloads, functional support for the execution of ASSESS II will be drawn from DFVLR and from ESTEC. In particular, the pre-integration of the European payload complement will be conducted in Porz-Wahn using the DFVLR facilities and support personnel. Needless to say, this is a unique opportunity to establish and/or improve the procedures under which the support for the First Spacelab Payload activities will be conducted.

## FLIGHT OPERATIONS

The flight operations, for which the responsibility rests with NASA's Johnson Space Center, will be controlled from the ground. A Mission Control Center will be set up to control the aircraft-related activities, while a Payload Operations Control Center will be equipped to enable 'real-time' payload support from the ground. During aircraft flight only voice communication will be possible, but transfer of data (video and voice) will be initiated immediately after landing and maintained as long as necessary during the time the aircraft is on the ground.

The Payload Operations Control Center will be manned by the participating scientists and the back-up payload specialists. All payload-related activities will be co-ordinated by the mission scientist who will be fully responsible for all scientific matters. One of the back-up payload specialists will be the spokesman between mission scientist and the payload specialists on-board. A mission director will control all aspects of the aircraft flight.

## EUROPEAN PAYLOAD SPECIALISTS

In all, eight candidates for posts as payload specialists on the ASSESS II flights were proposed by the participating experimenters and ESA. After an initial screening for scientific qualification by the Investigator Working Group, medical and psychological tests were conducted with the remaining candidates for ESA by DFVLR. These tests were performed using standards set for the selection of commercial airline flight engineers. The tests were not intended to be a firm selection criterion, but are considered more of a reference to show whether or not these tests, in whole or in part, could be applied in the future selection of payload specialists for Spacelab.

Four payload specialists have been selected for training, two of whom will fly and two will be assigned tasks in the Payload Operations Control Center. The European payload specialists will operate the ASSESS II payload with two US payload specialists, and a mission specialist will be provided by Johnson Space Center for the flight.

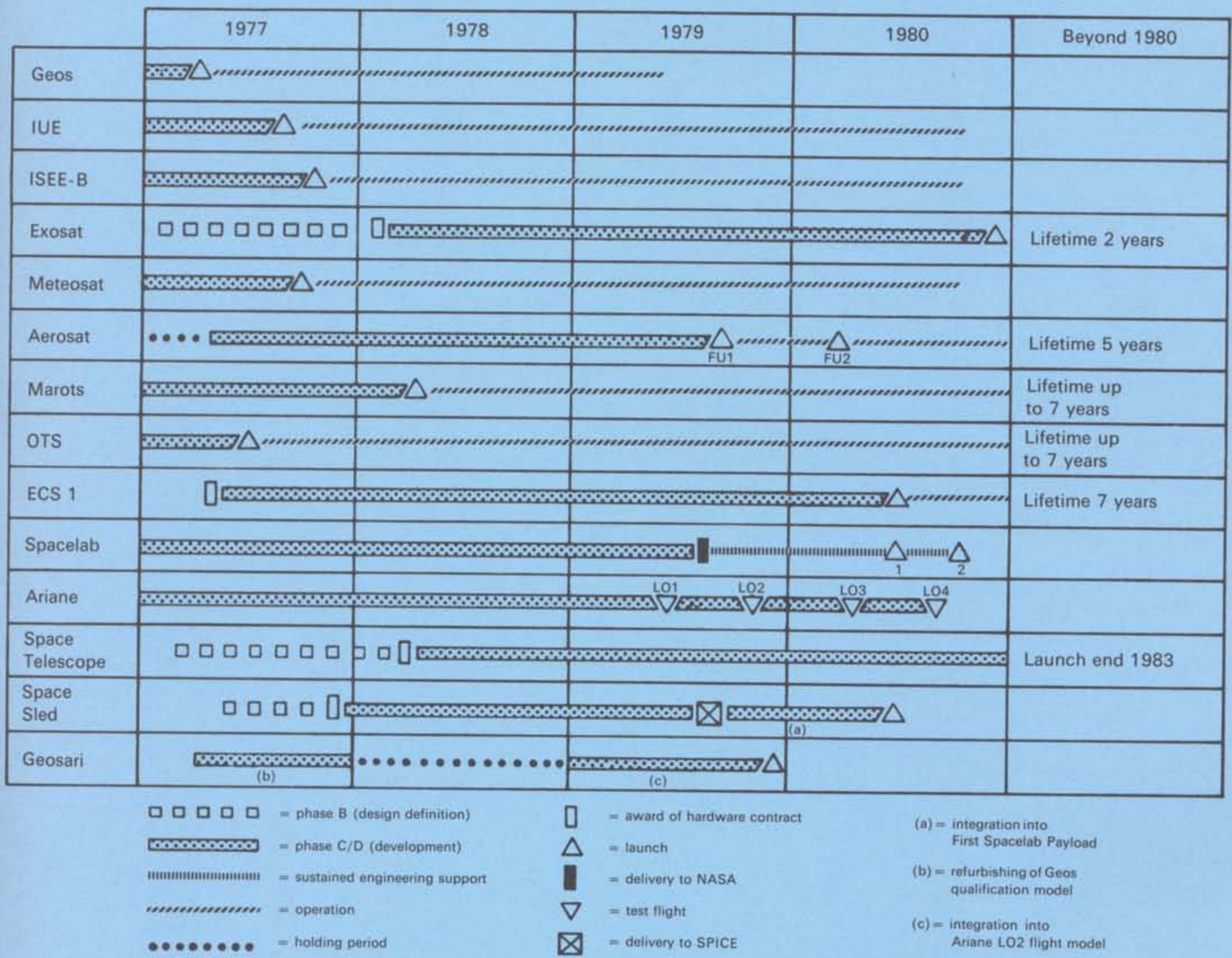
Payload-specialist training will involve mission-dependent and mission-independent activities. The former involve familiarisation with the scientific aspects of the experiments to be performed and practice in operating the experiment equipment. The latter concern living and working in the CV-990 and the ASSESS II living quarters. The training programme is now well under way.

## CONCLUDING REMARKS

Spacelab will be operational in the 1980s and its efficient and cost-effective use is essential to its future and that of the Space Shuttle itself. The ASSESS II mission has been planned to provide lessons to be applied to this end and it is therefore an important step in developing a sound operating philosophy for Spacelab and its payloads, and in establishing guidelines for experiment-equipment development, payload-specialist training and the role the experimenter has to play in the experiment cycle. □

# Projects under Development
# Projets en cours de réalisation

**THE ESA DEVELOPMENT AND OPERATION PROGRAMME (January 1977)**



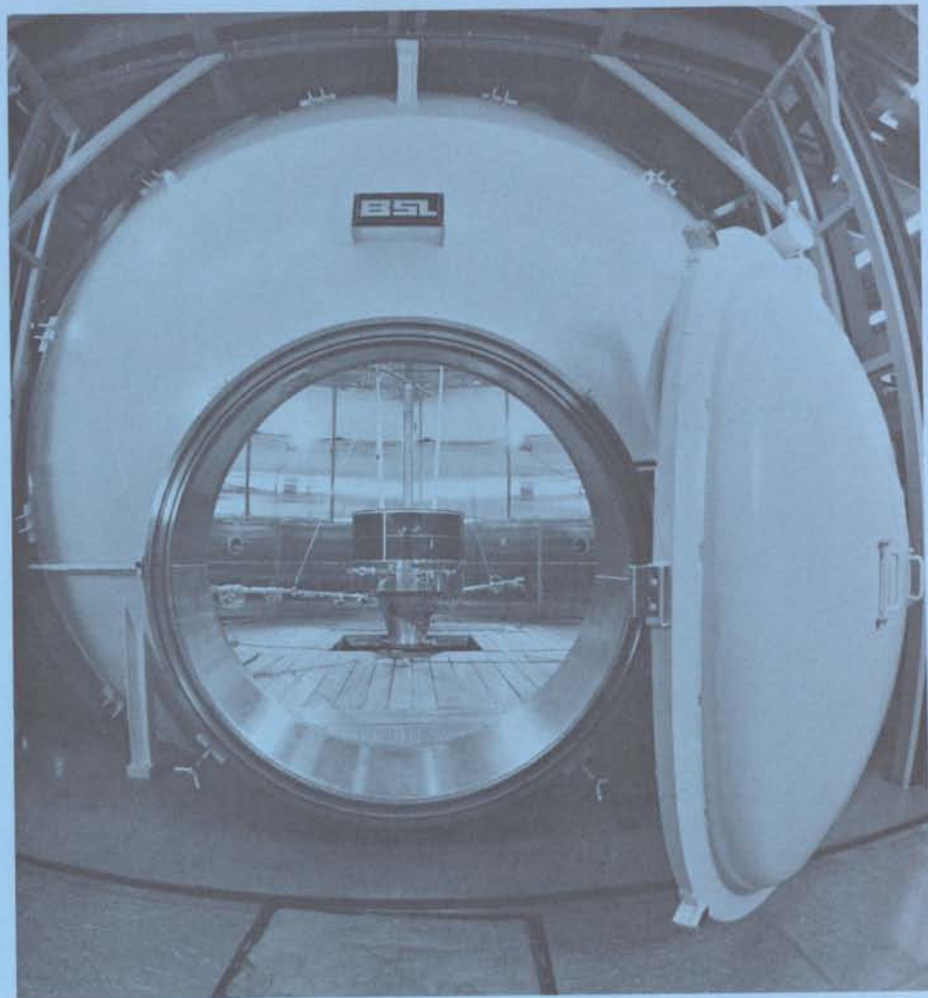

## GEOS

The programme has been maintained on schedule by intensive working during critical test periods. The qualification-model activities have been completed and the spacecraft is in store at ESTEC until required for the launch campaign. The flight model has successfully completed the scheduled acceptance tests, and preparations are being made for the Flight-Readiness Review.

*Qualification model*
The Qualification Test Review was held on September 30. The conclusion was that the status of qualification was satisfactory, but that a repetition of the boom-deployment spin tests was needed to show that the corrective actions mentioned in the previous Bulletin had been successful, and that extra testing of a particular thruster was required. These additional tests have been carried out with satisfactory results.

*Geos during spin boom-deployment tests at ESTEC*

*Geos au cours des essais de déploiement de bras en rotation à l'ESTEC*




*Flight model*
The flight model entered the second phase of acceptance testing, as foreseen, at the end of September, when the spare experiment units were installed, and the new ensemble submitted to a week of solar simulation in vacuum, to ensure that the new units were fully compatible and flightworthy. The test was successful and showed also that trimming of the thermal control surfaces has met its aim, in adjusting the spacecraft temperature by the few degrees needed for precision control. A vibration test of the new ensemble was performed without problems, and then the boom-deployment test was repeated using the newly optimised axial booms, and this was successful.

The spacecraft was then transported to Ottobrunn for system-level magnetic testing at IABG. The results of the particularly stringent tests were that the residual magnetic field in the most critical axis was only just above background noise of the test facility, that both flight and flight spare onboard magnetometers showed excellent agreement with external measurements, and that the compatibility of the payload was again demonstrated in the magnetically quiet conditions.

The flight model was then returned to BAC, Filton in December, for the confirmatory electromagnetic-cleanliness test in the special chamber. As was expected, performance was similar to that of the first test in June, and was fully acceptable. Further activities planned at BAC for January concern the reaction control system and minor work on mechanical systems.

*Scientific payload*
Experiments benefited very much from a second solar simulation and vibration test, as in this way the preferred and reserve units could be fully proven in the spacecraft. In general, the payload worked very satisfactorily during these tests. Minor anomalies resulting from solar interference were observed in some cases. The present state of testing indicates that all scientific mission objectives will be met.

*Ground segment*
During the period October – December 1976, closed loop system validation tests were carried out for a total of 6 weeks. This involved the satellite qualification model located at the Michelstadt ground station from where satellite telemetry was transmitted to the control centre at ESOC, high-speed and low-speed data via the UHF telemetry (2.3 GHz), and housekeeping data also via the VHF down link (137.2 MHz). At Darmstadt, the spacecraft data were processed and displayed, and commands sent back to the satellite, the link being closed by radio-frequency transmission to the spacecraft at 149 MHz. This test validated the spacecraft control software and served to check out parameter files, command files, and display formats. The functions of experiment command programmes for experiments S-300 and S-303, and the interaction with the experimenter-supplied computer for S-301, were also tested. For the other experiments, parameter files were validated in an open-loop mode, i.e. without commanding.

During the same period, system testing of orbit/attitude programmes for transfer and near-synchronous orbit was carried out in parallel.

*Launch preparations*
At a meeting with NASA at Eastern Test Range (Cape Canaveral) in December, the launch campaign plans and procedures were examined in detail, and found to be in an advanced state of completion.

# GEOS

*Le calendrier du programme a pu être respecté grâce à un travail intensif pendant les périodes d'essais critiques. Les activités relatives au modèle de qualification ont été menées à bien et le véhicule spatial va rester à l'ESTEC jusqu'au moment où il sera requis pour la campagne de lancement. Le modèle de vol a subi avec succès les essais de recette prévus et l'examen d'aptitude au vol (FRR) est en cours de préparation.*

Modèle de qualification
*L'examen critique des essais de qualification a eu lieu le 30 septembre, avec pour conclusion que l'état de qualification était satisfaisant, mais qu'il fallait renouveler les essais de déploiement des bras en rotation pour confirmer l'efficacité des mesures correctives mentionnées dans le précédent Bulletin; un propulseur devait également subir d'autres essais. Ces essais additionnels ont donné de bons résultats.*

Modèle de vol
*Le modèle de vol est entré dans la deuxième phase des essais de recette, comme prévu, fin septembre, avec la mise en place des unités de rechange des expériences et la soumission du nouvel ensemble à une semaine de simulation solaire sous vide pour vérifier que les nouvelles unités étaient pleinement compatibles et aptes au vol. Les essais, réussis, ont également permis de constater que l'ajustement des surfaces de régulation thermique avait atteint son objectif en apportant à la température du véhicule spatial les quelques degrés de correction nécessaires pour une régulation précise. Un essai en vibration du nouvel ensemble s'est effectué sans problème, puis l'essai de déploiement des bras a été répété, avec succès cette fois, avec les nouveaux bras axiaux optimisés.*

*Le véhicule spatial a ensuite été transporté à Ottobrunn pour des essais magnétiques du système chez IABG. Ces essais particulièrement sévères ont donné les résultats suivants: le champ magnétique résiduel sur l'axe le plus critique dépassait tout juste le bruit de fond de l'installation d'essais, la concordance entre les deux magnétomètres de bord – principal et de rechange – et les mesures extérieures s'est révélée excellente, et preuve a de nouveau été faite de la compatibilité de la charge utile en conditions de calme magnétique.*

*Le modèle de vol est ensuite retourné chez BAC (Filton) en décembre, pour le test EMC de contrôle en chambre spéciale. Les performances, similaires comme escompté à celles du premier essai de juin, ont été pleinement acceptables. D'autres activités, touchant le système de commande par réaction et des travaux mineurs sur le système mécanique, sont prévues chez BAC en janvier.*

Charge utile scientifique
*Le deuxième essai de simulation solaire et de vibration au niveau système a été extrêmement utile en ce qui concerne les expériences, car toutes les unités, tant préférées que de réserve, ont pu ainsi être pleinement mises à l'épreuve dans le véhicule spatial. De manière générale, la charge utile a fonctionné de façon très satisfaisante au cours de ces essais. Des anomalies mineures dues aux interférences solaires ont été observées dans certains cas. L'état actuel des essais indique que tous les objectifs de la mission scientifique seront atteints.*

Secteur sol
*D'octobre à décembre 1976, des essais de validation du système en boucle fermée ont été effectués sur une durée totale de six semaines. Ils ont été mis en oeuvre sur le modèle de qualification du satellite, situé à la station sol de Michelstadt, d'où les signaux de télémesure du satellite étaient transmis au Centre de contrôle de l'ESOC: via la liaison de télémesure UHF (2,3 GHz) pour les données à haute vitesse et à basse vitesse, et également via la liaison descendante VHF (137,2 MHz) pour les données de télémaintenance. A Darmstadt étaient traitées et visualisées les données provenant du véhicule spatial, et les ordres de télécommande renvoyés au satellite, tandis que des transmissions RF à 149 MHz vers le satellite fermaient la boucle. Cet essai a permis de valider le logiciel de contrôle du véhicule spatial et de vérifier les fichiers de paramètres, les fichiers de télécommande et les formats de visualisation. Ont également été testées les fonctions des programmes de télécommande des expériences S-300 et S-303, ainsi que l'interaction avec le calculateur fourni par les expérimentateurs pour S-301. Pour les autres expériences, les fichiers de paramètres ont été validés en boucle ouverte, c'est-à-dire sans télécommande.*

*Au cours de la même période, des essais au niveau système des programmes 'orbite/attitude' pour les orbites de transfert et quasi-synchrone ont été menés en parallèle.*

Préparation du lancement
*Examinés dans le détail lors d'une réunion avec la NASA à l'Eastern Test Range (Cape Canaveral) en décembre dernier, les plans et procédures de la campagne de lancement ont atteint un stade avancé de préparation.*

# IUE

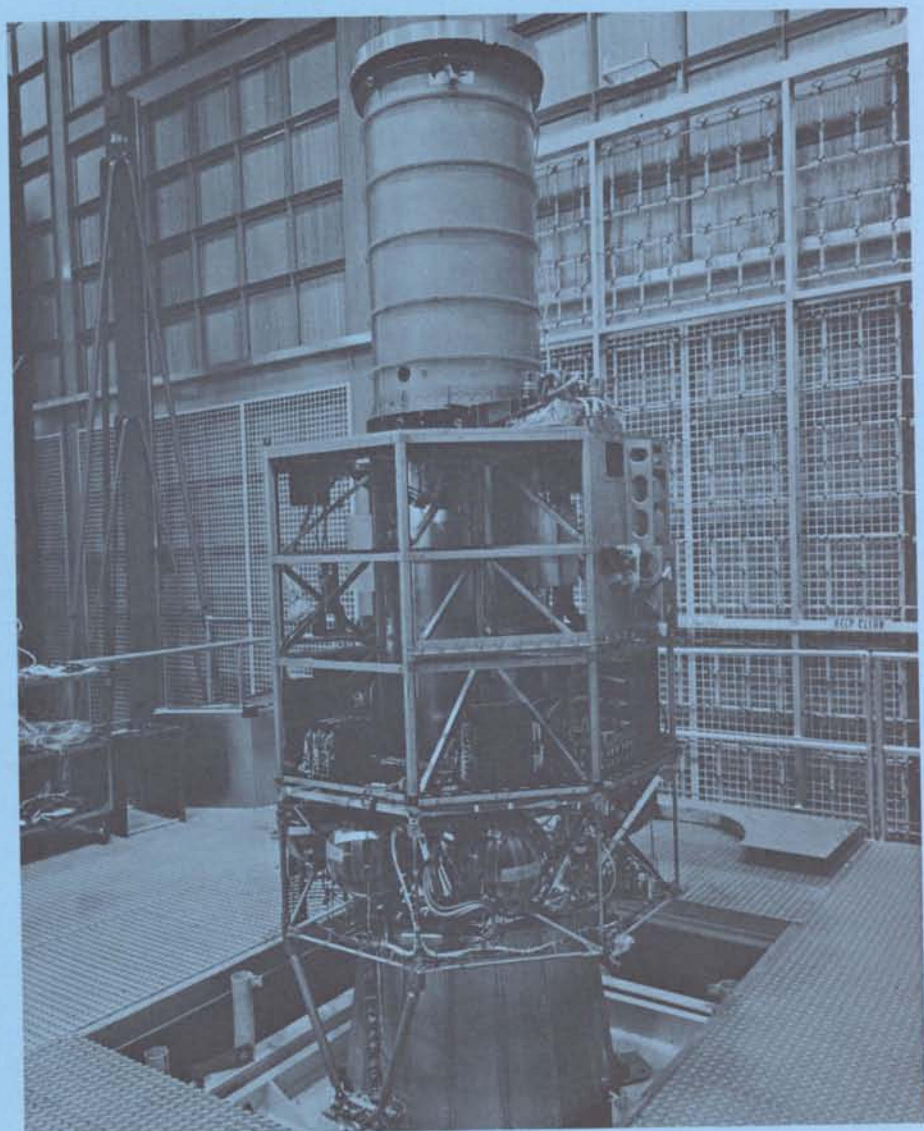
The first flight camera has been delivered by the UK Science Research Council (SRC) to NASA and this will allow the flight instrument to be placed in the vacuum optical bench facility for a long series of optical tests. The data obtained during these tests will be reviewed at a special three-agencies meeting in March and used to decide on the detailed calibration programme, both pre- and post-launch, required for the commissioning of IUE.

The flight spacecraft has now been completely integrated and system checks are being performed.

On the ground, schedule difficulties associated with the ground-station integration contract are under investigation with a view to identifying an acceptable solution.

The VHF command antenna (Satan) on loan from NASA is being transported to Madrid following completion of its refurbishment at Goddard Space Flight Center. Progress at the Villafranca station is satisfactory; the contractor for station maintenance and operation has already deployed 15 staff in order to provide the necessary support. The team of system analysts is complete and the first issue of the image processing software has been implemented successfully on the IUE ground computer system.

Improvement of the station access road is being hastened by the Spanish Authorities.



*IUE flight spacecraft under preparation for fine-pointing test at GSFC.*

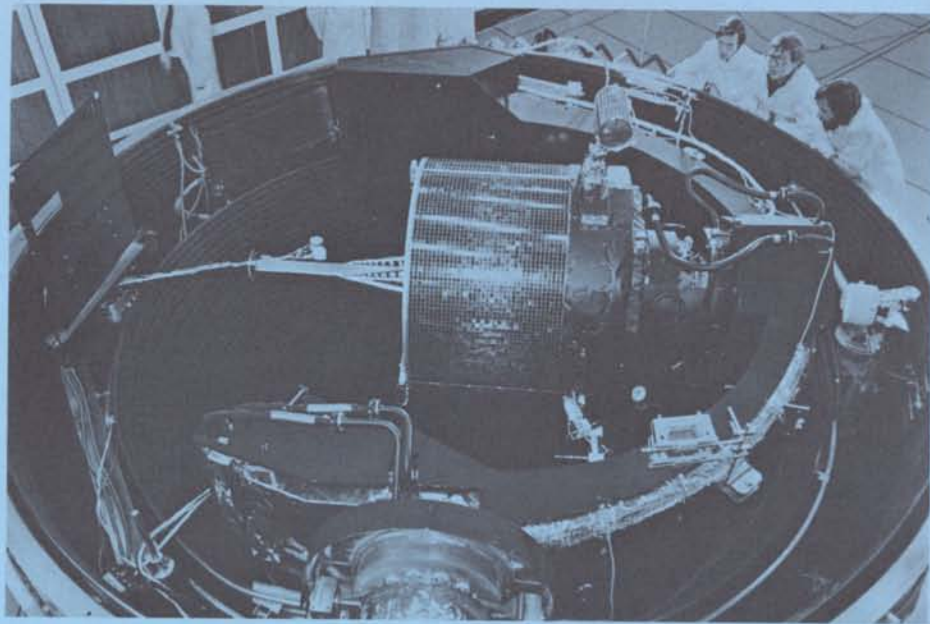
*Modèle de vol du véhicule spatial IUE en cours de préparation pour les essais de pointage fin au GSFC.*

# ISEE-B

*ISEE-B spacecraft*
The whole of the ISEE programme continues on schedule for the launch, now fixed for 14 October from Eastern Test Range in the USA. The testing of the integration model, which fills the joint role of the engineering model and the prototype in a more conventional programme, has almost been completed and only the magnetic tests, currently under way at IABG in Munich, remain. Following the Integrated System Test reported in the last issue of the Bulletin, the spacecraft was transferred to ESTEC where it underwent electromagnetic-compatibility and thermal-balance/

*Mise en place d'ISEE-B dans la chambre HBF3 de l'ESTEC pour les essais de bilan thermique/sous vide thermique.*

*ISEE-B entering ESTEC's HBF3 facility for thermal-balance and thermal-vacuum testing.*



# IUE

*Le premier modèle de vol de la chambre de prise de vues a été livré par le Conseil de la Recherche scientifique (SRC, Royaume-Uni) à la NASA, ce qui permettra de faire passer l'instrument de vol au banc d'essais optiques sous vide pour une longue série de tests optiques. Les données obtenues seront passées en revue lors d'une réunion spéciale entre les trois agences prévue pour mars et permettront de décider du programme détaillé d'étalonnage, avant lancement et après lancement, requis pour la mise en service du satellite.*

*L'intégration du modèle de vol du véhicule spatial est complètement achevée et les vérifications au niveau du système sont en cours.*

*Pour la station au sol, des problèmes de calendrier liés au contrat d'intégration de la station sont en cours d'examen en vue de dégager une solution acceptable.*

*L'antenne de télécommande VHF (Satan) prêtée par la NASA est actuellement en cours d'acheminement à destination de Madrid, après remise en état au GSFC de la NASA. Le développement de la station de Villafranca est satisfaisant. Le contractant responsable de la maintenance et de l'exploitation de la station a déjà mis en place un effectif de quinze personnes en vue d'assurer le soutien nécessaire. L'équipe d'analystes 'système' est au complet et la première version du logiciel spécial de traitement des images a été mise en oeuvre avec succès sur le système de calcul au sol.*

*Les autorités espagnoles font accélérer les travaux d'amélioration de la route d'accès à la station.*

# ISEE-B

Véhicule spatial ISEE-B
*L'ensemble du programme ISEE se déroule conformément au calendrier; le lancement est maintenant fixé au 14 octobre à partir de l'Eastern Test Range (Etats-Unis). Les essais du modèle d'intégration – qui remplit à la fois de le rôle du modèle d'identification et celui du prototype d'un programme plus classique – sont pratiquement achevés et il ne reste plus à effectuer que les essais magnétiques, au reste en cours à l'IABG à Munich. A la suite de l'essai du système intégré, mentionné dans le dernier numéro du Bulletin, le véhicule spatial a été transféré à l'ESTEC où il a été soumis à des essais de compatibilité électromagnétique ainsi qu'à des essais de bilan thermique/sous vide thermique. Les premiers ont permis de constater la très grande propreté électromagnétique du véhicule spatial et, s'il en est de même pour le modèle de vol, ceci devrait garantir aux groupes scientifiques que leurs expériences bénéficieront d'un environnement favorable dans l'espace. Les essais de vide thermique ont dû être arrêtés quelques heures plus tôt que prévu en raison de la déficience d'un collecteur de l'installation mais les résultats obtenus permettent de conclure que, moyennant des modifications mineures, la conception thermique du véhicule spatial convient elle aussi à la mission.*

*La plupart des sous-systèmes de l'unité de vol en sont maintenant soit au stade de la livraison soit à celui des essais définitifs et l'intégration du modèle de vol du véhicule spatial a commencé chez le contractant principal.*

*En décembre dernier on a procédé, à l'ESTEC, à l'examen définitif de la conception du véhicule spatial ISEE-B. Aucun défaut important n'a été décelé.*

Charge utile
*Bien que quelques problèmes mineurs se soient posés pour certaines expériences au cours des essais du modèle d'intégration, aucun défaut grave n'a été relevé et toutes les unités ont passé avec succès la série d'essais. Le calendrier de livraison des unités de vol est serré mais on devrait pouvoir le tenir.*

Véhicule spatial ISEE-A
*Les travaux se poursuivent au Centre spatial Goddard à peu près dans les temps et l'on ne prévoit pas de difficultés pour respecter la date de lancement prévue. L'examen de ce satellite, qui correspond à l'examen critique définitif de la conception d'ISEE-B, doit avoir lieu à la mi-janvier au GSFC.*

Lancement et opérations
*Les principales activités dans ce secteur sont maintenant l'élaboration et la mise en oeuvre du logiciel néces-*

vacuum testing. The former has shown the spacecraft to be very clean electromagnetically and this, if repeated on the flight spacecraft, should guarantee the scientific groups a favourable environment in space for their experiments. The last few hours of the thermal vacuum test had to be deleted because of the failure of a facility slip ring but, again, the results have been sufficient to show that, with minor modifications, the spacecraft thermal design is adequate for the mission.

The majority of the flight-unit subsystems are now either delivered or on final test, and integration of the flight spacecraft has started at the Prime Contractor's premises.

Last December, the Final Design Review for the ISEE-B spacecraft took place at ESTEC and no important deficiencies were found.

*Experiment payload*
Although a number of minor problems have occurred with some experiments during the testing of the integration model, no serious fault has been revealed and all units completed the test programme successfully. The schedule for delivery of the flight units is tight, but achievable.

*ISEE-A spacecraft*
Work continues at Goddard Space Flight Center, approximately on schedule, and no difficulty is anticipated in meeting the planned launch date. The ISEE-A review corresponding to the ISEE-B Final Design Review is scheduled for mid-January at GSFC.

*Launch and operations*
The major activity in this area is now the writing and implementation of the software for manoeuvring of the ISEE-B satellite in orbit. A number of specialist meetings with NASA have been held and all major interfaces resolved. The two spacecraft controllers assigned to ISEE-B joined the team on 1 January.

# EXOSAT

*Satellite*
Following the evaluation of proposals from Industry, in response to the Invitation to Tender, the Industrial Policy Committee has approved the Director General's recommendation to award a contract for Phases B and C/D to Messerschmitt-Bölkow-Blohm (MBB), Prime Contractor for the COSMOS Consortium.

In accordance with the approved procurement policy, the contract will be awarded in two parts, the first for Phase B (project definition) being due to start in January 1977, and the second to be awarded for Phase C/D (development) after satisfactory completion of Phase B. Phase C/D is scheduled to start in January 1978.

Negotiations between the project and MBB on both technical and contractual points have been completed, and the contract, based on the concept of launching Exosat on a Delta-2914 vehicle, is ready for signature.

As regards the Ariane launcher, further studies have led to a relaxation in some of the more critical parameters associated with the launch environment. Meanwhile, MBB has been requested to quote for an adaptation study which is to determine the technical and financial implications of modifying the currently proposed baseline concept to make the satellite fully compatible with an Ariane launch. This study will start in February 1977 and be completed in May 1977. Its results should enable the Agency to make a final decision on whether to use an Ariane or Delta launcher.

*Payload*
Work on various hardware items for the scientific model is proceeding on schedule. Test results from a full-size hyperboloidal mirror destined for the imaging telescope, obtained using an X-ray test facility, have proved entirely satisfactory. Encouraging performance has also been observed from tests on the gas-flow position-sensitive detectors (PSD) and channel multiplier array detectors (CMA).

In the meantime, Invitations to Tender were made to Industry in October, with a request for all offers to be in during the second half of January 1977. Contract awards are scheduled to start in April.

*ESOC Activities*
Activities at ESOC have been largely concerned with drawing up a project support plan and detailing work packages based on the project's requirements. Preliminary studies have been started on the various types of strategy to be adopted for the occultation mode of operation.

In parallel, ESOC staff have been investigating the feasibility of using an alternative to the Villafranca (Spain) ground station, namely a station at Weilheim (Germany), built to support the HELIOS mission. In general, the station appears adequate for Exosat's support requirements, without the substantial modifications needed at Villafranca. A detailed work statement currently in preparation will lead to detailed cost proposals for a number of minor modifications. In the meantime, negotiations with the German Authorities on S-band frequency allocation are continuing.

*saire aux manoeuvres du satellite ISEE-B en orbite. Plusieurs réunions d'experts ont eu lieu avec la NASA et les principaux problèmes d'interfaces ont été résolus. Le 1er janvier, les deux contrôleurs du véhicule spatial affectés à ISEE-B ont rejoint l'équipe.*

## EXOSAT

Satellite

*Après évaluation des propositions envoyées par l'industrie en réponse à l'appel d'offres, le Comité de Politique industrielle a approuvé la recommandation du Directeur général de conclure avec Messerschmitt-Bölkow-Blohm (MBB), chef de file du Consortium COSMOS, un contrat pour les phases B et C/D.*

*Conformément à la politique d'approvisionnement approuvée, le contrat sera passé en deux parties, la première pour la phase B (définition du projet) devant démarrer en janvier 1977, et la seconde pour la phase C/D (développement) lorsque la phase B aura été menée à bonne fin. La phase C/D devrait débuter en janvier 1978.*

*L'équipe de projet et MBB ont terminé leurs négociations sur différents points techniques et contractuels, et le contrat, fondé sur l'hypothèse d'un lancement par la fusée Delta-2914, est prêt pour la signature.*

*En ce qui concerne le lanceur Ariane, un supplément d'études a permis d'assouplir certains des paramètres les plus critiques, relatifs à l'environnement du lancement. Entre temps, MBB a été invité à chiffrer les coûts d'une étude sur l'adaptation du satellite en vue de déterminer quelles seraient les implifications financières d'une modification de la conception de référence actuellement proposée, tendant à rendre Exosat totalement compatible avec le lanceur Ariane. Cette étude doit démarrer en février et s'achever en mai 1977. Les résultats de l'étude devraient permettre à l'Agence de prendre une décision sur l'utilisation d'un lanceur Ariane ou Delta.*

Charge Utile

*Les travaux sur certains éléments du modèle scientifique se poursuivent conformément au calendrier. Les essais d'un miroir hyperbolique en grandeur réelle, destiné au télescope de prise d'images, sur une installation d'essai à rayons X ont donné des résultats tout à fait satisfaisants. Des données encourageantes ont également été obtenues lors d'essais sur les compteurs proportionnels à gaz sensibles à la position des particules (PSD) et sur les détecteurs à galette de micro-canaux (CMA).*

*Dans l'intervalle, des appels d'offres ont été lancés en octobre à l'industrie, toutes les propositions devant être reçues au cours de la seconde quinzaine de janvier 1977. La procédure d'attribution des contrats devrait démarrer en avril.*

Activités de l'ESOC

*Les activités de l'ESOC ont porté principalement sur l'établissement d'un plan de soutien du projet et de lots de travaux détaillés fondés sur les impératifs du projet. Des études préliminaires ont démarré sur les différentes stratégies à adopter pour le fonctionnement en occultation.*

*Parallèlement, le personnel de l'ESOC a étudié la possibilité d'utiliser une autre station sol que celle de Villafranca (Espagne). Il s'agit d'une station construite pour le soutien de la mission HELIOS, à Weilheim (Allemagne). D'une façon générale, elle semble en mesure de faire face aux impératifs de soutien d'Exosat sans qu'il soit besoin de procéder, comme à Villafranca, à des modifications importantes. Un descriptif des travaux actuellement en cours de préparation permettra d'obtenir des devis détaillés pour un certain nombre de modifications mineures. Dans l'intervalle, les négociations se poursuivent avec les autorités allemandes sur l'affectation des fréquences en bande S.*

## METEOSAT

Secteur spatial

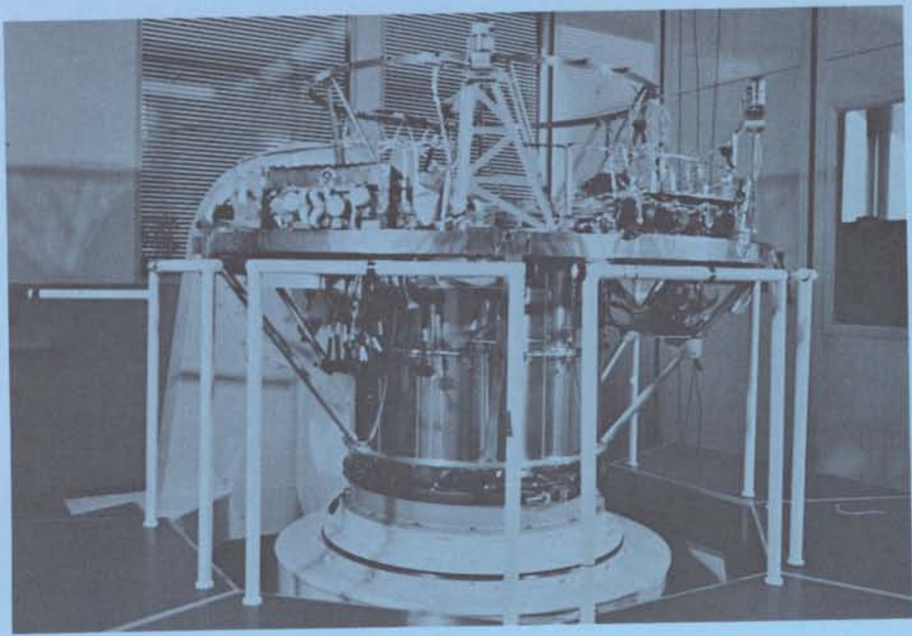
*La première partie des essais de compatibilité secteur spatial/secteur terrien s'est achevée avec succès à la SNIAS à Cannes. Le modèle d'identification (P1) de Météosat, qui avait été utilisé pour ces essais, doit être envoyé à la station de l'Odenwald (Allemagne) pour les essais de compatibilité avec la DATTS (Station d'acquisition des données, de télécommande et de poursuite), qui doivent commencer en janvier.*

*Le modèle prototype (P2) subit actuellement des essais de performances électriques et mécaniques. On prévoit de l'expédier au Centre spatial de Toulouse fin janvier, avec l'un des deux jeux d'équipement électrique de soutien au sol (EGSE), pour des essais de vibrations et de simulation solaire.*

*L'intégration du modèle F1 se déroule comme prévu et jusqu'à présent le calendrier du programme est respecté, la date nominale de lancement étant fixée à fin août-début septembre de cette année.*

Secteur terrien

*En dépit des efforts accrus de l'industrie, la situation du système*



*Meteosat flight model (F1) during integration.*

*Modèle de vol (F1) de Météosat en cours d'intégration.*

# METEOSAT

*Space segment*
The first series of space/ground compatibility tests has been successfully completed at SNIAS, Cannes. The Meteosat engineering model (PI) used will now be sent to Odenwald (Germany) for the compatibility tests with the Data Acquisition Telecommand and Tracking Station (DATTS) there, starting in January.

The prototype model (P2) is now undergoing electrical and mechanical performance tests. It is planned to transport it and one of the two sets of Electrical Ground Support Equipment (EGSE) to the Centre Spatial de Toulouse at the end of January for vibration and solar simulation tests.

The integration of the satellite flight model (F1) is progressing as foreseen, and so far the programme is on schedule, with a nominal launch at the end of August/beginning of September this year.

*Ground segment*
In spite of increased effort by industry, the Meteosat computer system is still causing major concern, particularly as regards readiness for launch. The Executive is at present studying several back-up solutions including the possible replacement of the main-frame computers and the temporary use of national computer facilities.

Apart from this serious problem, the development, installation and testing of the Meteosat Ground Segment is progressing satisfactorily:
- the DATTS is now being prepared for the second series of space/ground compatibility tests
- the Data Collection Platform (DCP) is now being installed at Odenwald
- the work on installation of the Land-Based Transponder (LBT) at Kourou has started
- the Lannion relay station is being integrated
- the development of User's Stations is progressing on schedule.

*Operations*
To date, the Protocol concerning the exploitation of Meteosat, beginning six months after launch, has been signed by Belgium, Switzerland, the United Kingdom and the Director General of ESA, and several other delegations have already announced their Government's intention to sign. It is hoped that the Governments of all participating Member States will sign before 28 February 1977, the date to which the period for signature has recently been extended. In the meantime, the Executive has started to prepare the setting-up of the Meteosat Operations Division, in accordance with plans presented to the Programme Board.

# AEROSAT

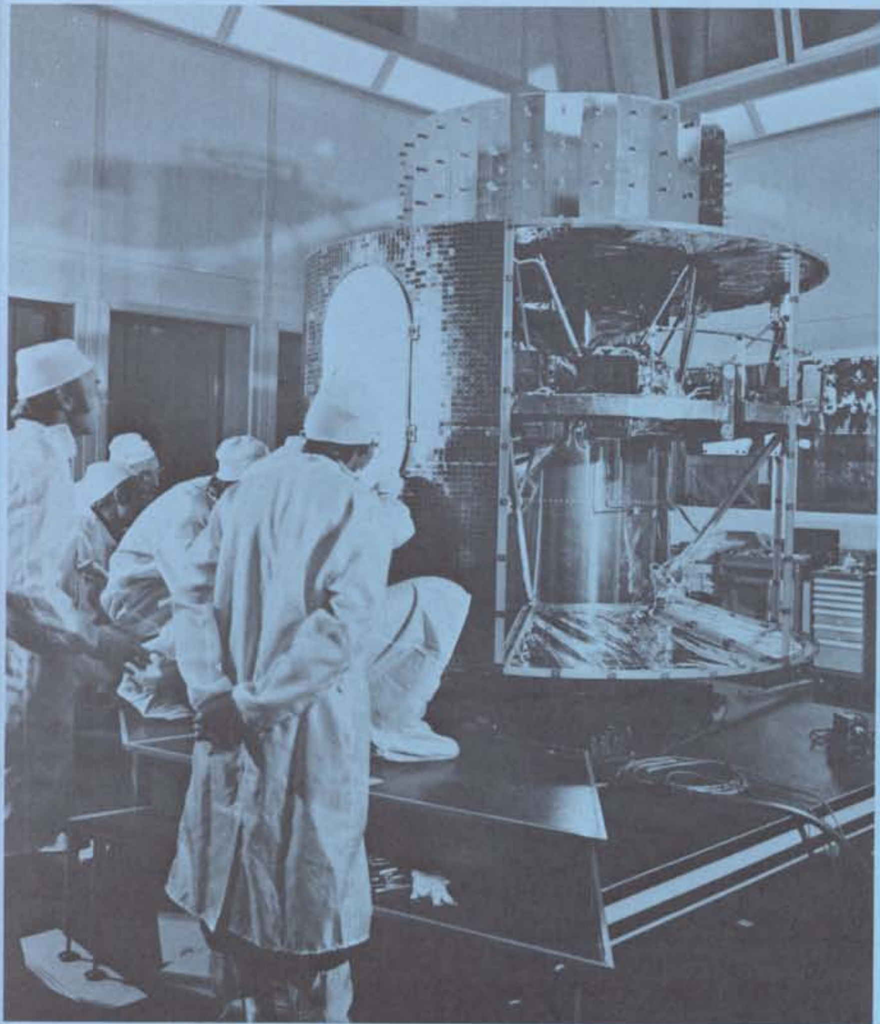
During 1976, an international call for tenders was conducted by a joint project team representing the Agency, the Canadian Government, and COMSAT-General Corporation (as the United States industrial entity co-responsible for the space segment procurement), for the supply of the satellites for this programme; a winning United States/European/Canadian industrial consortium has been identified. It has not yet, however, been possible to award the contract due to funding problems on the American side. ESA's American partner for the intergovernmental aspect of the programme, the United States Federal Aviation Administration (FAA), now appears to need further approval from the United States Congress in order to proceed with the programme.

# MAROTS

Integration of the Marots payload engineering model is in progress at MSDS, Portsmouth (UK) and manufacture of most of the flight-model hardware of the payload subsystems is under way.

The Spacecraft Structure Model Dynamic Test programme was successfully completed in mid-November 1976 and the former OTS service module (engineering model) is being prepared for use in the Marots engineering model test programme due to take place in the middle of this year.

Ground-station construction at Villafranca is in progress, with the antenna structure about to be erected.



*Montage des panneaux solaires sur le prototype de Météosat.*

*Mounting of solar panels on Meteosat prototype.*

*calcul Météosat demeure préoccupante, notamment en ce qui concerne son achèvement pour le lancement. L'Exécutif étudie actuellement plusieurs solutions de repli, parmi lesquelles le remplacement éventuel des calculateurs de l'unité centrale et l'utilisation temporaire des moyens nationaux de calcul.*

*En dehors de ce grave problème, le développement, l'installation et les essais du secteur terrien de Météosat progressent de façon satisfaisante:*

- *on prépare actuellement la deuxième partie des essais de compatibilité secteur spatial/secteur terrien de la DATTS;*
- *la plate-forme de collecte des données (DCP) est en cours d'installation dans l'Odenwald;*
- *les travaux ont commencé pour l'installation à Kourou du transpondeur terrestre (LBT);*
- *la station de relais de Lannion est en cours d'intégration;*
- *le développement des stations d'utilisation des données se déroule conformément au calendrier.*

Opérations

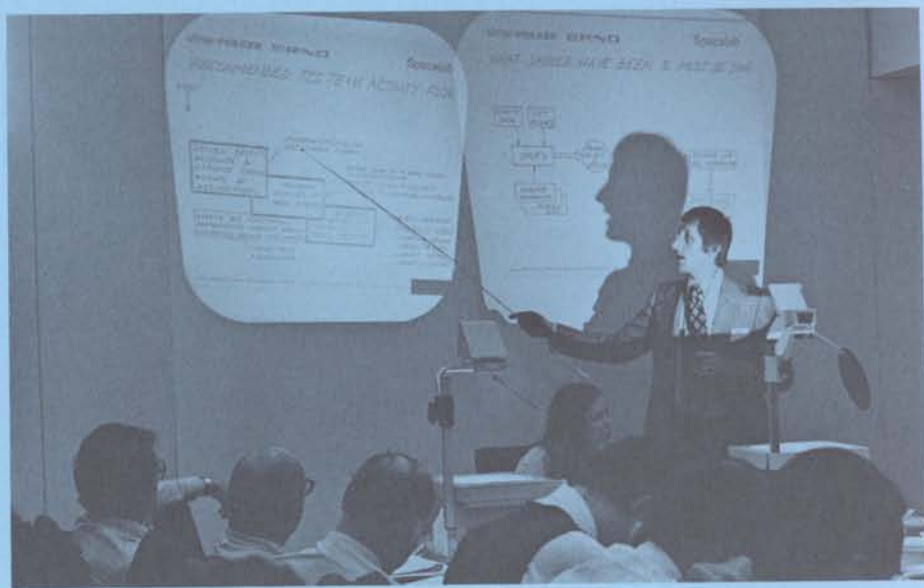
*A ce jour, le Protocole relatif à l'exploitation de Météosat, qui commencera six mois après le premier lancement, a été signé par la Belgique, le Royaume-Uni, la Suisse et le Directeur général de l'ASE. Plusieurs autres délégations ont fait part de l'intention de leurs gouvernements de le signer prochainement. On espère que les gouvernements de tous les Etats membres participants l'auront signé avant le 28 février 1977, date à laquelle a été récemment reportée l'expiration de la période d'ouverture du Protocole à la signature. Entre temps, l'Exécutif a commencé à préparer la mise sur pied de la Division 'Opérations' de Météosat conformément au plan présenté au Conseil directeur du programme.*

## AEROSAT

*Au cours de l'année 1976, une équipe de projet mixte représentant l'Agence, le Gouvernement du Canada et COMSAT-General Corporation (en tant qu'entité industrielle coresponsable pour les Etats-Unis de l'approvisionnement du secteur spatial) a lancé un appel d'offres international pour la fourniture des satellites du programme; la proposition d'un consortium américano-canado-européen a été jugée la meilleure. Il n'a toutefois pas été possible jusqu'à présent de passer le contrat en raison de problèmes de financement qui se posent du côté américain. Il semble actuellement que l'Administration fédérale de l'Aviation (FAA), qui est le partenaire américain de l'Agence en ce qui concerne les aspects intergouvernementaux du programme, doive encore obtenir une autorisation du Congrès des Etats-Unis pour poursuivre le programme.*

Spacelab Preliminary Design Review in progress at ERNO, Bremen

*Examen préliminaire de la conception de Spacelab, chez ERNO (Brême).*



# OTS

*Space segment*
The OTS qualification model testing programme started at MATRA, Toulouse, in early December and so far transfer orbit solar simulation and electromagnetic compatibility testing have been completed. Vibration testing has been planned for January 1977 and acoustic testing will follow at IABG, Munich.

The flight model is currently undergoing integration, with coupling of the service and communication modules anticipated for early January. Completion of testing is expected by the end of April, and launch is expected on schedule in June.

*Ground segment*
The contract for procurement of the Satellite Control and Test Station at Fucino (Italy) is in the final stages. Electrical measurements for the antenna have been completed and final acceptance testing of the high-power amplifiers is in progress. The contract completion date is end of February 1977.

Work is in progress to assemble the necessary test equipment to perform compatibility tests between the OTS engineering model, located on Monte Magnola, and Fucino, and for subsequent orbital testing of OTS.

Construction and testing of power-flux-measurement terminals is proceeding. Arrangements are being made to locate these terminals in Sweden, Ireland, Sicily and at Villafranca (Spain) so that OTS measurements can be made for incentive scheme purposes.

# SPACELAB

*Preliminary Design Review*
The Preliminary Design Review (PDR) was successfully completed in December 1976. The primary objective of the system PDR was to formally review the technical design baseline of the complete Spacelab system to ensure compatibility with previously established technical requirements and the adequacy of the design approach.

The objectives of the Preliminary Design Review were fully met. The data package was sufficiently detailed to allow a comprehensive review to take place. Excellent end-to-end system visibility has been provided and the system design capabilities have been clearly documented. Interface definition has advanced significantly. Design deficiencies and incompatibilities have been highlighted which can be resolved without major cost or schedule impacts if full co-contractor co-operation is achieved. As a result of the PDR, engineering-model activities presently planned can go ahead.

On the basis of the technical baseline established at the Preliminary Design Review, the cost-to-completion of the project is at present under review. A definitive report is to be presented to the Spacelab Programme Board in January 1977, after a further meeting between the Director General and the Administrator of NASA. Severe cuts in the deliverable hardware will be necessary in order to accomplish the development project within the established funding ceiling.

*SPICE*
On 21 December 1976 the Director General inaugurated ESA's SPICE (Spacelab Payload Integration and Co-ordination in Europe) Group, located at the German national space centre at Porz-Wahn. SPICE's func-

## MAROTS

*L'intégration du modèle d'identification de la charge utile de Marots est en cours chez MSDS, à Portsmouth (Royaume-Uni) et la plupart des matériels du modèle de vol des sous-systèmes de la charge utile sont en cours de fabrication.*

*Le programme d'essais dynamiques du modèle structurel du véhicule spatial s'est achevé avec succès à la mi-novembre 1976 et l'on prépare actuellement l'utilisation de l'ancien module de service OTS (modèle d'identification) pour le programme d'essais du modèle d'identification de Marots qui doit se dérouler au milieu de cette année.*

*La construction de la station sol de Villafranca se poursuit, la structure de l'antenne devant être érigée sous peu.*

## OTS

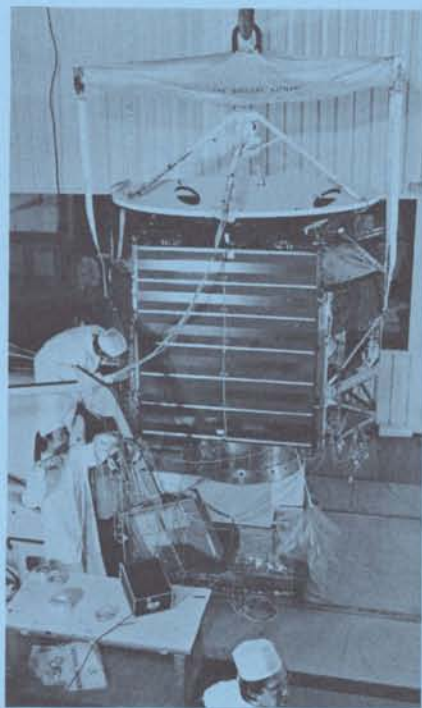
Secteur spatial
*Le programme d'essais du modèle de qualification d'OTS a commencé chez MATRA, à Toulouse, début décembre; à ce jour, les essais de simulation d'ensoleillement du satellite en orbite de transfert ainsi que les essais de compatibilité électromagnétique sont terminés. Les essais de vibrations doivent être effectués en janvier et les essais acoustiques suivront à l'IABG, à Munich.*

*Le modèle de vol est en cours d'intégration, le couplage des modules de service et de communications est prévu pour début janvier. On pense que les essais seront achevés vers fin avril et le lancement reste fixé au mois de juin.*

Secteur terrien
*Le contrat pour la fourniture de la station de contrôle et d'essais de satellites de Fucino (Italie) en est à son stade final. Les mesures électriques de l'antenne sont terminées et les essais de recette définitifs des amplificateurs de grande puissance sont en cours. L'achèvement du contrat est prévu pour fin février.*

*Les travaux d'assemblage des équipements nécessaires sont en cours pour effectuer les essais de compatibilité entre le modèle d'identification installé à Monte Magnola et la station de Fucino ainsi que pour les essais orbitaux ultérieurs du satellite.*

*La construction et les essais des terminaux pour la mesure des flux de puissance se poursuivent. Des dispositions sont prises pour installer ces terminaux en Suède, en Irlande, en Sicile et à Villafranca (Espagne) afin de pouvoir effectuer les mesures prévues au plan d'intéressement d'OTS.*



*Préparation du modèle de structure de Marots aux essais de vibrations au CNES (Toulouse).*

*Marots structural model being prepared for vibration tests, at CNES, Toulouse.*

## SPACELAB

Examen préliminaire de la conception
*L'examen préliminaire de la conception (PDR) s'est terminé avec succès en décembre 1976. Son principal objectif était de passer officiellement en revue le concept technique de référence du système Spacelab complet afin d'en assurer la compatibilité avec les impératifs techniques établis antérieurement et de garantir la validité de la méthode suivie dans l'élaboration de ce concept.*

*Le PDR a entièrement atteint ses buts. Le dossier était suffisamment détaillé pour permettre un examen approfondi. Une excellente visibilité de l'ensemble du système a été obtenue et les capacités nominales de celui-ci ont été exposées à l'aide d'une documentation claire. La définition des interfaces a considérablement progressé. Des déficiences et des incompatibilités de conception ont été mises en lumière, qui pourront être corrigées sans répercussions sur le coût ou le calendrier moyennant une coopération complète des co-contractants. Les résultats de l'examen permettent le démarrage des activités relatives au modèle d'identification telles qu'elles sont actuellement envisagées.*

*Le coût à l'achèvement du projet est en cours d'examen sur la base du concept technique de référence établi lors du PDR. Un rapport définitif doit être présenté au Conseil directeur du programme Spacelab en janvier après une nouvelle réunion entre le Directeur général et l'Administrateur de la*

*Test firing (G1) of Ariane first stage at SEP, Vernon.*

*Tir G1 du premier étage d'Ariane à la SEP (Vernon).*

tion is to ensure the co-ordination of European activities for the First Spacelab Payload (FSLP) by supporting the chosen experimenters in the analytical and hardware areas. It will draw support from the resources available within the Member States, and it will also set up a nucleus of trained Spacelab payload specialists.

*First Spacelab Payload*
Europe's First Spacelab Payload is scheduled for launch in the third quarter of 1980 and is of particular interest since it is a co-operative ESA/NASA venture. The experimental objectives have been agreed between NASA and the Agency and the European contribution will utilise some 50% of the available resources – weight, volume, power, crew time, etc. Although not yet finalised, it is likely that the FSLP will include passive atmospheric-sounding equipment, a material-sciences laboratory, small astronomy experiments, a metric camera, a sled for vestibular studies, and various technology development experiments. A joint NASA/ESA decision on the composition of the Payload is expected in February.

## ARIANE

*First firing of the propulsion system*
The Ariane first-stage propulsion system comprising four Viking II engines underwent its first firing test on 17 November 1976 at SEP, Vernon. This firing test, developing a nominal thrust of 244 t, was terminated after 59 s – instead of 75 s as planned – because of an abnormal rise in the ambient temperature. The latter was found to be due to the failure of a small pipe associated with a pressure sensor, hence to the combustion of UDMH flow inside the bay. This test also showed an unexpected acoustic level, which is probably peculiar to the test stand.

Taking into account the multiple objectives associated with this test:
- qualification of Europe's largest test stand built by SEP at Vernon
- simultaneous start-up and functioning of the four Viking II engines
- commissioning of the water reservoir
- functioning of the hot-gas pressurisation system.

the operation can be considered a complete success.

Data processing has yielded very satisfactory results. The hot-gas pressurisation system proved to operate nominally. The pressure surge phenomenon – which occurs at the end of propulsion during the sudden cut-off of propellant flow in the tubes – did not exceed the admissible values. The pressure peak at start-up, its level during the test and the temperature rise in the engines remained within the predicted limits.

*Second-stage propulsion system*
The G1 and G2 firings of the second stage propulsion system – a Viking III engine with a truncated diverging section (the contoured diverging section Viking IV being designed for the flight model) – performed at DFVLR (Hardthausen) were also highly successful (130 s of functioning developing a thrust of over 60 t). Subsequent tests will make use of the

*NASA. Il sera nécessaire de réduire sérieusement les matériels à fournir afin de pouvoir exécuter le projet dans le cadre de l'enveloppe financière fixée.*

SPICE

*Le 21 décembre 1976, le Directeur général a procédé à la mise en place du Groupe SPICE (Intégration et coordination des charges utiles du Spacelab en Europe) qui est installé a l'Institut spatial national allemand de Porz-Wahn. Le SPICE a pour fonction d'assurer la coordination des activités européennes relatives à la première charge utile du Spacelab en apportant aux expérimentateurs sélectionnés son soutien sur le plan de l'analyse et sur celui des matériels. Pour ses tâches de soutien, il fera appel aux ressources disponibles dans les Etats membres. D'autre part, le SPICE formera un noyau de spécialistes des charges utiles du Spacelab.*

Première charge utile Spacelab

*La première charge utile européene du Spacelab (FSLP), qui doit être lancée au cours du troisième trimestre de 1980, présente un intérêt particulier puisqu'il s'agit d'une entreprise menée en coopération par l'ASE et la NASA. Ses objectifs expérimentaux ont été convenus entre la NASA et l'Agence, et la contribution européenne utilisera environ 50% des ressources disponibles – poids, volume, puissance, temps alloué aux équipages, etc. Bien qu'aucune décision définitive n'ait encore été prise à son sujet, il est vraisemblable que la FSLP comprendra un équipement de sondage passif de l'atmosphère, un laboratoire de sciences des matériaux, de petites expériences d'astronomie, une chambre photogrammétrique, un traîneau coulissant pour études vestibulaires et diverses expériences de développement technologique. Une décision sur la composition de la charge utile doit être prise en commun par la NASA et l'ASE au mois de février.*

# ARIANE

Premier tir de l'ensemble propulsif

*Le premier tir de groupement des quatre moteurs 'Viking II' de l'ensemble propulsif du premier étage a eu lieu le 17 novembre 1976 à la SEP, à Vernon. Ce tir de la baie de propulsion, qui a développé une poussée nominale de 244 t, a été arrêté après 59 s de fonctionnement au lieu des 75 s prévues suite à une élévation anormale de la température d'ambiance. Après expertise, la cause de ce phénomène a été attribuée à la rupture d'une petite tuyauterie associée à un capteur de pression, et par conséquent à la combustion d'un débit d'UDMH à l'intérieur de la baie. Ce tir a fait également apparaître un niveau acoustique inattendu qui est très probablement spécifique au banc d'essais.*

*Compte tenu des multiples objectifs associés à ce tir:*

- *validation du plus grand banc d'essais d'Europe construit à Vernon par la SEP*
- *démarrage et fonctionnement simultanés des quatre moteurs Viking II*
- *validation du réservoir d'eau*
- *fonctionnement du système de pressurisation à gaz chaud*

*on peut considérer que l'opération a été réellement un succès.*

*Le dépouillement des mesures a fourni des résultats très satisfaisants. La pressurisation à gaz chauds a été nominale. L'effet de 'coups de bélier' qui se produit en fin de propulsion lors de l'arrêt brusque des débits d'ergols dans les canalisations n'a pas dépassé les valeurs admissibles. La pointe de pression en début de tir, la pression en régime établie et la montée en température des moteurs se sont situées dans les limites prévues.*

Ensemble propulsif du deuxième étage

*Les tirs G1 et G2 de l'ensemble propulsif du deuxième étage – moteur Viking III à divergent court (le Viking IV à divergent galbé étant destiné aux modèles de vol) – effectués à la DFVLR à Hardthausen ont donné également des résultats très satisfaisants (130 s par tir à plus de 60 t de poussée). Les prochains tirs mettront en oeuvre le système vol de pressurisation à gaz froids. Parallèlement débuteront à Hardthausen les essais sous vide du moteur Viking IV.*

Trois tirs à durée nominale du moteur complet HM 7

*Aussi important que le premier tir de groupement du premier étage est le fonctionnement à durée nominale, pendant trois essais, du moteur complet HM 7 du troisième étage, les 30 novembre, 1er décembre et 8 décembre (1710 s de fonctionnement avec des résultats excellents). Il s'agit du moteur cryogénique pour lequel un potentiel d'essai considérable a été mis en oeuvre à Vernon. Le développement de la chambre de combustion par MBB est terminé et les essais de qualification commenceront en janvier 1977. Cette chambre fournit une impulsion spécifique de 440 s (par rapport à 434 s exigées par la spécification) et des modifications sont en cours pour augmenter encore la performance.*

*Les prochaines étapes importantes du développement du troisième étage sont l'essai B1 de la baie de propulsion avec réservoirs lourds qui est prévu pour fin janvier et le premier essai sous vide du moteur complet HM7 prévu pour le 15 mars.*

flight-model cold-gas pressurisation system. Simultaneously, vacuum testing of the Viking IV engine will start at Hardthausen.

*Three firings of the complete HM 7 engine*

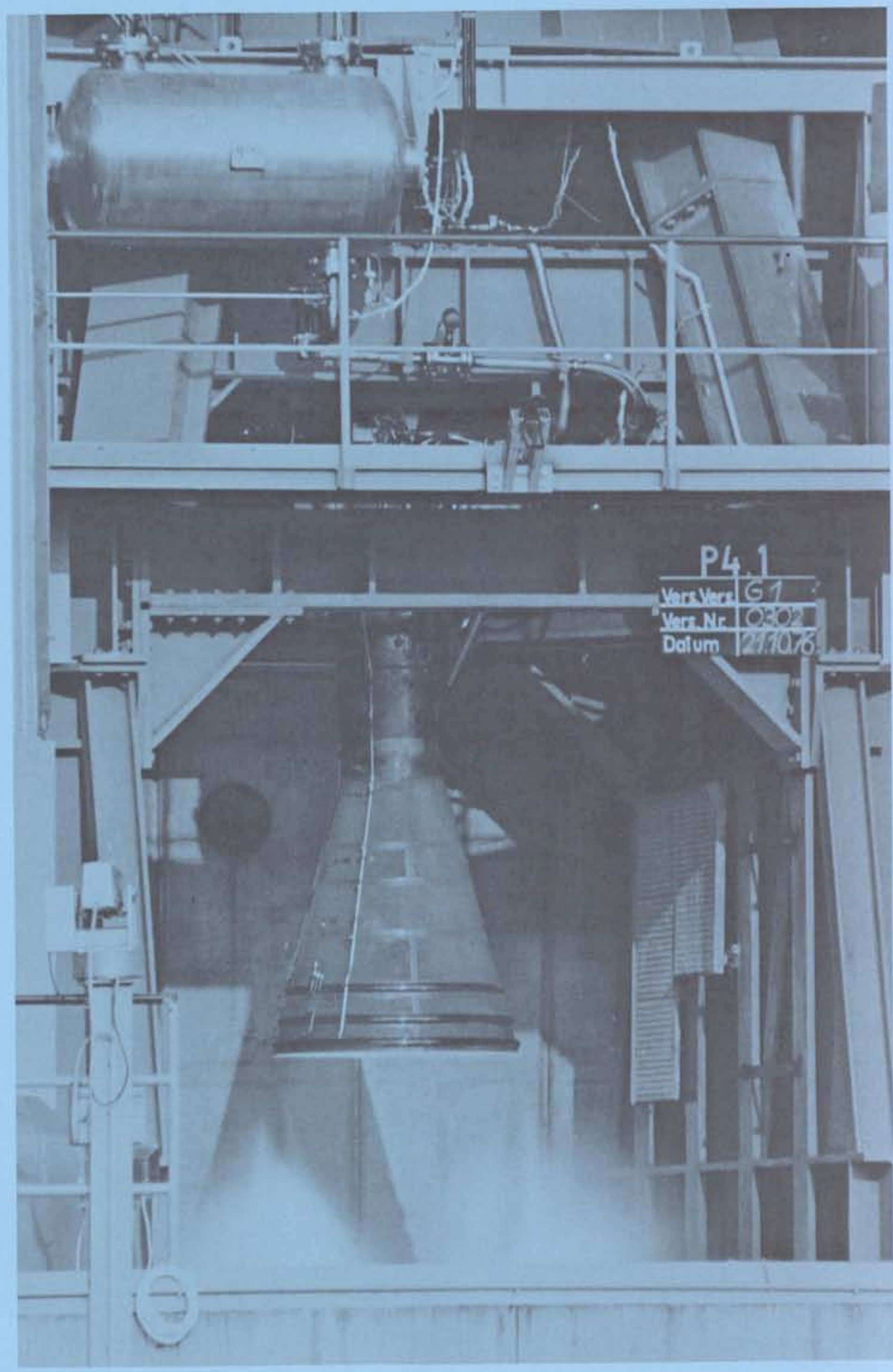
As significant as the combined firing of the first stage's engines was the functioning of the third stage's complete HM 7 engine during three tests on 30 November, 1 and 8 December (1710 s of operation with excellent results). This was the cryogenic engine for which a major test facility had been built at Vernon. Development of the combustion chamber at MBB has been completed and qualification tests are due to start in January 1977. This chamber provides a specific impulse of 440 s (compared with the 434 s required by the specification) and modifications are being made in order to improve its performance.

The next major phases in the development of the third stage will be the propulsion bay test with full tanks scheduled for January 1977 and the first vacuum testing of the complete HM 7 engine planned for 15 March.

*Fairing*

Dynamic testing of the fairing (diameter: 3.2 m, height: 8.65 m), development of which was assigned to Contraves, has just begun with two separation tests for the rear cone. Detailed results are not yet known, but a quick analysis of the first test revealed a satisfactory lateral velocity and successful separation.

The fairing jettison tests will start in March in ESTEC's large vacuum test chamber.




*Test firing (G1) of Ariane second stage at DFVLR, Hardthausen.*

*Tir G1 du deuxième étage d'Ariane à la DFVLR (Hardthausen).*

Coiffe

*Les essais dynamiques de la coiffe (3,2 m de diamètre et 8,65 m de hauteur) dont le développement a été confié à la firme Contraves viennent de commencer avec deux essais de séparation du cône arrière. Les résultats détaillés ne sont pas encore connus, mais une analyse rapide du premier essai a mis en évidence une vitesse latérale satisfaisante et une séparation réussie.*

*En mars 1977 débuteront, dans la grande chambre à vide de l'ESTEC, les essais de largage de la coiffe.*

*Le télescope spatial de 2.4 m.*

*The 2.4 m Space Telescope*

# TELESCOPE SPATIAL

*Cet élément du programme scientifique de l'ASE constitue la contribution européenne au télescope spatial de 2,4 m de la NASA qui doit être lancé vers la fin de 1983 par la Navette spatiale. Le télescope spatial devrait être approuvé par le Congrès dans le courant de 1977.*

*La contribution de l'Europe comportera trois éléments principaux:*
- *fourniture du réseau solaire et des mécanismes associés de commande et d'orientation;*
- *fourniture d'un des instruments placé au plan focal, à savoir une chambre de prise de vues pour objets à faible luminosité;*
- *participation à l'exploitation du télescope pendant ses dix premières années et remise en état et/ou remplacement des deux équipements ci-dessus pendant la période d'exploitation.*

*La phase B des travaux concernant le réseau solaire et la chambre de prise de vues commencera en 1977 et sera suivie en 1978 des phases C/D. Les diverses interfaces techniques et gestionnelles sont en cours de définition dans le cadre du plan NASA/ASE de réalisation du projet (voir ce Bulletin, pp. 13).*

# TRAINEAU COULISSANT

*L'ASE vient d'entreprendre le développement du traîneau coulissant (Sled) en vue de l'incorporer dans la première charge utile du Spacelab. Le Sled doit permettre d'étudier chez l'homme et l'animal l'adaptation de l'appareil vestibulaire à l'apesanteur, les problèmes d'adaptation visio-vestibulaire et l'interaction entre les canaux semi-circulaires et le système otolithique.*

*Le programme est actuellement axé sur la livraison du Sled au SPICE à la fin d'août 1977 en vue de son intégration dans le Spacelab et d'un premier vol prévu pour le milieu de 1980. Des spécifications sont en cours de rédaction pour permettre le démarrage de la phase B vers le mois de mai 1977 et celui des phases C/D vers la fin de l'annee (voir Bulletin N° 4, février 1976).*

# GEOSARI

*Geosari est le modèle de qualification du satellite Geos, adapté au lanceur Ariane dans le cadre du programme APEX. Ce sera le passager principal du vol expérimental LO2 d'Ariane, le satellite radio-amateur (AMSAT) étant embarqué comme passager latéral. Il utilisera le moteur d'apogée de Geos.*

*Le programme comportera trois phases principales:*
- *au cours du second semestre de 1977, la modification du modèle de qualification de Geos;*
- *en 1978, une 'période de mise en sommeil' pendant laquelle il ne sera procédé qu'à des vérifications intermittentes du véhicule spatial, lequel demeurera le reste du temps dans son conteneur;*
- *en 1979, la répétition des opérations d'intégration et d'essai du véhicule spatial pour qu'il soit prêt pour le vol expérimental LO2 d'Ariane en décembre de la même année.*

*L'exploitation du satellite est prévue pour un an.*

## SPACE TELESCOPE

This item of the ESA scientific Programme is Europe's contribution to NASA's 2.4 m Space Telescope to be launched in late 1983 by the Shuttle. The Space Telescope is expected to get Congressional approval later this year.

The European contribution will consist of three main components:
- provision of the solar array, with associated drive and orientation mechanisms
- provision of one of the focal-plane instruments, namely a Faint Object Camera (FOC)
- participation in the initial ten years of operation of the telescope and refurbishment and/or replacement of the two hardware components during the operational period.

Phase-B studies for the solar array and the FOC will start in 1977 and Phases C/D will follow in 1978. The various technical and management interfaces are being defined as part of the common NASA/ESA Project Plan (see this Bulletin, pp.13).

*Space Sled for examining the effects of acceleration on astronauts under weightless conditions.*

*Traîneau coulissant destiné à l'étude des effets de l'accélération sur les astronautes en conditions d'impesanteur.*

## SPACE SLED

ESA is undertaking development of a Space Sled facility with a view to its inclusion in the first Spacelab payload. This facility is expected to allow the study, in man and animal, of vestibular adaptation to weightlessness, problems of visuo-vestibular adaptation, and the interaction between the semicircular canals and the otolithic system.

The programme is presently geared to meet a delivery date of end August 1979 to SPICE, for integration into Spacelab, and a first flight in mid-1980. Specifications are being written to allow the initiation of Phase-B studies around May 1977, and Phases C/D late in 1977 (see Bulletin No. 4, February 1976).

## GEOSARI

GEOSARI is the qualification model of the GEOS satellite, adapted for Ariane flight as part of the APEX programme. It will be the principal passenger for the Ariane LO2 test flight, together with the radio-amateur satellite (AMSAT) as a lateral passenger, and will make use of the Geos apogee boost motor.

The programme will comprise three main phases:
- refurbishment of the Geos qualification model in the second half of 1977
- a 'dormant' period in 1978 during which only occasional checkouts will be performed on the spacecraft, which will otherwise be stored in its container
- a re-integration and re-testing of the spacecraft in 1979 to be ready for launch in December on the Ariane LO2 test flight.

An operational lifetime of one year is foreseen for Geosari.

# A Policy for International Relations

*H. Kaltenecker, Department of International and Legal Affairs, ESA, Paris*

**Within ESA, the term international relations covers all relations between the Agency and its organs on the one hand and the governments and institutions of non-Member States and international organisations on the other. In ESA's two predecessor organisations (ESRO and ELDO), these relations were conducted on an ad hoc basis in the light of specific programme requirements or particular scientific, technical or economic interests of those organisations. There were no principles or general guidelines governing the conduct of their international relations. The ESRO and ELDO Conventions indicated no more than that, subject to a unanimous Council decision, co-operation with other international organisations and institutions and with non-Member States and their organisations could be permitted. The signature of the ESA Convention in 1975 provided a starting point for the fuller development of the Agency's international relations.**

The new Convention specifically includes among the Agency's obligations that of co-ordinating the policies of its Member States vis-à-vis other national and international organisations and institutions, and makes provision for more detailed co-operation with non-Member States. For the implementation of this task and to provide an appropriate forum for the discussion of international relations, the ESA Council has set up an International Relations Advisory Group (IRAG), composed of delegates of Member States and observers, which reports its recommendations to Council. This group has taken over, in particular, the majority of the tasks formerly entrusted to the European Space Conference Working Group on United Nations Organisation business.

The framework for the application of the relevant provisions of the Convention has been established. It now remains to define the general objectives in co-operation and relations with other states and international organisations, and the guiding principles of their implementation. In this respect IRAG has already recommended some guidelines which have been discussed and noted by Council. In addition, Council has set up a special Working Group with a mandate, inter alia, to draw up a document governing the Agency's international relations in the form of a resolution for submission to the Council session at ministerial level scheduled for February 1977. The decision at that session will mark the end of the interim period and the start of systematic actions in the field of international relations.

In considering the implementation of the objectives already mentioned, it should be realised that:

- it is impossible for the Agency to operate in an international vacuum, without any contacts with other states and organisations interested in space or related fields
- the Agency is important in terms both of its budget and its programmes and in these respects inevitably exercises great impact in Europe and in other parts of the world
- the policies of some nations are such that, in space matters, they welcome, as an addition to the big space powers such as the USA or USSR as possible interlocuters, the advice and co-operation of a European space co-ordinator such as ESA.

It is also important to realise the need for ESA to develop and maintain relations with non-Member-State organisations which may be potential users of space systems developed by the Agency and its Member-State industries – such as applications satellites or space transport systems. Many non-Member-State institutions and international organisations attach great importance to the Agency's competence in the fields of space science and technology, programme management, information exchange and other space-related matters.

Against this background, the Agency's international relations can be considered as falling into two broad categories:

- First, relations with non-Member-State or international institutions and organisations which already possess well-developed space programmes and capacities. In these cases it is in the interests of the Agency and its Member States to stimulate co-operation for the benefit of European space activities, and vice-versa.

- Second, by relations with non-Member-State or international institutions and organisations which are newly developing in the space field and are interested, in a general way, in availing themselves of the Agency's competence or are interested in exploiting space systems and for this would like to make use of the Agency's achievements.

This division should not, of course, be seen as absolute; the separation is not rigid and different interests may lead to various combinations in co-operation. Existing examples of the first category are the co-operative agreements concluded in 1972 between ESRO on the one hand and the USSR Academy of Sciences and the Governments of Japan and Canada; the recent agreement to co-operate between ESA and the Canadian Centre for Remote Sensing; also the numerous arrangements established in the past between ESRO and the US Government, and with NASA in particular, for co-operation in many areas of space technology and science. Examples within the second category are the 1971 agreement between ESRO and the Indian Space Research Organisation (an extension of which has been proposed by the ESA Executive); the co-operative agreement concluded with Australia, and proposed agreements with the Indonesian and Iranian authorities for the exchange of information.

Another kind of activity within the field of international affairs is the propagation of the Agency's achievements in the space domain and related sectors. This activity is mainly manifested by the Agency's participation in the many international or national conferences to which it is frequently invited; the preparation and co-ordination of these participations demands considerable time and effort. The mounting of ESA's own conferences on specific space activities is yet another example of effort leading to international publicity.

One of the elements of the draft resolution mentioned above is that the Executive should annually propose to Council a list of actions to enable the Executive to prepare and co-ordinate appropriate steps and to reply to requests for co-operation. After approval by Council, the list would constitute its principal guidelines to the Executive in its handling of ESA's relations with other states and organisations. It would of course be necessary to permit subsequent corrections and additions in order to cope with unforeseen events and circumstances in the international field.

Means available to the Executive for the implementation of the Council's approved action plan and any policy directive include in particular:

- presentations on the Agency and its activities to interested States and organisations
- exchange of information and data on projects and programmes (past, present or future)
- technical assistance
- loan of equipment
- training of personnel
- quality assurance
- participation in the technical evaluation of tenders
- conclusion of co-operative agreements of a general or specific nature.

Whilst the establishment and up-dating of policy directives and the approval of the overall action plan are the Council's concern, the Executive should be allowed flexibility and initiative in their implementation. In other words, there should be a sound balance between policy and control functions (delegate level) and execution (Executive level).

Another facet to be kept in mind is that ESA activities in this field must remain complementary to any activities in similar fields by individual ESA Member States vis-à-vis other States or organisations, for example by bilateral agreements. The same applies in regard to actions by Member-State industries vis-à-vis governments and national institutions vis-à-vis international organisations. Here the Agency's role should be to provide those industries with support from European technical achievements, to advise, and, if requested, to assist in the preparation of tenders for industrial contracts – but it should not be ESA's aim to replace European firms or consortia by itself entering into contracts. In this role, the Agency must be careful to adopt an attitude of impartiality so as to enhance in an equitable manner the possibilities of all Member-State institutions and industries to benefit from new markets. With appropriate co-ordination of these efforts by the Agency it is hoped to avoid any adverse effects of competition which could reduce the chances of success for European industry.

Naturally, the financial consequence of all the actions described has to be considered and it is a concern for the Executive as well as for the Member States. However, most of the activities will be arranged on a cost-reimbursement basis covering both ESA's direct and indirect costs arising from the particular operation. Normally, the Agency will only be called upon to fund its mission expenses and some minor nonidentifiable costs. Any special expenses, arising for example under a particular co-operative agreement, would require prior approval by the Council. It is estimated that the costs to the Agency of developing and maintaining its external relations as outlined in this article, will remain well below 0.1% of its overall budget.

This article has hopefully highlighted some of the complexity and, in some respects, delicacy of the problem of 'international relations'. It is now a matter of urgency to define clear policy directives which take all due account of the Agency's role in the international sphere in which it has been placed by the signatories to its Convention. In this context, ESA Member-State governments will also need to consider the general political trends and orientations of Europe in the fields of science and technology – such as the transfer of technology or questions arising from the North-South dialogue. Whilst doing so they should recognise, as already pointed out (ESA Bulletin No. 1), that the Agency constitutes an important element in the creation of a united Europe and that its activities are a significant contribution to the increase of Europe's political prestige. □

## International conference on the attitude control of space vehicles

The European Space Agency and the Centre National d'Etudes Spatiales (France) are organising a conference on a specialised aspect of space-vehicle stabilisation, namely the technological and dynamical problems associated with the presence of liquids, on 10-12 October 1977, in Toulouse (France).

The conference will cover the general field of fluid satellite-dynamics interactions, emphasis being given to engineering aspects and practical results.

Papers will be presented in French or English, with simultaneous translation in these languages. A registration fee will be charged for speakers and participants (300 and 400 French Francs, respectively). As attendance will be limited, those interested should contact Mr. J.L. Cendral, Attitude and Orbit Control Division, ESTEC, Noordwijk, The Netherlands, for registration material, as soon as possible. □

## Colloque international sur la stabilisation des véhicules spatiaux

*L'Agence Spatiale Européenne et le Centre National d'Etudes Spatiales organisent un colloque centré sur un domaine spécialisé de la stabilisation des véhicules spatiaux: les problèmes technologiques et dynamiques posés par les liquides. Ce colloque se tiendra du 10 au 12 octobre 1977 à Toulouse.*

*Le colloque couvrira le domaine général des interactions dynamiques entre le fluide et le véhicule spatial, l'accent étant mis sur les aspects techniques et les résultats pratiques.*

*Les communications seront présentées en français ou en anglais avec traduction simultanée dans les deux langues. Un droit de participation de 400 FF pour les participants et de 300 FF pour les conférenciers sera demandé. Le nombre des participants étant limité, les personnes intéressées doivent écrire dans les meilleurs délais à M. J.L. Cendral, Division Contrôle d'Attitude et d'Orbite, ESTEC, Noordwijk, Pays-Bas, afin d'obtenir les formulaires d'inscription.* □

# European Developments in Antenna Technology

*J. Aasted, Space Communications Division, ESTEC, Noordwijk, The Netherlands*

**Once the umbilical cord has been disconnected and a launcher, with its satellite payload, has lifted off, the only means of passing information to and from the satellite is via antenna systems. The latter provide key input and output elements for communication to and from the satellite. The development work being conducted in Europe to design the antennas for the current and future generations of satellites, the methods employed to verify designs, and the research needed to overcome limitations constitute the basis for the following paragraphs.**

In developing antennas, not only does the hardware have to be designed to satisfy specific electrical requirements under all environmental conditions, but the design itself must be verified by extrapolation from the limited environmental tests that are possible. Both the electrical/mechanical design and the design verification require extensive use of computers.

Because of the size of satellite antennas and their requirements for unobstructed visibility, in terms of radio-frequency transmission/reception, they cannot normally be duplicated for redundancy like other key links in the telemetry or payload chains.

A further complexity lies in the fact that it is not possible with today's test techniques to measure a satellite antenna's electrical performance on the ground in an environment similar to that in space.

## ANTENNA DESIGN

Traditionally, antenna design has involved a great deal of experimental work on test ranges. This is costly in terms of both time and manhours and rarely leads to a full appraisal of the antenna's performance under the extreme conditions that it will encounter in space.

It is almost impossible, for example, to simulate on a test range the temperature variations, typically from −150° to

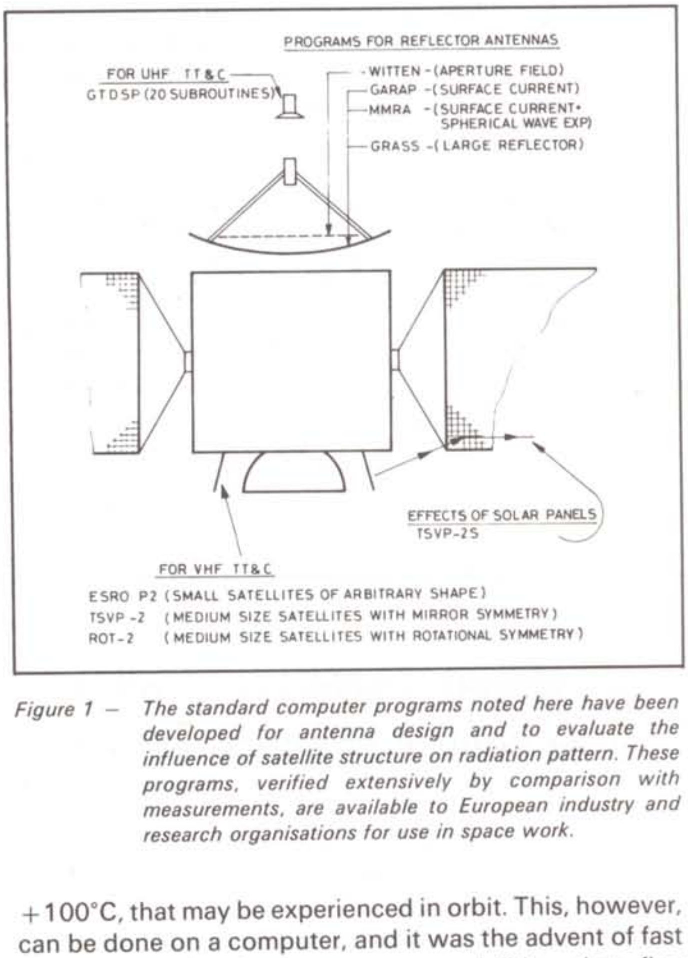



*Figure 1 — The standard computer programs noted here have been developed for antenna design and to evaluate the influence of satellite structure on radiation pattern. These programs, verified extensively by comparison with measurements, are available to European industry and research organisations for use in space work.*

+100°C, that may be experienced in orbit. This, however, can be done on a computer, and it was the advent of fast computers with large storage capabilities that first allowed adequately accurate modelling of antennas, mechanically as well as electrically. It is now possible to perform the trade-off analyses between the numerous parameters that enter into antenna design, in a matter of minutes; trade-offs that previously took days or even weeks, using the traditional 'cut-and-try' method.

When the Agency's applications satellite programmes were started some years ago, sophisticated computer programs were already available for structural and thermal analysis, but programs for electrical analysis were not as far advanced. For a given reflector antenna, one could compute how thermal variations would lead to structural deformation, but the effect on its electrical characteristics could only be judged indirectly and approximately. A

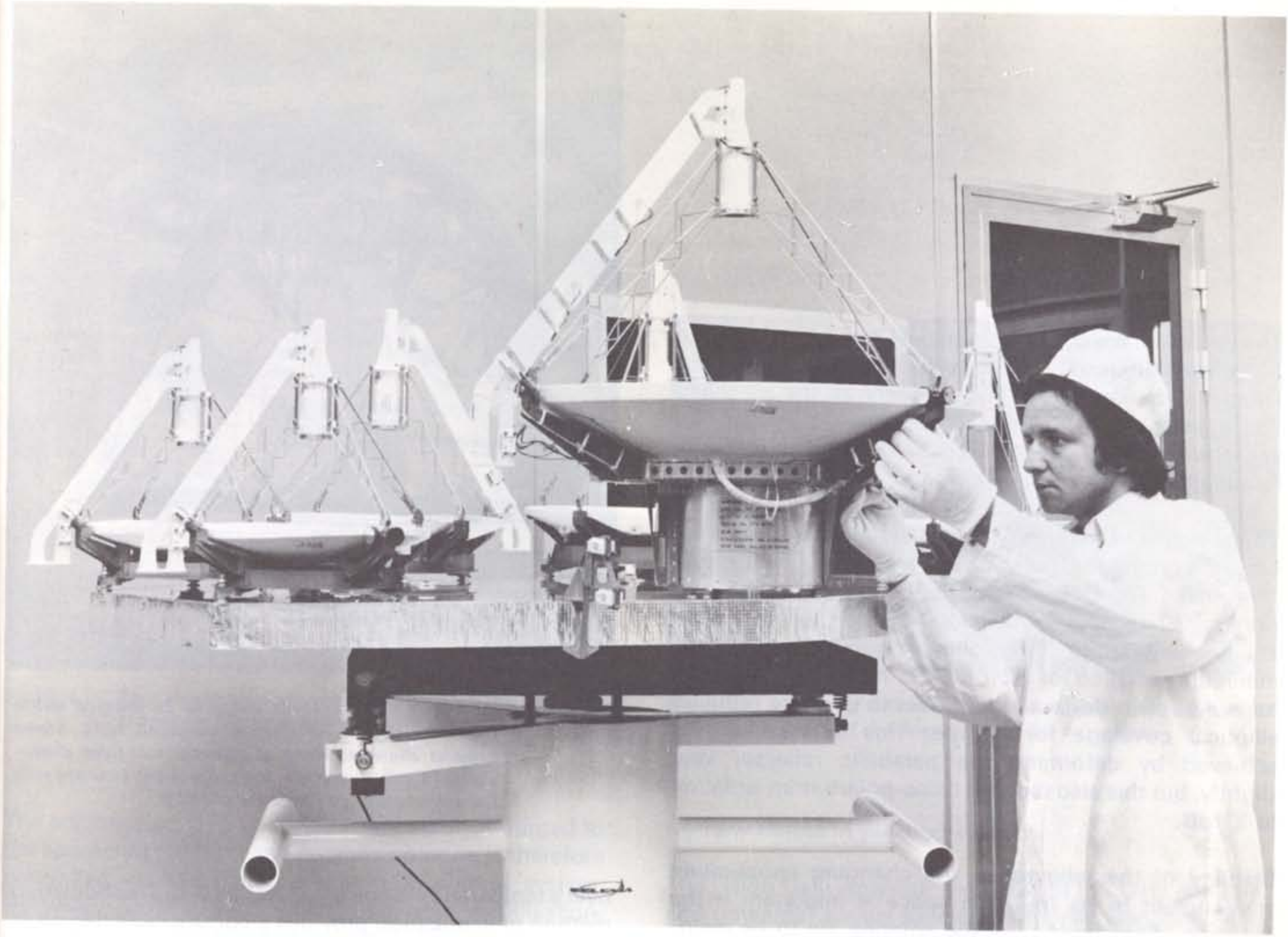


*Figure 2 – OTS payload antennas will be the first on-board antennas to employ frequency re-use. Each antenna can handle dual polarisation in the same frequency band and in the same beam.*

systematic research effort was started by ESA to bridge this gap and this work has resulted in a number of antenna-pattern prediction programs, applicable to the most commonly used types of antennas.

Figure 1 shows a typical satellite antenna system layout, and the various computer programs now available for the different parts of the system are indicated. The programs, which have been developed by a number of ESA contractors, including ERA (UK), Marconi Research Laboratories (UK), the Technical University of Denmark and TICRA (Denmark) have been used extensively in all antenna developments currently under way and are also available to European industry and research organisations for work on space-related subjects (detailed program descriptions can be found in ESA Scientific and Technical Review No. 1, 1976).

The work on pattern prediction is being continued with the aim of improving and simplifying the programs. One technique currently attracting much attention due to its conceptual simplicity is that relying on the 'Geometrical Theory of Diffraction', in which the radiated energy is considered as rays, which are reflected or diffracted by the satellite's metallic structure. This technique is especially attractive for large satellites, for which other analysis programs can lead to excessive computer storage requirements.

## ANTENNA TECHNOLOGY

The applications satellite programmes have also given rise to significant developments in hardware technology, the best example being the dual-polarised antennas built by Selenia (Italy), for the Agency's OTS telecommunications satellite, to be launched in June. Figure 2 shows the OTS antenna platform with the six antennas designed and qualified to carry dual polarisation for frequency re-use. This will be the first time that antennas capable of handling two independent signals in the same frequency band and for the same coverage area have been carried by a telecommunications spacecraft.

The reflectors are built of aluminium honeycomb with a fibreglass skin, resulting in a high-precision, lightweight structure: the largest of the six antennas, the so-called 'Spot Beam' antenna, has a reflector diameter of 72 cm, yet it weighs less than $^3/_4$ kg. A thin metallic grid is moulded into its surface to give increased reflectivity.

The principle of frequency re-use requires high isolation between orthogonal polarisations in the antenna to avoid 'crosstalk'. The OTS antennas will have isolation in the order of 30 dB over the coverage zones. The Spot Beam antenna, with its perfectly focussed circular beam, has a minimum isolation of 32 dB. The remaining antennas have a built-in de-focussing effect to give the required elliptical coverage for Europe. This de-focussing is achieved by deforming the parabolic reflector very slightly, but this also reduces cross-polarisation isolation to 27 dB.

Stability of the reflector in the changing temperature environment to be found in space is important if the radiation characteristics of the antenna are to be maintained. Improper mechanical design can cause the reflector's shell to distort when it is heated from one side by the sun and the other side is simultaneously exposed to the cold environment of deep space. Such deformation will cause de-focussing and so reduce the strength of the radiated signal.

To determine how an antenna performs over a wide temperature range, a set of combined hardware and software tests are carried out. The thermal model of the antenna is first verified in a thermal vacuum facility. As the temperature is varied, typically from $-130°$ to $+130°C$, a set of stereo cameras records a dot pattern painted on the antenna reflector. These photographs are subsequently evaluated in a stereo comparator to compute the structural deformation. The values obtained are then compared with predictions, and the distortions over the full temperature range are computed and introduced into the radiation pattern prediction program to determine the resulting electrical changes.

This method was used by Selenia to verify the design of the OTS Spot Beam antenna. Figure 3 shows the test set-up before it was lowered into the test chamber at ESTEC. The results showed a predicted beam shift of only $\pm 0.1°$

*Figure 3 – OTS Spot Beam antenna about to be lowered into a vacuum chamber for thermal distortion tests. Stereo cameras allow recording of distortions in three dimensions. To minimise errors, the cameras are mounted with the antenna and go inside the chamber.*

over a temperature range of $-160°$ to $0°C$. This bootstrap method of verification provides a considerable degree of confidence in flight hardware behaviour where direct measurements are not possible.

Another significant hardware development is represented by the reflector antenna being developed for the Agency's Marots maritime communications satellite. This is unique in several respects. Firstly, it uses a reflector profile shaped to give a radiation pattern with increased gain towards the edge of the earth. Secondly, with its 2m diameter, it is the largest satellite reflector antenna yet built in Europe, and it is also the first to use carbon-fibre skins over the honeycomb structure.

The use of carbon fibre, or more correctly carbon-fibre-reinforced plastics, for antennas has aroused considerable interest among antenna designers because of its attractive mechanical properties, such as high specific strength, high specific stiffness and low thermal expansion coefficient. An additional advantage is that some and possibly all types of carbon-fibre material act as good reflecting material at microwave frequencies, so eliminating the need for a metallic surface or grid on reflectors. Several companies in Europe have started development programmes for carbon-fibre antennas and without doubt the material will be used extensively in the future.

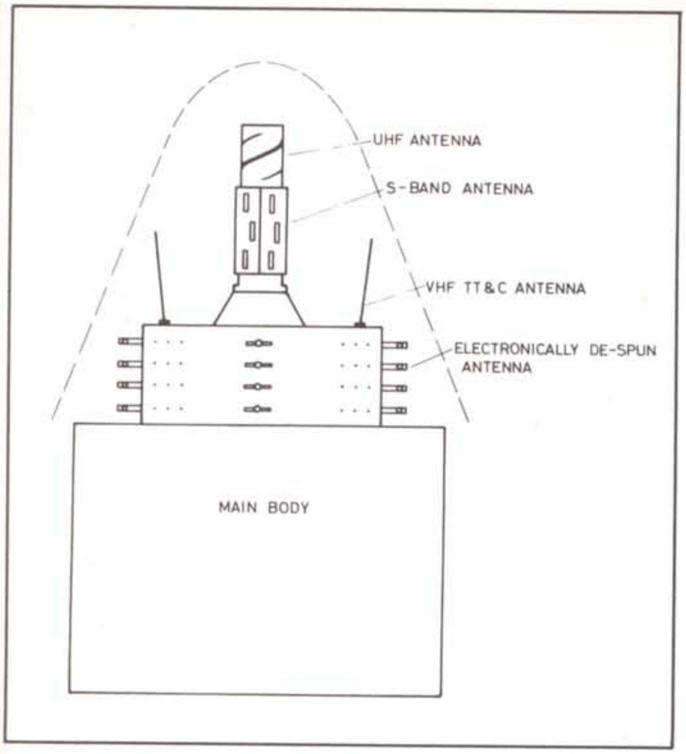



*Figure 4 – Four independent antennas make up Meteosat's antenna subsystem (dimensions in mm).*

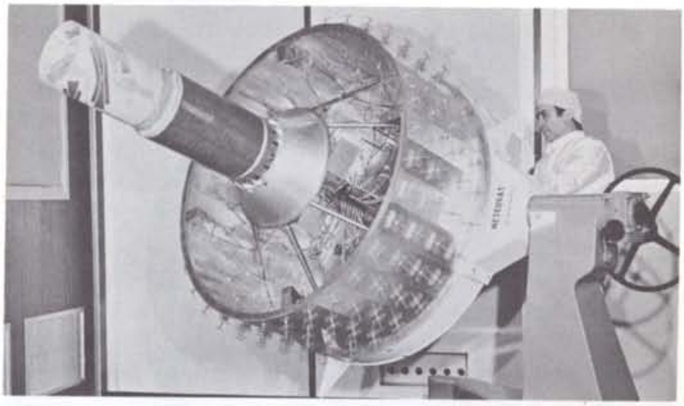


*Figure 5 – A total of 138 individual radiators and slotted waveguides are used in Meteosat's antenna subsystem.*

The antennas on OTS and Marots are rigidly mounted to the spacecraft platform and antenna pointing is therefore controlled via the platform's attitude control system. However, on Meteosat, which uses spin stabilisation, electronics are used to counteract the rotation of the spin-stabilised platform of one of the four antennas. The other three have rotationally symmetric patterns, so that no de-spinning is required.

The several communication functions to be served by Meteosat result in a fairly complex antenna subsystem. Figure 4 shows the four antenna systems carried while Figure 5 shows the hardware, less the four-element VHF antenna for telemetry and telecommand which had been dismounted when the picture was taken. A total of 138 individual radiators are employed. The digital variable-ratio power dividers which feed energy to the 32 columns in the despun antenna in a 'tread-mill' fashion are built by Siemens, while Selenia provides the antennas and antenna control electronics.

## APPLIED RESEARCH

The hardware developments for ESA's applications satellite antennas have been backed by a significant research effort, comprising two main programmes, with a view to establishing how the various limitations in existing designs can be overcome and also to preparing for new trends in payload systems.

The 'High Gain Antenna' programme (11 GHz antennas and upwards) covers several disciplines associated with future-generation satellite payloads. The 'switchboard in the sky' concept for point-to-point communication, for example, will require on-board antennas with multiple, narrow beams. To optimise coverage over areas that are not compatible with the standard circular or elliptical beam shapes will require the development of antennas with contoured beams. In these developments it is foreseen that future systems may require frequency re-use.

To use narrow or contoured beams efficiently it will be necessary to ensure that they can be 'pointed' accurately. For antennas with high gain this translates into pointing accuracies closer than the $\pm 0.25°$ which can be provided by the platform's IR sensors. One approach is to use the antenna as a receiver to sense the direction of a ground beacon and then to use this information to steer the same antenna in a given direction as a transmitter, the so-called 'radio-frequency sensing principle'.

Another important aim of the 'High Gain Antenna' programme is the development of improved test techniques. Rather like optical systems, satellite communication antennas can be considered focussed at infinity, which means that large distances are needed on

*Figure 6 – To avoid exposing antennas under test to the elements, one wall of MBB's anechoic chamber (top of building) is transparent to radio frequencies. The movable tower allows testing at various distances.*

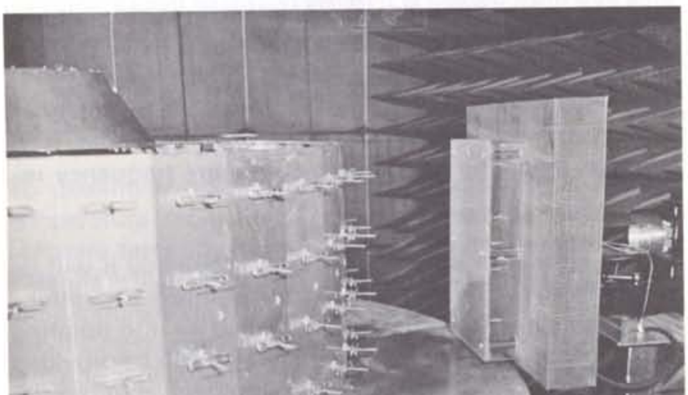


*Figure 7 – This 'near-field' probing system was set up to verify the performance of the electronically de-spun Meteosat antenna after environmental testing. This verification, with the accompanying computer calculations shown in Figure 8, made it unnecessary to return the antenna for far-field testing.*

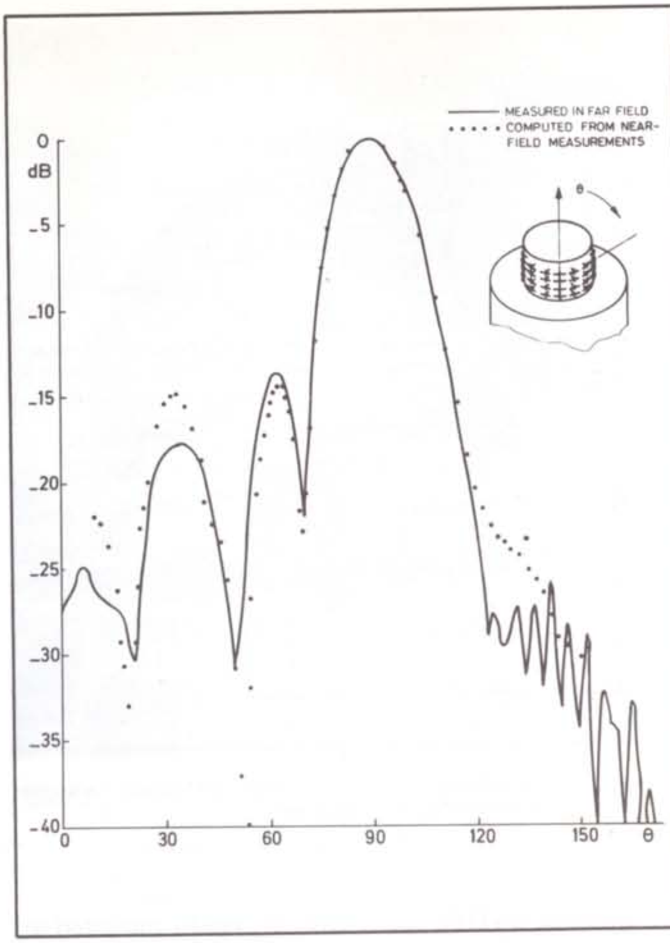



*Figure 8 – Results of 'near-field' probe measurements on Meteosat transformed to 'far-field' values and compared with direct measurements; this represents one of the first uses of the near-field test principle.*

test ranges for proper evaluation. How large a distance is required depends upon the antenna's size and the frequency to be used, but separations of several hundred metres are not uncommon. Not only does this rule out indoor testing, but outdoor ranges must also be arranged so that ground reflections are avoided.

One possibility is to site the test range in a mountainous region, as CNET (France) has done with its 1450 m 'La Turbie' range, which spans a 350 m deep valley. The SHF antennas for the Franco-German experimental communications satellite Symphonie were tested here.

Another possibility, combining an indoor facility with a maximum outdoor range of 200 m, is utilised by MBB in Germany (Fig. 6). Here, one side of an anechoic chamber consists of a weather-protective screen which is transparent to radio-frequency waves. The antenna under test is placed in the chamber and illuminated from the remote tower. This solution has the advantage of allowing a protected environment for the hardware under test.

Other outdoor ranges exist elsewhere in Europe, but all

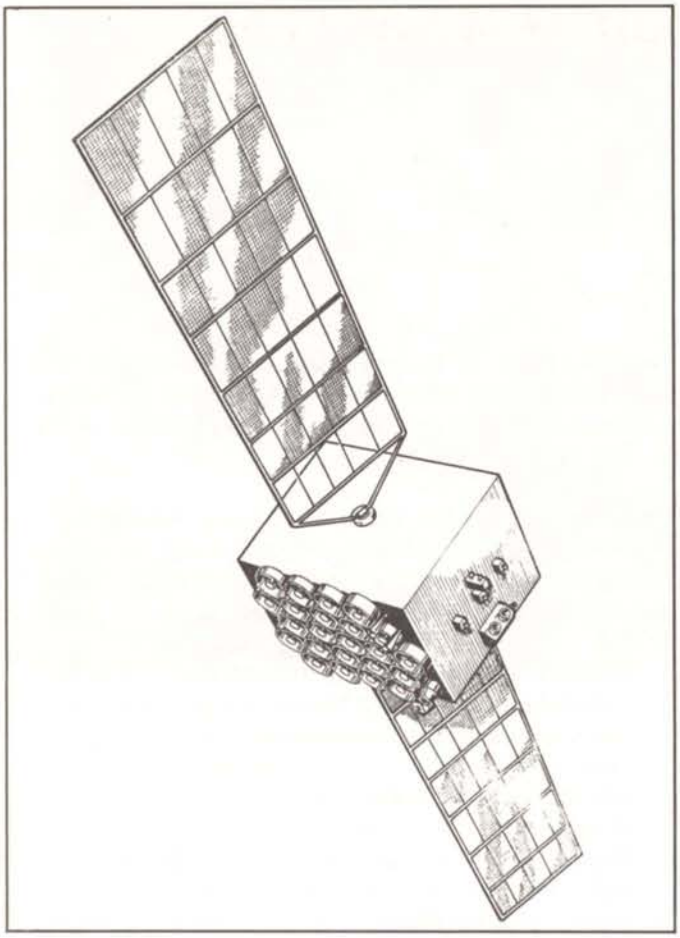


*Figure 9 – Multibeam array concept permits communication with aircraft, ships and other mobiles from the same payload.*

are sensitive to weather conditions and ground reflections. To circumvent these problems, a new technique is now being explored by ESA in which the radiation from the antenna is measured at close range and the corresponding far-field data are derived by computation. The necessary software and methodology is being developed at the Technical University of Denmark.

A range of intermediate length (107 m) which also uses data handling for far-field determination has been built by Marconi Research Laboratories for testing the Marots shaped-beam antenna.

Another direct application of near-field test techniques was developed as a diagnostic tool for the electronically de-spun antenna on Meteosat, to verify the performance of the antenna following environmental tests (Fig. 7). In this case, it was possible to compare the far-field pattern extrapolated from the near-field sampling with direct far-field measurements performed earlier: the good agreement, illustrated in Figure 8, meant that the method was sufficiently accurate to spot changes before and after testing, making it unnecessary to send the antenna system back to the manufacturer for far-field testing.

The second, 'Multibeam Array Antenna' research programme is aimed at payloads covering the frequencies allocated to communication with mobiles, namely the 1500-1600 MHz band. By using multiple overlapping beams for earth coverage, it is possible to significantly raise the effective radiated power compared with single-beam systems. The multiple beams rely on an array of elements, which makes it attractive to allocate one power amplifier to each element to increase the reliability of the system. This approach requires the development of several new system elements, including a high-gain radiator, diplexing filters, and beam-forming networks. In addition, a solid-state linear power amplifier that uses European transistors is being developed. The work is being carried out by a consortium led by L.M. Ericsson.

The Multibeam Array Antenna research programme has already been under way for more than a year, and the plan, because several new technologies are involved, is to demonstrate an electrical model of the concept in 1978. One interesting aspect of the study is that the multibeam concept offers the possibility to serve several types of mobile terminal simultaneously, including ships, aircraft and even emergency-type terminals (Fig. 9).

## CONCLUSIONS

Applications satellites have necessitated the development of completely new antenna types. European industry and research organisations have developed the necessary tools, software, hardware and test methods for this development, giving reasonable confidence that the flight hardware will perform as expected. Applied research efforts are being conducted in parallel in preparation for the second generation of satellites. □

# Co-ordinated Use of European Test Facilities

*R. Broezel, Directorate of Planning and Future Programmes, ESA, Paris*

**Unmanned automatic satellites are very expensive to develop and produce, and they are expensive to launch. Once in orbit, it is impracticable to repair any malfunction, and this will remain the norm even with the advent of Spacelab and its potential for satellite-repair missions. Consequently, they must be built to a high degree of overall reliability.**

**These days, many mathematical tools exist for the theoretical prediction of the in-orbit behaviour of a satellite and its subsystems. But these methods are only as good as the assumptions which are fed into them and which are necessarily a simplification of the actual complex systems and the many influences to which they are exposed. Thus, whilst mathematical models are important aids in the design and development of a space system, they are in themselves insufficient to qualify the system for reliable operation. It is for this reason that space hardware has to be subjected to physical tests which simulate actual operational conditions in areas such as thermal/vacuum, mechanical and acoustic vibration, spin, linear acceleration, deployment and mass properties, electromagnetic compatibility and magnetic properties.**

To the earth-bound engineer, some of the conditions that have to be endured in orbit by automatic satellites are quite exotic – unimpeded solar radiation, ultrahigh vacuum, and the extreme cold of space are just some of the features of the space environment that are not easily reproduced on earth over a volume sufficient to permit the testing of spacecraft. The facilities needed for these purposes are expensive in terms of both investment (in particular) and operation. A single test may well cost half a million US dollars, and the testing expenses for an automatic satellite could account for up to one third of its total development cost. Investment costs for the larger test facilities are typically of the order of several million dollars. In these circumstances it would have been unwise for the various European space firms to have constructed their own facilities. Europe's larger facilities have in fact been constructed either by the Agency or by national agencies, and made available to industry for the execution of their programmes.

There have always been sound economic motives for co-ordinating both the provision and use of these facilities on a European scale. The creation of ESA added considerable impetus to this trend for several reasons:

- Member States opted for reductions in their own national programmes in favour of a greatly expanded common European programme. This increased the Agency's test load beyond the capacity of its own facilities and a means had to be found of accommodating the 'overflow'.
- The other side of the coin was that Member States were left with much less of their own programme work to place in their test laboratories, and this posed the question of the future of these laboratories.
- The Agency's facilities had been matched to the smaller scientific satellites of the ESRO programme, and could not accommodate the larger applications satellites included in the ESA programme, but facilities of sufficient size did exist in the Member States.
- Lastly, the use and co-ordination of Member States' facilities had been formally incorporated as one of the tasks of the new Agency.

ESA's Testing Division at ESTEC had foreseen the future trends to some extent and in 1973 made a study of the Agency's anticipated requirements and the potential availability of facilities, a task made simpler because the Division had earlier compiled a catalogue of the test facilities in Europe. The results of the study confirmed the Division's anxiety: unless the whole of Europe's test facilities were used in the most rational way possible, the ambitious ESA programme would run into serious difficulties. To cope with the situation, in 1974 the Testing Division created a system for the central co-ordination of the use and maintenance of all major test facilities usable by ESA, whether ESA-owned or not. Today the work of more than 200 people at national test centres is being organised in this way.

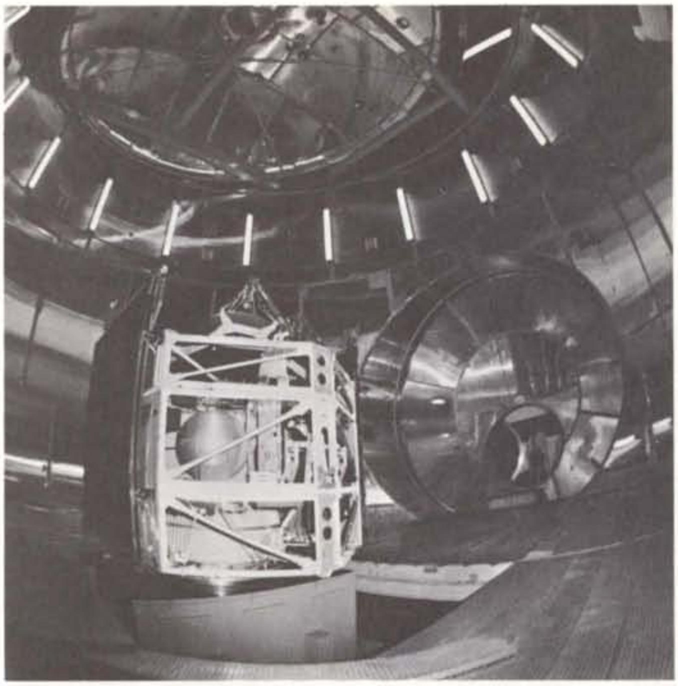


*Figure 1 – Large Dynamic Test Chamber at ESTEC, used for deployment and spin tests and mass-properties measurements under vacuum. (Dimensions: 10 m diameter × 14 m height; vacuum to $10^{-2}$ torr, internal mounting table connected to 90 ton seismic block).*

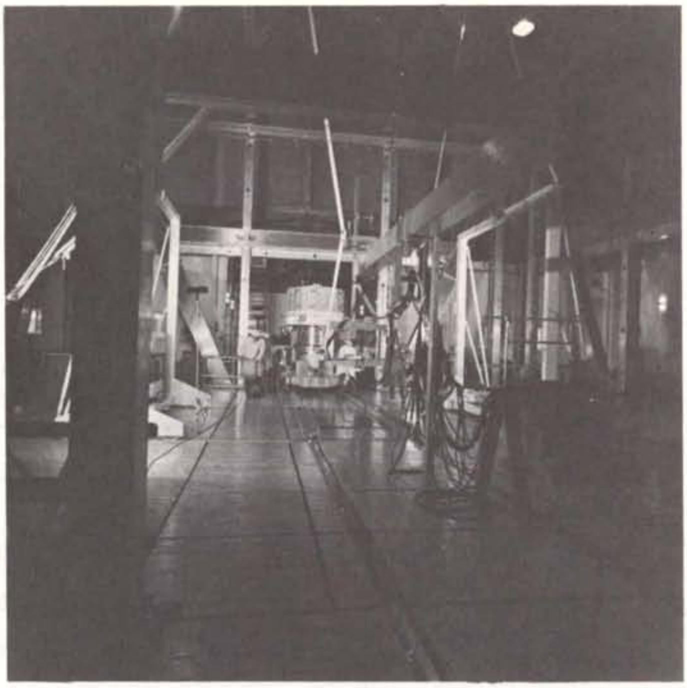


*Figure 2 – Large Magnetic Test Facility at IABG, Munich. (Facility is capable of creating, within a spherical volume of 3 m diameter, a residual magnetic field one hundred thousand times smaller than that of the earth. The magnetic coils are 15 m × 15 m × 15 m).*

## THE CO-ORDINATION SYSTEM

To illustrate what the system does and how it operates, it is convenient to see it as a commodity exchange, matching offer to demand, but with two important differences. First the price does not fluctuate with demand, and secondly, since the market is extremely restricted it cannot be operated on a first-come first-served basis. This would mean that neither the 'sellers' nor the 'buyers' would be well-served; the exchange has to be managed in an orderly manner and in the interests of everyone. The major 'sellers' and their commodities are listed in Table 1 (the full inventory of European environmental test facilities in fact amounts to several thousand items), whilst Table 2 shows the major 'buyers'.

The buyers or users (Table 2) comprise a significant number of independently-managed projects, each of which is continually seeking to optimise its own schedule and to minimise its costs. Each of these schedules is affected by access to limited test facilities which can only be used on a one project at a time basis. Schedule conflicts at the point of testing are inevitable. It is obvious then that there must be a central information system which receives the changing requirements of the customers in real time so that schedule conflicts can be identified for action.

This central master information file is maintained on ESTEC's computer by Testing Division's Operations Controller and is updated daily from a remote console. It contains around a thousand test requirements together with information which could affect the availability of the various test facilities (whether ESA or external), such as down-time for maintenance. The number of schedule changes entered per day is of the order of 10. The file extends in time as far as current information is available. Apart from its primary use for schedule co-ordination and the monitoring of problems areas, it includes detailed cost estimates which facilitate the rolling preparation of Testing Division's budget.

Testing Division assigns a Test Manager to each customer-project for any of the co-ordinated test facilities. His task is the co-ordination and follow-up of all testing requirements for that project, including schedule, test software and report writing, as well as feeding the central master information file. He is kept informed of the overall planning situation by the Operations Controller via a weekly short-term operational programme which covers the subsequent six months, in work units of half a day. This is the working tool for each Test Manager and for the Testing Division as a whole. The Operations Controller also issues when required a long-term plan covering four years, as well as individual project test programmes (when requested) and the planned programmes for each European testing centre.

TABLE 1

*Distribution of Major European Space Test Facilities*

| Facility | Utilisation |
|---|---|
| ESTEC | |
| – Dynamic Test Chamber | Dynamic tests under vacuum |
| – 3m Heat Balance Facility | Space simulation tests on spacecraft up to the size of Geos |
| – 2m Heat Balance Facility | Space simulation for subsystems of larger satellites |
| – 1.5m Thermal Vacuum Chambers | Temperature and vacuum tests on small satellites and subsystems |
| – Corona Chamber | Launch-pressure simulation. Corona tests on small spacecraft |
| – 14 ton and 7 ton Vibrators | Vibration testing of spacecraft, subsystems and experiments |
| – Magnetic Test Facilities | Magnetic measurements on subsystems and experiments |
| – Electromagnetic Compatibility Test Facilities | EMC tests on small satellites and subsystems |
| CNES, TOULOUSE | |
| – Large Space Simulator (SIMLES) | Heat-balance tests on applications satellites |
| – Small Space Simulator (SIMDIA) | Heat-balance tests on small satellites and subsystems |
| – 14 ton Vibrator | Vibration testing of all space hardware |
| IABG, MUNICH | |
| – Large Magnetic Test Facility | Testing of magnetically clean scientific satellites and experiments |
| – High-Intensity Acoustic Test Facility | Simulation of acoustic environment for space vehicles up to the size of Spacelab |
| – 14 ton Vibrator | Vibration testing of spacecraft, subsystems and experiments |
| – 2m Space Simulator | Space simulation testing of small satellites and subsystems of large area, e.g. solar panels |
| – Large Thermal Vacuum Facility | Vacuum temperature tests on large satellites, particularly those with high heat loads (e.g. Helios ) |
| UNIVERSITY OF LIEGE | |
| – Vacuum Optical Calibration Facility | Calibration of optical sensors, telescopes, radiometers (e.g. radiometer for Meteosat) |
| CEA-CESTA, BORDEAUX | |
| – Large Centrifuge | Linear acçeleration tests on large satellites |
| SNIAS, LES GATINES | |
| – Multi-Shaker Vibration System | Vibration tests on large structures (e.g. Ariane, Spacelab) |

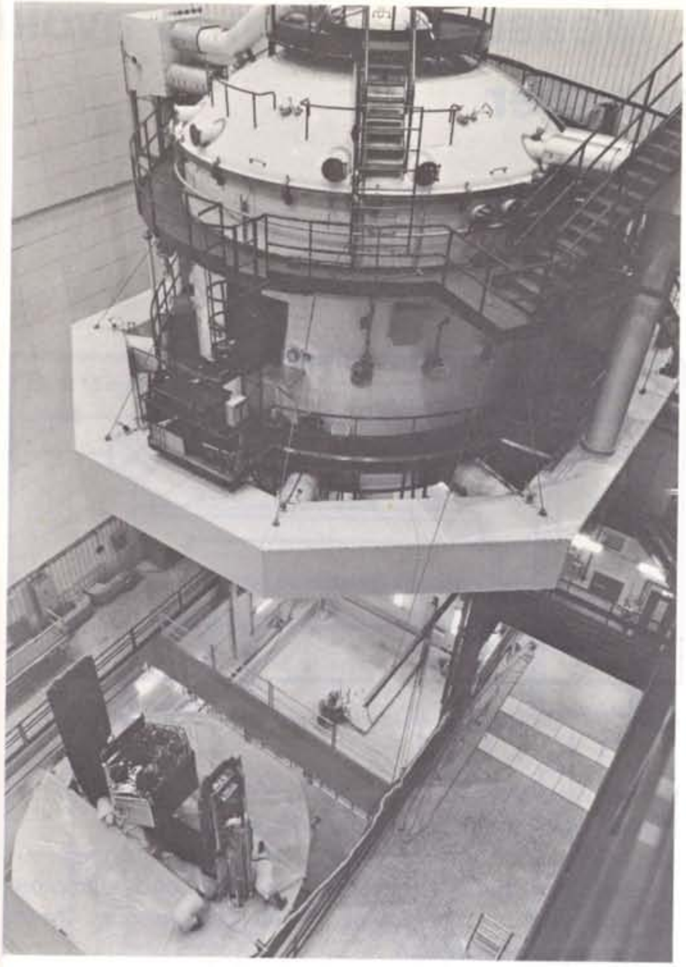


*Figure 3 – Large Space Simulation Chamber at CNES, Toulouse, used for heat-balance tests. (Dimensions (main chamber): 7 m diameter × 9 m height. Parallel solar beam of 3 m diameter and max. solar intensity 1.4 times that in earth orbit. Shroud temperature 100-360 K. Motion simulator has continuous spin motion).*

Finalisation of the co-ordinated programme is effected by the Division's Test Management Section. Here the technical and schedule requirements are married with availabilities, and conflicts are resolved by what is known as 'active scheduling' – discussing with the parties involved and trying to solve problems by agreement without the imposition of priorities. Experience has shown that this method works well; up to now there have been only two major 'hard conflicts' which have had to be referred to the Directorate for a decision.

The tests themselves are carried out either in ESTEC facilities by the Division's Operations Section or at external test centres under contracts managed by the Test Management Section. Memoranda of Understanding have been established between ESA and the operators of the two major extramural test centres (IABG and CNES) to define the general contractual relationships; within the terms of these agreements, annual contracts are concluded to cover the work planned for the year in question. With other test centres, individual contracts are placed in accordance with requirements.

TABLE 2
*Major Current European Space Development Programmes*

| | |
|---|---|
| Aerosat | Marots |
| Ariane | Meteosat |
| Ariane Passenger Experiments | OTS |
| Exosat | Sirio |
| Geos | Spacelab |
| IRAS | Spacelab Payloads |
| ISEE-B | Space Technology |
| IUE | |

## INTER-CENTRE TEST COMPATIBILITY

The shared use of test facilities developed and installed in different centres and at different times raises many problems of a technical as well as managerial nature. If testing work is to be moved freely around the various European facilities, plainly standardisation must be attempted not only in test methods and interpretation of results, but also in the interfaces between the test facilities and the test specimens. These include such aspects as:
- mechanical interfaces (e.g. hole patterns on shaker tables)
- electrical interfaces (e.g. connectors, voltages, earthing patterns)
- measurements (e.g. types of thermocouples and accelerometers; solar-intensity standards, solar-intensity sensors)
- software (e.g. data-handling procedures, computer programs, quality-assurance procedures).

Considerable progress has already been made in all these areas. There is now a common European solar-intensity standard which is co-operatively updated; there exists a *de facto* European pool of accelerometers which avoids the need for their disassembly whenever a specimen is moved from one laboratory to another; in future, only one type of thermocouple will be used, requiring only one type of connector. Much has been done – thanks to the goodwill of all the organisations involved – but much still remains to be done. □

# Launch-Vehicle Vibrations – Measures taken to avoid 'POGO' on ESA's Ariane Launcher

*Ph. Couillard, Ariane Project Team, CNES, Paris*
*W.G. Naumann, Ariane Department, ESA, Paris*

**Experience shows that heavy launch vehicles that rely on liquid propellants can be susceptible to oscillations resulting from vibrational coupling between the vehicle's structure and its propulsion system. As such oscillations can be detrimental to both the launcher itself and its payloads, special attention is being paid to their elimination in designing and building the Agency's heavy launch vehicle.**

## THE POGO PHENOMENON

The vibrational coupling between a launch vehicle's structure and its hydraulic/propulsion system which can give rise to mechanical oscillations – termed the 'POGO' phenomenon – during flight is illustrated schematically in Figure 1. When the thrust from the vehicle's engines fluctuates, structural vibrations occur which lead to fluctuations in pressure and flow rate in the propellant feed lines. Consequently, the engine's chamber pressure and thrust fluctuate in sympathy. Because of the large amounts of energy produced, this closed loop can be unstable, in which case POGO effects occur.

To study the stability of the POGO 'loop' one assumes that the coupling between propulsion system and structure occurs in the vicinity of one particular oscillatory mode of the structure; the validity of this assumption is borne out by experiment. The behaviour of the structure can then be represented by a modal equation. Assuming that pressure and flow-rate fluctuations are small compared with static pressure and flow rates, one can obtain a linear differential equation representing hydraulic behaviour for each feed line.

In representing the combustion chamber, the condition for mass conservation in the chamber yields a fourth equation. These four equations together lead to a linear differential system, the stability of which has to be determined in order to ascertain the mechanical behaviour of the launch vehicle.

By examining the four equations, it can be deduced that of

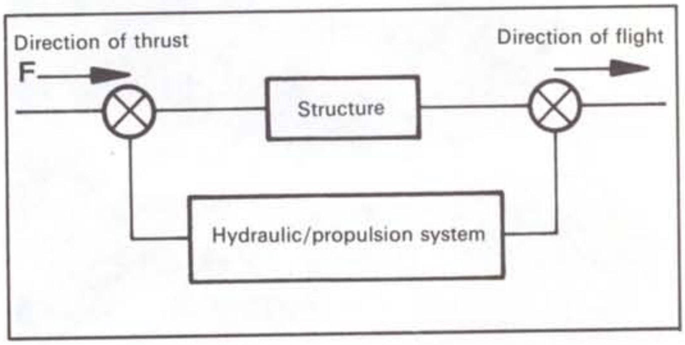



*Figure 1 – Concept of vibrational coupling and POGO effect.*

the many parameters that can influence the stability of the POGO loop, the most important are:

- the 'excitability' of the structural modes characterised by their generalised masses and damping coefficients; the risk of POGO decreases as these parameters increase
- the characteristics of the feed lines (mainly the resonant frequencies of long feed lines) and the pumps
- the combustion chamber parameters, although these are generally not of primary importance.

Because structural rigidity is one of the parameters that plays a role in determining the presence or degree of vibrational coupling, the thrust frames of all three stages of the Ariane launcher will be designed to have a fundamental frequency higher than 80 Hz. The configuration of the first stage's thrust frame in particular has been chosen from a number of possible solutions using the problem of POGO as a selection criterion.

## STUDIES OF POGO

The Ariane POGO studies are studies of stability, involving essentially a search for unstable frequency regions by modelling the structural, hydraulic and propulsion characteristics of the launch vehicle and applying stability criteria. Instabilities among the first three modes can be identified with comparatively high accuracy, and experience has shown that there is a very low risk of POGO effects occurring at higher modes.

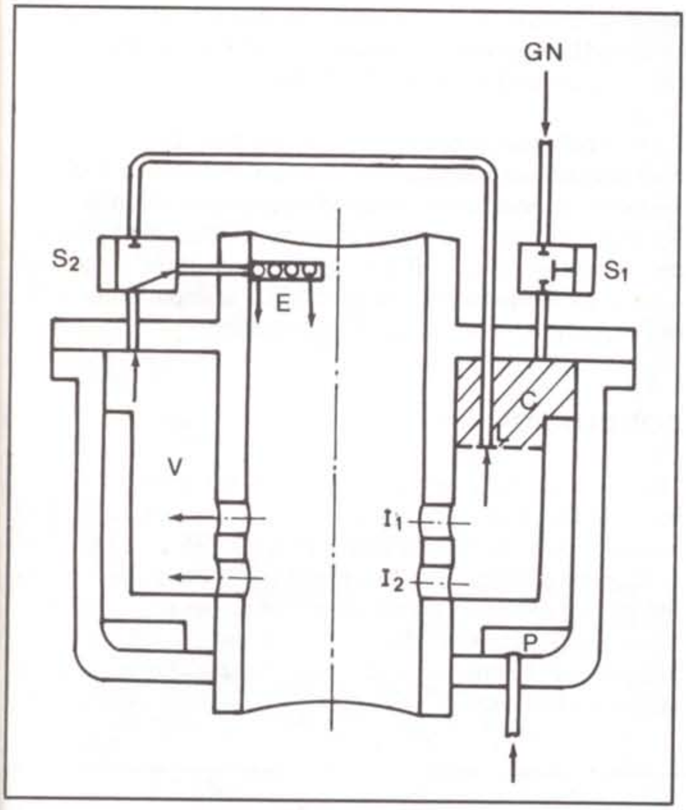



*Figure 2 – Schematic of the POGO Correction System (PCS).*

It must be realised, however, that no prediction can be made from such studies as far as *levels* of vibration are concerned. Nor is any other sort of calculation or test considered capable of providing realistic information on the levels to be expected in flight. Figures presently quoted for the vibrational levels to be withstood by Ariane payloads are therefore global values derived from earlier vehicles that have already flown. In view of the nature of the phenomenon, it will not be known until the actual flight tests whether POGO will occur, and to which level. However, this uncertainty should not create problems for operational users, in view of the stated objective of eliminating its effects from the vehicle by the first operational launch at the latest.

It is hoped to achieve this by employing what is called the 'POGO Correction System' (PCS). In electrical oscillating circuits, instabilities are damped out by the introduction of capacitances and inductances. Drawing on the analogy between electrical and mechanical circuits, it is intended to damp any POGO oscillations on Ariane by introducing a mechanical device into the hydraulic circuits that has appropriate equivalent 'capacitance' and 'inductance' characteristics.

In practice, this means shifting the hydraulic circuit frequencies away from the structural resonance frequencies by proper choice of the capacity of the PCS. Determination of these characteristics is one of the major objectives of the current POGO studies, which are iterative in nature. At each iteration, previous calculations are repeated, but with inputs that are gradually improved and refined as more and more test data become available.

Since the POGO effect is very sensitive to structural and hydraulic characteristics, it is important to ensure good knowledge of these parameters in order to establish mathematical models that are as realistic as possible. Dynamic structural characteristics are being measured on a full-scale model of the Ariane vehicle and, in addition to specific tests, measurements are being made during normal development testing to determine POGO-sensitive functional characteristics of the propellant feed lines, turbopumps and combustion chamber.

Four iterations have been foreseen:

| | |
|---|---|
| First phase: | prediction of unstable frequency regions and modes for static firings and for flights (preliminary POGO study) |
| Second phase: | definition of functional PCS requirements |
| Third phase: | setting of PCS characteristics for ground testing and for the first Ariane flight |
| Fourth phase: | analysis of flight results and resetting of PCS characteristics if necessary. |

By the end of last year, the second study phase for the Ariane launcher's first and second stages had been completed, making it possible to arrive at a formulation for the POGO Correction System and to specify its functional characteristics. The third phase of the study, which will be carried out during 1977 and the first half of 1978, will rely largely on structural and hydraulic characteristics derived from testing (dynamic mock-up; specific hydraulic and propulsion tests). Finally, the results obtained will be refined during the first quarter of 1979 to set the PCS characteristics to be employed for the first Ariane flight (June 1979).

### THE POGO CORRECTION SYSTEM

The PCS system consists of several correction devices which form part of the launch vehicle's feed lines and ancillary equipment. Its operating principle can be seen from Figure 2. 'Inductance' is determined by the holes $I_1$ and $I_2$, and 'capacitance' by the level L. In the absence of any pressure (GN) in the capacity C (passive state), the propellant fills V completely, any remaining gas being evacuated through the line V-$S_2$-E. When pressure is supplied and at the same time the connection between V and E is interrupted – by simultaneously operating the corresponding valves $S_1$ and $S_2$ – the volume V is filled by nitrogen gas to level L, where equilibrium is attained (activated state). When the propellant pressure rises, the propellant rises above the level L and closes the orifice of the line L-$S_2$-E. The gas still arriving increases the pressure in the capacity C and displaces the gas until it again reaches level L. The inductance of the system can be changed by applying gas pressure at P, causing the piston to move up and obstruct the holes $I_2$.

Functional models of the PCS have already been tested in order to choose a basic configuration. Procurement of the system has now been initiated and qualification will be achieved in mid-1977. The system will then be operated during static firings of the first and second stages of Ariane to demonstrate its functional compatibility with the launch vehicle's propulsion system.

### CONCLUSION

The studies and tests carried out so far would seem to indicate that it should be possible to eliminate any POGO instabilities on Ariane by employing the POGO Correction System proposed. It is intended to use the PCS system on the launch vehicle's first and second stages only, it having been demonstrated that there is much less risk of vibrational coupling occurring during firing of the vehicle's third stage. □

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## Satellite Meteorology – Summer School

Alpbach, Austria, 3-12 August 1977

This Summer School, sponsored by

- Osterreichische Gesellschaft für Sonnenenergie und Weltraumfragen (Austrian Solar and Space Agency, ASSA), Vienna
- Centre National d'Etudes Spatiales (CNES), Paris
- Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR), Köln Porz-Wahn
- European Space Agency (ESA), Paris
- Royal Norwegian Council for Scientific and Industrial Research (NTNF), Oslo
- Swedish Board for Space Activities (SBSA), Stockholm
- Kommission für Weltraumforschung, Schweizerische Naturforschende Gesellschaft (SNG), Bern

will be concerned with:

- meteorological requirements for satellite data
- satellite systems and instrumentation
- data interpretation
- special investigations (ice, snow)
- image interpretation
- economic aspects and future prospects.

The course will comprise morning lectures, practical workshops in the afternoons, and lectures and film presentations in the evenings. All lectures and workshops will be conducted in English. The course fee is 500 Austrian Schillings (accommodation not included).
The number of participants will be limited to fifty and selection will be restricted to applicants from Austria, Norway and ESA Member States. Further information can be obtained from:

The Austrian Solar and Space Agency
Attention – Dr. Mondre
Garnisongasse 7
A-1090 WIEN, Austria.

# The Agency's New Head Office

*G. Nichols, Directorate of Administration, ESA, Paris*

After starting life in a number of buildings in the La Perouse – Iéna – Marceau area in Paris, the European Space Research Organisation and European Launcher Development Organisation came together in 1967 in rented premises at 114 Avenue Charles de Gaulle, Neuilly-sur-Seine. It was at this address that the European Space Agency came into being, replacing the two original Organisations.

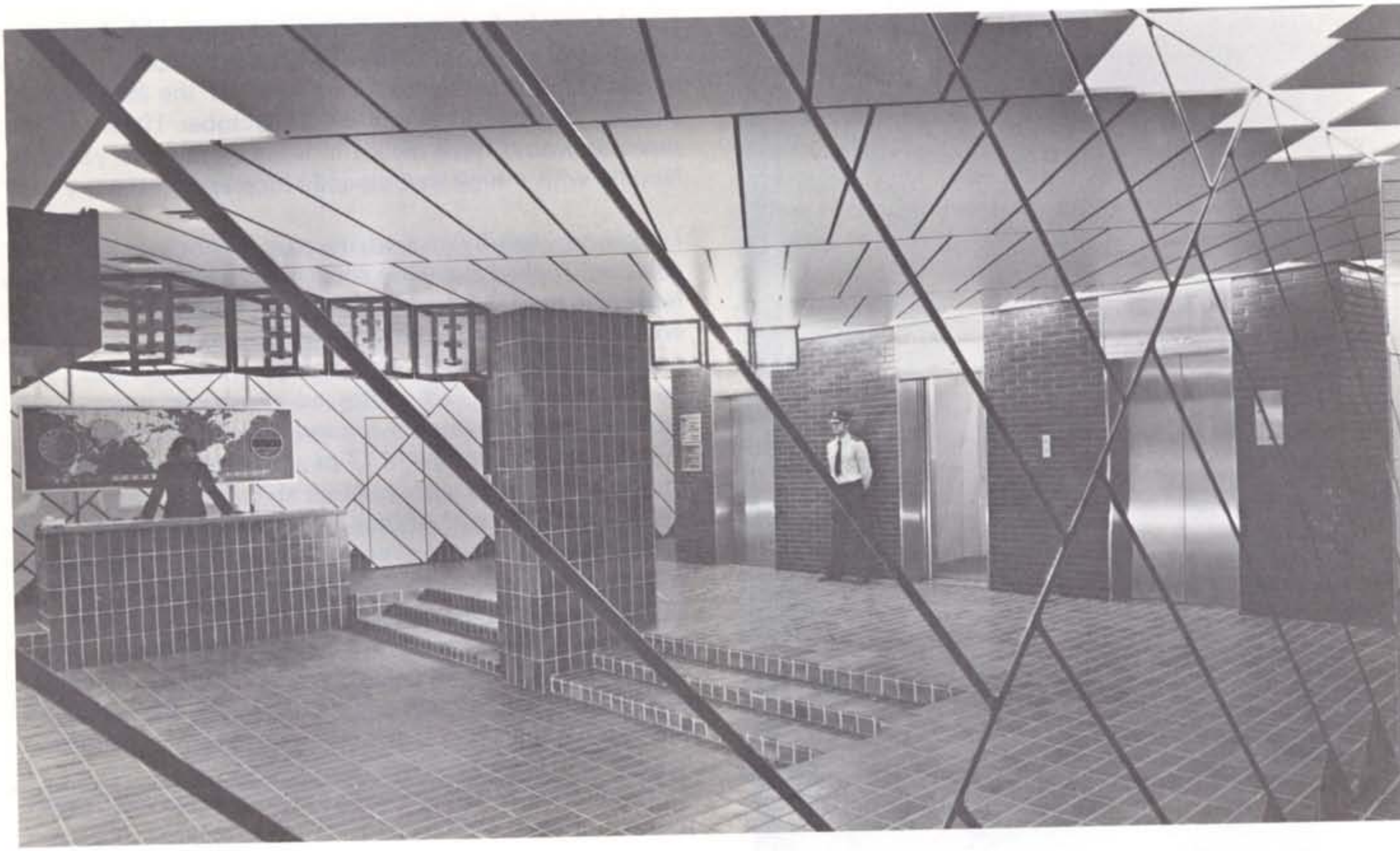
The Council of the new Agency decided in 1975 that we should be housed in our own building, and a search was made in the Paris area for a suitable solution. At that time, it was estimated that there were about one million m² of unoccupied, newly built office space in the Paris area, but prices were high and it was not easy to find a parcel of about 10 000 m² which would suit ESA. On the other hand, to embark on a new construction would also have been costly and would certainly have taken too long. Time was an important factor. The lease of the building in Neuilly was due to expire on 31 October 1976 and its renewal would have meant at least three more years in Neuilly with a high and steadily increasing rent.

Luck undoubtedly played its part in finding the right solution. Tucked away in a small private road called Mario Nikis – a road unknown even to the Paris taxi-drivers – we found an old building which had been in the possession of Thomson-Brandt since 1953 and was used partly as offices and partly as electronic component laboratories. It covered a ground surface of about 1720 m², about 100 m long and 17 m wide. In fact, it consisted of three buildings constructed at different times from 1936 onwards, with different architectural styles, and which had been made, over the years, into one building. It was the right size, the right price and conveniently situated, just off the Avenue Suffren within sight of the UNESCO building. But the inside would have to be carved out and rebuilt entirely and, as for the outside, no one could deny that it was ugly. However, the walls and the foundations were solid and made to last for centuries.

In the summer of 1975, small study contracts were given to three firms of architects, who were required to submit plans for renovating the building and converting it to meet ESA's requirements. They were also required to give detailed cost estimates, a description of the management system proposed, and time-planning schedules. Mario Nikis had become an ESA project in its own right and we were well into Phase A.

The project presented three interesting problems, for which the competing architects had to propose solutions:

- The first was inherent in the conversion of an old building, particularly one that had seen so many changes in its structure during its lifetime. The architectural plans were not complete and were inaccurate in parts. The thickness of the floors varied and successive layers of cement, plaster tiles, etc. had been added over the years. In fact, there were surprises around every corner.
- The second was what to do with the facade.
- The third was to plan the whole operation within the



*Entrance Hall*

extremely tight time scale and, of course, within the financial envelope approved for the project.

The three firms of architects presented the results of their studies to a committee set up by the Director General under the chairmanship of the Director of Administration and with the participation of an expert kindly made available to the Agency by CNES.

The architects selected were the Atelier de l'Urbanisme et de l'Architecture (AUA), represented by Valentin Fabre and Jean Perrottet.

A management team was set up consisting of ESA as 'maître d'ouvrage', with two associated firms (Burt and Lyon SA and Gerba SARL) as management and technical consultants, the architects (AUA) with their Design Office as 'maître d'oeuvre', and GCE (Groupe de Coordination d'Entreprises) as planning co-ordinators. The team's first task was to prepare the invitations to tender for the main building contract. These were issued on 7 November 1975, with 26 November 1975 as the closing date, probably one of the shortest ever tender periods for such a project.

The invitation to tender came at a time when the building trade in Paris was going through a slack period after the boom of the previous years. Seven major firms replied and competition was fierce.

The contractor selected was Fougerolle, whose recent achievements include the Charles de Gaulle Airport in Roissy, the Sofitel-Sèvres Hotel, the Porte Maillot roundabout and the Tour Aquitaine (one of the office towers in La Défense).

*Large Conference Room*

*Restaurant and Snackbar*

The contract was signed on 17 December, with a contractual period of nine months for completing the work. Because of the importance of respecting the time scale, a very high penalty for each day's delay in delivering the building was written into the main contract.

Although the baseline concept for the project had been defined by the end of 1975, there had to be close collaboration between the management team and the contractors to refine the detailed specifications and to take account of the difficulties and the surprises that were met as the work progressed. In fact, this close collaboration continued throughout the project and was undoubtedly one of the factors that enabled the work to be completed on time.

As foreseen, the building was ready for occupation on 1 October 1976, and by mid-October the Agency's Head Office was fully installed in its own building.

In addition to the individual offices, which have been distributed on a functional basis, there are two main Conference Rooms separated by a spacious foyer where delegates can meet less formally. The larger Conference Room can seat 51 around the table, with a total seating capacity of 150; the smaller seats 34 around the table, with a total capacity of 72. The restaurant is run by outside caterers, and also contains a snack bar. There are seats for 74 in the restaurant and 26 at the snack bar.

Finally, a word about the facade. One can like it, one can dislike it, but no-one can be indifferent to it. The outside appearance of the building has been likened to an ocean liner, as well as to certain less exotic edifices which form part of Victoria Station in London! What is certain is that it is striking and that it has completely transformed the small street of which it forms the largest part. □

# In Brief/En bref

## Director General visits Hughes Aircraft Company

In the accompanying photograph, Mr. A.D. Wheelon (Vice-President of Hughes Aircraft Company and Group Executive) can be seen presenting part of Intelsat IV A to his visitors during Mr. Roy Gibson's visit to Hughes Aircraft Company in Los Angeles, on the occasion of the Ariane presentations made in the United States and Canada last October.

## Visite de la Base de Lancement de Kourou

Au cours d'une visite effectuée les 25 et 26 novembre 1976 sur la Base de Lancement de Kourou (Guyane française), M. Hubert Curien, Président du Centre National d'Etudes Spatiales (CNES) et M. Roy Gibson, Directeur général de l'ASE, ont pu observer l'avancement des travaux sur l'Ensemble de Lancement de l'Agence, à partir duquel seront lancés à compter de la mi-1979 les lanceurs Ariane. Ils ont également passé en revue toutes les principales installations du Centre Spatial Guyanais ainsi que du Bureau de l'Agence à Kourou.

## Creation of a European Ocean Satellite Programme

During a meeting held in London on 30 November and 1 December 1976 a European oceanographic programme was formulated with a view to using data from the American oceanographic satellite Seasat-A, to be launched in May 1978. The meeting was arranged by the European Association of Remote Sensing Laboratories (EARSeL), an association formed during a remote-sensing meeting at the Technical University of Denmark, Lyngby, in September 1976, under the auspices of the Parliamentary Assembly of the Council of Europe, the Commission of the European Communities, and ESA. The aims of EARSeL are:

- to promote co-ordination of European research on various aspects of remote sensing to the benefit of mankind
- to facilitate the exchange of ideas and scientific information between the participating institutions, and
- to identify priority sectors of research in remote sensing.

The London meeting, attended by 35 European scientists and engineers, with representatives from the Council of Europe, ESA and the American Seasat programme, formulated a European programme related initially to the North Sea and the Northeast Atlantic, where various oceanographic investigations are already planned for 1978/79.

One part of the programme concerns sea-surface topography, which can be measured by means of the microwave altimeter on board Seasat-A. The measurements will also be used to determine the shape of the earth with high accuracy and a comparison will be made with the geoid determined by other methods. The high accuracy is made possible by very exact tracking of the satellite's orbit, by five laser ranging stations and some ten Doppler tracking stations which will be operating in Europe during the programme. In addition, it will be possible to determine wave heights to an accuracy of 20 cm.

Apart from the scientific value of the measurements in establishing an exact geoid, they will provide experience with models for forecasting sea flooding around North-Sea coasts and for determining tidal powers.

The other part of the European programme is related to other oceanographic features, such as waves, wind, surface temperature and salinity, which may be determined by combining data from Seasat-A's other sensors; namely the synthetic aperture radar, the scatterometer, the scanning multifrequency microwave radiometer system, and the infrared and visual sensors. The satellite measurements will be compared with an extensive set of measurements made in a co-operative effort over the same areas, from ships and buoys, from oil rigs and research platforms, and from aircraft fitted with sensors equivalent to those on board the satellite.

This research will further our physical understanding of the dynamics of waves, needed for designing ships and oil rigs and for harbour construction. The carefully controlled measurements will also serve to calibrate the satellite's sensors for the vast oceanic areas for which sea-surface information is not yet available.

The success of the European programme is dependent upon the provision of a station in Europe equipped to receive and pre-process the satellite data. Such a station is included in the Agency's plans for a European satellite data network. □

# ESA Scientific and Technical Review
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The following papers were published in Vol. 2, No. 4:

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**Material sciences in space - A brief review of proposals for the First Spacelab Mission,** *by G. Seibert*

ESA has recently conducted a number of studies and surveys on the value of performing material-science experiments in space. After evaluating replies to a 'Call for Ideas' and an 'Announcement of Opportunity' for the First Spacelab Payload, it has been decided that the first phase of utilisation of the near-zero-gravity environment should be devoted to applied research. The rationale of the material-science experiment payload recommended by the Agency for the first Spacelab mission is presented, and the equipment and facilities needed for mission support are described.

*L'Agence spatiale européenne a récemment effectué des études et recherches sur l'intérêt des expériences en sciences des matériaux dans l'espace. Une fois évaluées les réponses faites à la 'Demande de suggestions' et à 'l'Invitation à participer aux expériences' pour la Première Charge utile Spacelab, il a été décidé que la première phase des expériences en conditions proches de l'apesanteur serait consacrée à la recherche appliquée. On présente le principe des expériences en science des matériaux recommandées par l'Agence pour la première mission Spacelab et on décrit les équipements et installations requis pour le soutien de la mission.*

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**The future use of European electric propulsion by ESA,** *by H.A. Pfeffer, E. Slachmuylders & C. Rosetti*

ESA interest in electric propulsion (EP) for north-south station keeping (NSSK) of high power, long-life communication satellites is discussed. NSSK mass savings made possible by using EP instead of chemical propulsion are identified. Technical options, corresponding economic impacts for utilisation of mass savings for payload capacity increases, reliability and satellite life extension are discussed. The case is presented for a low risk, cost and time effective progressive introduction of EP for NSSK utilising a new 'heavy' European platform. Design options for an EP system are presented and the status of European EP technology is reviewed. Activities necessary to reach first-flight status are discussed. It should be noted that the views expressed in this paper do not represent an agreed policy or programme on the part of the Agency.

*On examine dans cet article l'intérêt que présente pour l'Agence spatiale européenne l'utilisation de la propulsion électrique pour la mise à poste nord-sud de satellites de télécommunications de grande puissance et de longue durée. Après avoir déterminé les gains de masse obtenus par rapport à la propulsion chimique, on discute les différentes options techniques et l'incidence économique de la marge de poids ainsi rendue disponible pour une plus grande capacité d'emport, une meilleure fiabilité et un fonctionnement plus durable. On fait valoir les avantages que présente l'utilisation planifiée - et par là même peu risquée et peu coûteuse - de la propulsion électrique sur une nouvelle plate-forme 'lourde' de conception européenne. On passe en revue les différentes solutions possibles ainsi que l'état actuel de la technique européenne en la matière. Enfin on examine quelles sont les tâches à accomplir pour parvenir au niveau requis pour un premier vol. Les vues exprimées dans cet article ne préjugent pas de la politique qui sera suivie par l'Agence ni de ses activités dans ce domaine.*

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**Evaluation de fiabilité fonctionnelle des systèmes de communication en hyperfréquence pour satellites,** *par M. Pollacsek*

*L'évaluation de la fiabilité des systèmes de communication en hyperfréquence requiert une connaissance suffisante à un triple niveau: système de communication, sous-systèmes divers et composants hyperfréquences. On passe en revue les trois méthodes d'analyse couramment utilisées (méthode analytique, techniques* *de graphe de fluence et simulation 'Monte Carlo'). On en conclut que la fiabilité fonctionnelle d'un système de communication doit être une activité suivie tout au long du programme depuis la phase conceptuelle jusqu'à la réalisation intégrale du satellite.*

Evaluation of the reliability of microwave communication systems requires sufficient knowledge at three levels, embracing the communication system, various sub-systems and the microwave components. The three methods of analysis currently in use (analytic method, flow graph technique and 'Monte Carlo simulation') are described. It can be concluded that the pursuit of functional reliability for a communication system should constitute a continuous task throughout the duration of the project, from the design phase to readiness of the complete satellite.

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**Les composants semi-conducteurs hyperfréquences dans les satellites de télécommunications,** *par P. Monier*

*On compare les différents types de composants semi-conducteurs hyperfréquences utilisés dans les satellites de télécommunications. Quelques indications sont données concernant les avantages et inconvénients de chaque type et leur évolution probable pour les années à venir. Les problèmes posés par les conditions d'emploi et la fiabilité des composants sont brièvement analysés.*

Different types of microwave semiconductors used in telecommunications satellites are compared with an assessment of the respective advantages and drawbacks of each type and their probable evolution in the years to come. Problems arising as a result of operating conditions and component reliability are briefly discussed.

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**European tests on materials outgassing,** *by A. Zwaal*

With a view to international co-ordination of spacecraft materials, a number of European firms and institutes have performed outgassing tests on identical materials at 125°C in high vacuum. This paper presents the outgassing data obtained with the different types of equipment and discusses both the results and the critical parameters.

*En vue de coordonner leurs activités dans le domaine des matériaux à usage spatial, un certain nombre de firmes et instituts européens ont procédé, à partir de matériaux identiques, à des essais parallèles de dégazage sous ultra-vide à 125°C. Les résultats obtenus sur différents types d'installations sont présentés puis discutés, en même temps que les paramètres critiques.*

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**Study of the dynamic interaction between the two ISEE spacecraft in launch configuration,** *by A. Fournier-Sicre, J. de Kruyf & I. Quintas*

The dynamic interaction of the two ISEE satellites riding piggy-back during launch has been analysed. This particular analysis is critical because of the low stiffness of the lower satellite and of the upper satellite's 'appendages.' The mathematical model of the lower satellite was generated by NASA, and that of the upper by ESA, who also modelled the coupling. Dynamic transmissibility curves from the base of the lower satellite have been derived, and a short parametric study of the effects of the upper satellite's appendages is also presented.

*On analyse l'interaction dynamique du couple de satellites ISEE en position superposée au cours de la phase de lancement. Cette analyse revêt un caractère critique du fait de la faible rigidité, d'une part, du satellite 'portant', d'autre part, des appendices du satellite 'porté'. Le modèle mathématique du premier satellite a été élaboré par la NASA, et celui du second par l'ASE, qui en a également étudié le couplage par simulation. Après avoir déterminé les courbes de transmissibilité dynamique à partir de la base du satellite inférieur, on présente une brève analyse paramétrique des effets subis par les appendices du satellite supérieur.* □

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