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The Netherlands astronomical satellite (ANS)

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In the summer of 1974 an American space vehicle will put into orbit round the Earth a satellite that was designed and constructed (except for one of the measuring systems) in the Netherlands for astronomical research. The article below is the first of several that will appear in Philips Technical Review about the design and construction of this satellite (known in the Netherlands as 'ANS'), which has been entrusted to a consortium formed by Fokker-VFW and Philips. In this first article the authors have confined themselves to a general description of the configuration and operation of the satellite and to a brief account of the nature, history and organization of the project. Later articles will deal more thoroughly with some of the components of the satellite such as the attitude-control system, the onboard computer, and the sensors and actuators.

Nature and aims of the project

Work has been going on in the Netherlands for some time on a project whose aim is to put a small astronomical satellite into orbit around the Earth. The project is known in the Netherlands as 'ANS', an acronym for *Astronomische Nederlandse Satelliet*. This activity was preceded by an earlier phase that started in about 1965.

By this time it had begun to become clear that industry — not only in America, but in Europe too — received new stimuli ('spin-off') through taking part in advanced activities connected with space technology. In Europe a considerable amount of the work in space technology was carried out under the auspices of the European space agencies ESRO and ELDO, financed by the member countries, which included the Netherlands. Apart from these activities a number of European countries also had their own space programmes, which is still the case today. The effect of this was that the industrial organizations in these countries were well placed to serve as contractors for ESRO and ELDO, because of their greater experience, as was confirmed by the contracts that were given to these firms. In order to obtain the experience necessary for effective contribution to international space activities it therefore appeared that a national space programme would also be desirable for the Netherlands.

At about the same time it began to be apparent that space technology had much to offer astronomy in the way of completely new possibilities: with instruments in satellites observations could be continued during long periods of time outside the undesirable influences of the Earth's atmosphere. There was considerable interest in these ideas in the Netherlands, a country that has long occupied a prominent place in astronomy. This could only partly have been satisfied by the limited facilities offered for installing observing instruments on board European or American satellites.

These incentives, which remain equally strong today, led to the formation of a working group, in consultation with the Ministries concerned, consisting of representatives from astronomical groups and industrial firms. There were representatives from the Departments of Astronomy at the Universities of Groningen, Leiden and Utrecht, from the industrial firms Fokker, Van der Heem and Philips, and at the initial phase also from the Netherlands Aero Space Laboratory (NLR). Two separate proposals emerged from the deliberations of the working group, both based on the same kind of scheme. These proposals were formally presented in July 1966; the astronomers presented their proposal to the Minister of Education and Sciences, and their industrial partners presented theirs to the Minister of Economic Affairs. In each of the proposals a plan for the technical realization of the project was included, accompanied by a brief time scale and a cost estimate. On the basis of these proposals and after positive advice from NLR the industrial firms were asked by the Netherlands Government to carry out a design study.

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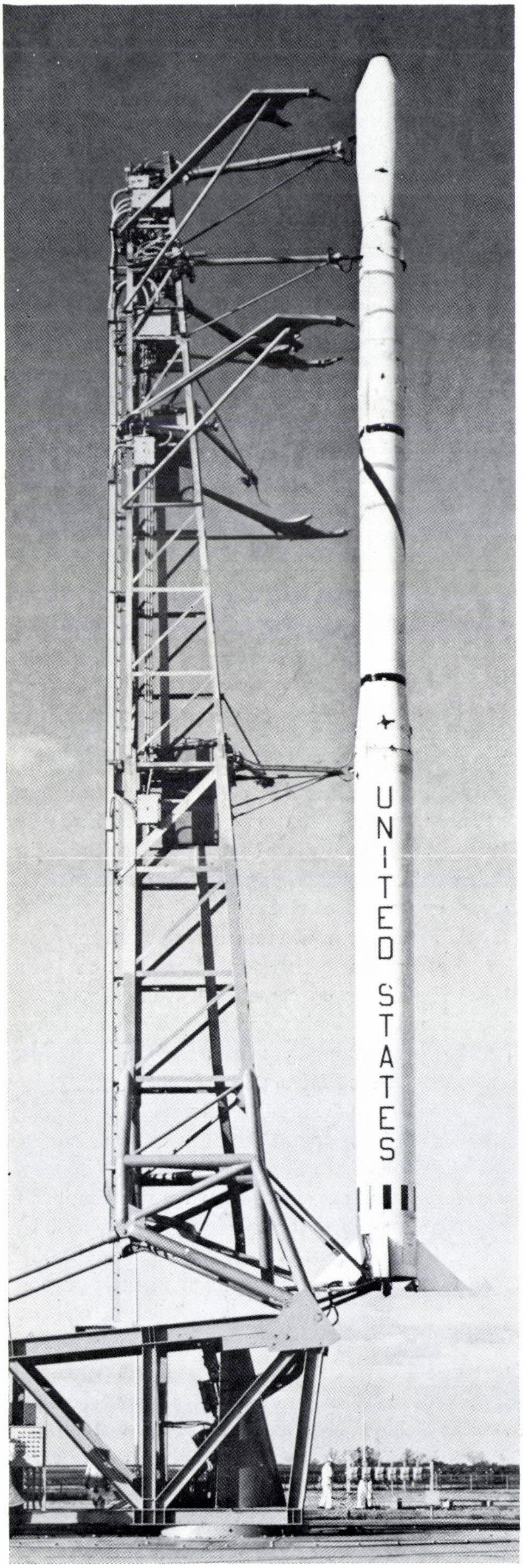


Fig. 1. A space vehicle of the Scout type on its launching tower. This four-stage rocket (length 22 m, launching weight 20 tons) will be used to put the Netherlands astronomical satellite (ANS) into orbit around the Earth.

To enable this study — and later on the project, if one resulted — to be carried out in the most effective way consultation was set up between Fokker and Philips (Van der Heem had in the meantime joined the Philips group of companies). This consultation has led to the setting up of the 'ANS Industrial Consortium' (ICANS). This has the legal status of a partnership firm, with Philips and Fokker as the two partners. The board consists of four members: the chairman, the secretary and two executive members — the authors of this article. The agreement setting up the consortium was signed in November 1968.

In the meantime, in consultation with the Ministry of Economic Affairs, a start had been made in October 1968 with the design study, for which a contract was signed in January 1969. As the result of a number of detailed studies that had been made in the interim period, a number of modifications to the original proposal were included. The number of observation systems ('experiments') to be included in the satellite was fixed at two: one from the University of Groningen and one from the University of Utrecht.

As soon as the consortium had been set up an American advisory body was sought for the next phase of the project. After extensive consultation General Electric [*] was chosen, a company that is one of the leaders in American space technology.

The first activity of the study was to discuss the project thoroughly with the GE experts, who expressed their confidence in the feasibility of the project.

Since it was clear that any launch would have to be made with an American launch vehicle, contact was made in 1969 with NASA [**]. After a study of the satellite and its scientific objectives, NASA proposed that they should make available a Scout vehicle with increased thrust (*fig. 1*) and use part of the greater load-carrying capacity to include in the satellite an observation system of American origin. With this arrangement the ANS project obtained the status of a 'cooperative programme' with NASA; this was later confirmed by a 'memorandum of understanding' exchanged between the Netherlands Government and NASA.

The study phase continued until the end of 1969 and was completed in December by a detailed technical report [1], accompanied by a planning schedule and an estimate of the costs. On the basis of this report the Netherlands Government decided that it would instruct the consortium and the two scientific institutions to carry out the project under investigation. The contract for the project was signed in December 1970.

The astrophysical observation systems

The central place among the observation systems to be carried by the satellite was taken by the equipment from the University of Groningen. It is desired to measure the brightness of a number of 'very blue' stars in the ultraviolet part of the spectrum, at five wavelengths situated between 1500 and 3300 Å. The objective in this work is to extend the existing classification of stars, which for young hot stars is rather uncertain, towards the ultraviolet. If such a classification is to be of genuine use measurement of a large number of objects is necessary. The limiting sensitivity of the equipment is therefore made equal to the tenth magnitude. Faint stars of this type are mainly to be found in the plane of the Milky Way. This requires that the equipment should only have a small field of view (2.5×2.5 minutes of arc) and should also be aimed ('pointed') with corresponding accuracy.

The instrument consists of a Cassegrain telescope, followed by a grating spectroscope, and contains five photomultiplier tubes, which act as detectors. The telescope plays an important subsidiary role in that it produces, via a system of lenses and mirrors, an image of the surroundings of the star being investigated on the photocathode of a star sensor. As will be explained later, this enables the reference of the attitude control to be produced by the instrument itself, so that alignment errors are largely eliminated. Since the full aperture of the telescope is used for this purpose, this is also the most sensitive way of obtaining the reference signal.

The instruments from the University of Utrecht will be used to measure the radiation from particular X-ray sources. The equipment consists of two parts: one for measurements in the wavelength range 44 to 55 Å, and the other for the ranges 2-4, 4-12 and 27-35 Å. This equipment can be used to detect faint X-ray sources; the spectral distribution and the time dependence of the strength of the radiation from these and other known objects can be measured. The measurement of time dependence — the investigation of the 'pulsars' — is a completely new field, in which remarkable results have already been achieved.

The American observation system to be mounted in the satellite is being constructed by American Science and Engineering (AS & E), who have designed it in close cooperation with the Massachusetts Institute of Technology (MIT). The objective is to perform measurements similar to those of the Utrecht group, but in a different wavelength range (0.3-6 Å), and it will also be used to detect a pair of particular spectrum lines with the aid of a Bragg crystal. The existence of X-ray sources in the universe was first discovered by AS & E scientists, who are among the leaders in this field today.

The satellite

At a very early stage it had already been decided that the ANS would have to be launched by the smallest available vehicle, the Scout, to keep the costs of the project within reasonable limits. This implied immediately that severe limitations would have to be applied to the design concerning mass and dimensions. *Fig. 2* gives an impression of the exterior of the satellite; detailed drawings of the arrangement are shown in *fig. 3*.

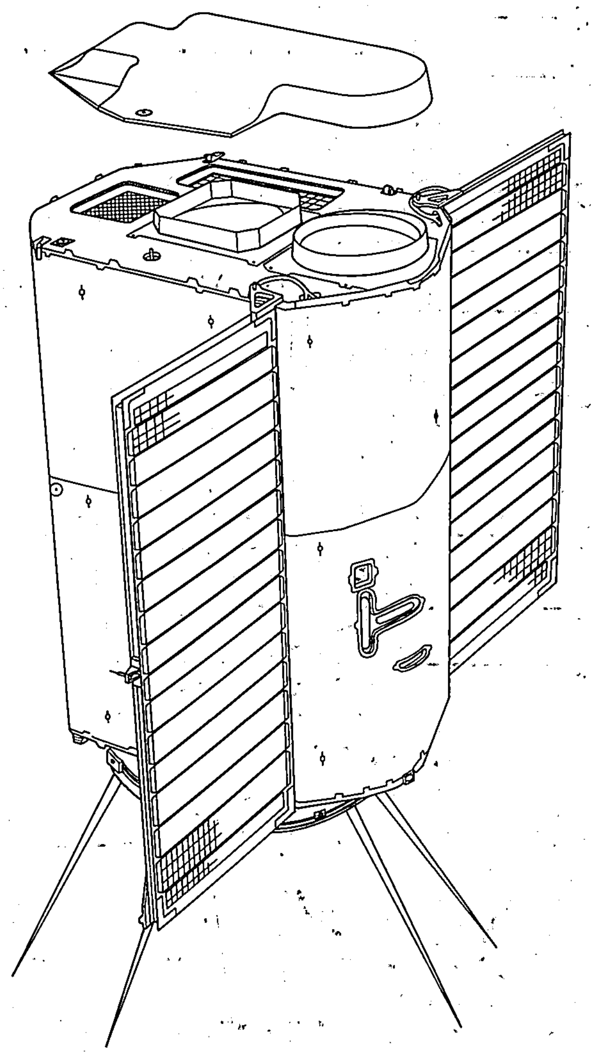


Fig. 2. The exterior of the satellite. The radiation to be measured reaches the measurement systems through the openings at the top. The solar panels can be seen on the left and the right in the deployed position. Between the solar panels there is an opening through which light can reach the solar sensors. The rods underneath are the aerials. The maximum total mass will be about 130 kg.

[*] General Electric Co., Philadelphia, Pa., U.S.A., Valley Forge Space Technology Center.
[**] National Aeronautics and Space Administration, Goddard Space Flight Center, U.S.A.
[1] A design study for an astronomical Netherlands satellite, performed by the ANS Industrial Consortium.

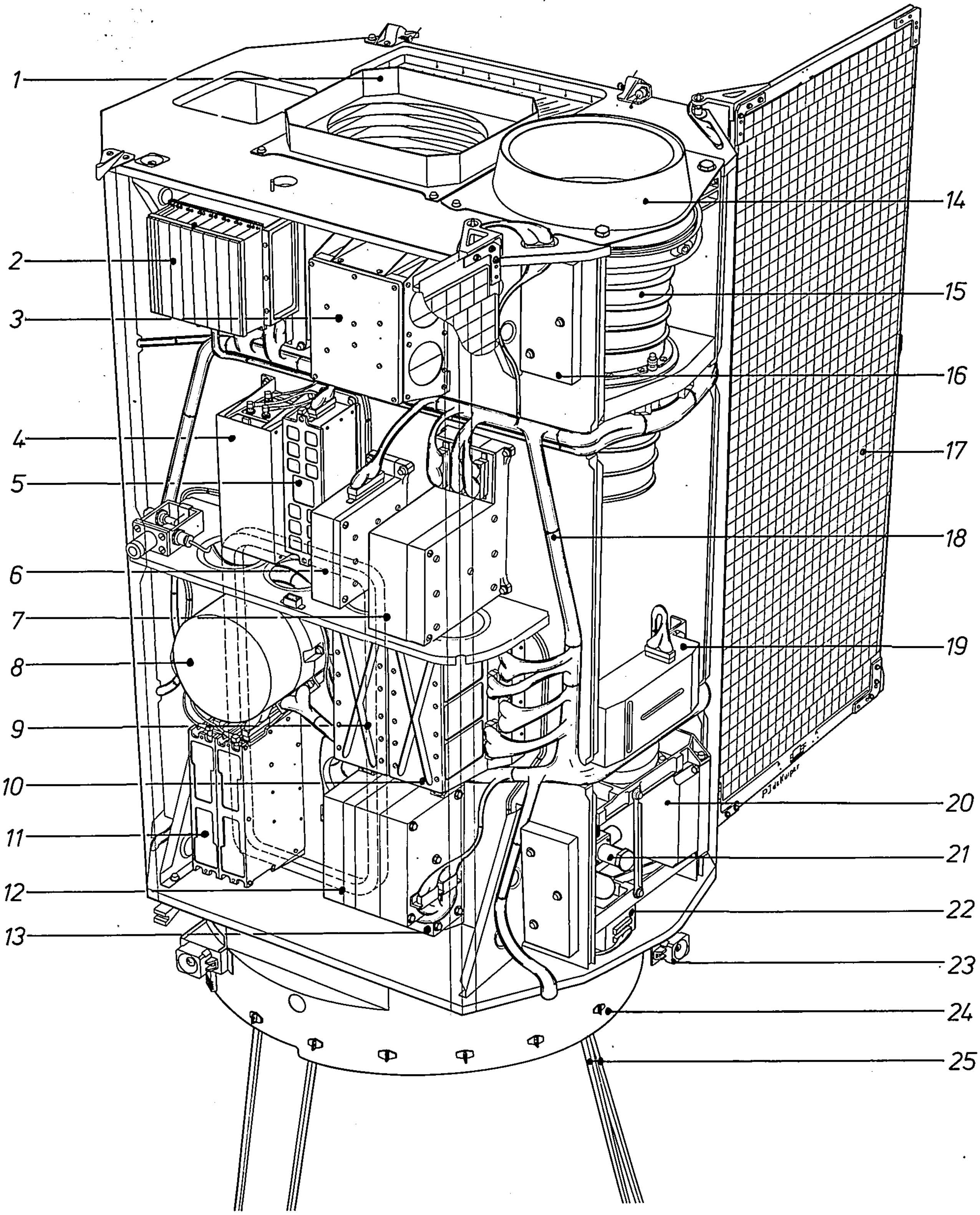


Fig. 3. *a*) Detailed arrangement of the Netherlands astronomical satellite (ANS). *1* shield to keep out scattered light. *2* power-supply control unit. *3* battery. *4* aerial coupling unit. *5* transmitter. *6* analog-to-digital converter for magnetometer signals. *7* electronic unit for attitude control. *8* reaction wheel for *y*-axis. *9* command decoder. *10* telemetry unit. *11* receivers. *12* magnet coil for *y*-direction. *13* data-processing circuit for soft X-ray radiation. *14* shield to keep out scattered light. *15* parabolic mirror, part of the observation system for soft X-ray radiation (44-55 Å). *16* balance weight. *17* solar panel (deployed). *18* cable-form. *19* solar sensors for *x*- and *y*-directions. *20* preamplifier for small X-ray detector. *21* gas-feed system for small X-ray detector. *22* electronic unit for gas-feed system. *23* coarse solar sensor. *24* 'yo-yo ring' (see the article of note [2]). *25* aerial.

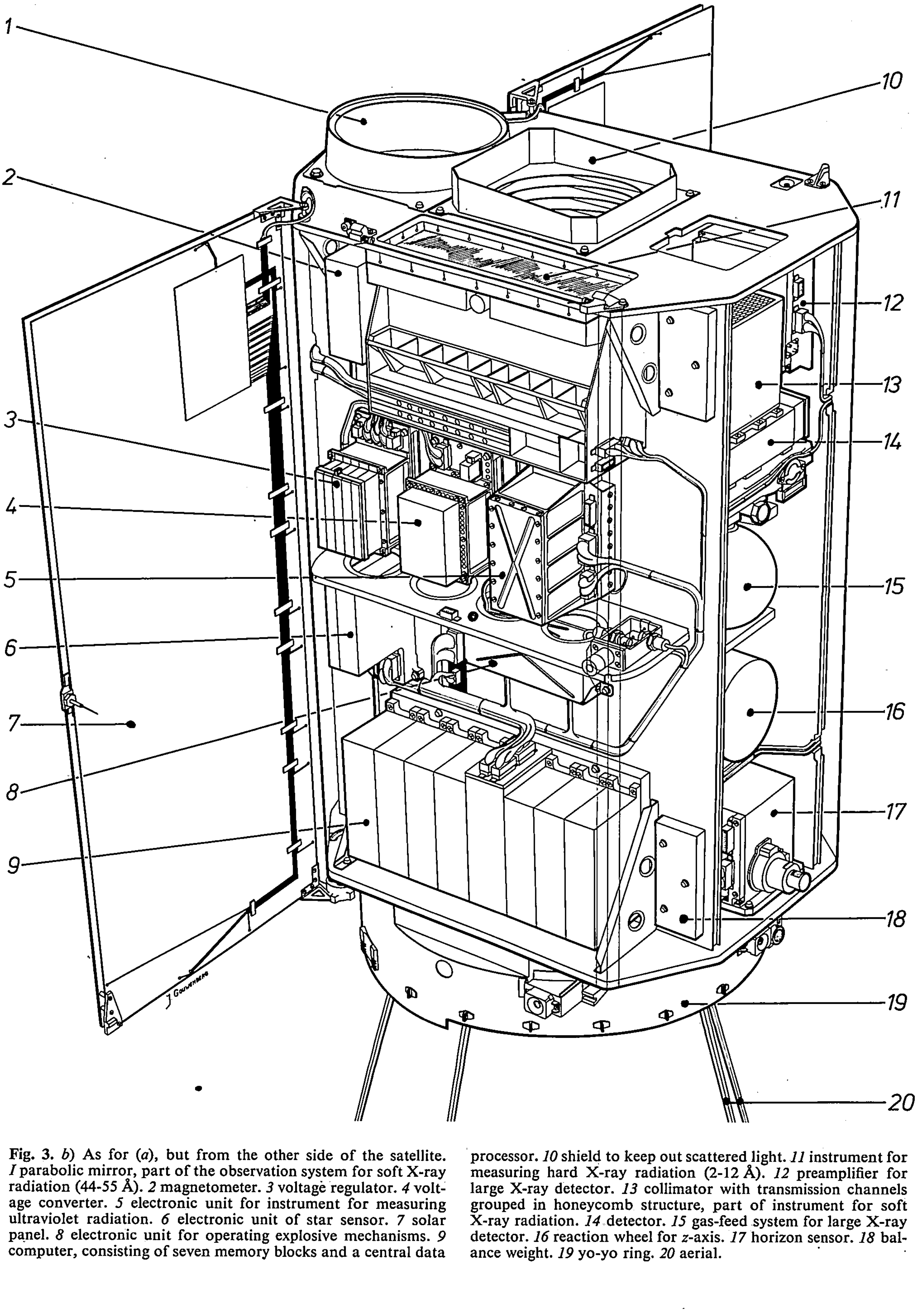


Fig. 3. *b*) As for (*a*), but from the other side of the satellite. *1* parabolic mirror, part of the observation system for soft X-ray radiation (44-55 Å). *2* magnetometer. *3* voltage regulator. *4* voltage converter. *5* electronic unit for instrument for measuring ultraviolet radiation. *6* electronic unit of star sensor. *7* solar panel. *8* electronic unit for operating explosive mechanisms. *9* computer, consisting of seven memory blocks and a central data processor. *10* shield to keep out scattered light. *11* instrument for measuring hard X-ray radiation (2-12 Å). *12* preamplifier for large X-ray detector. *13* collimator with transmission channels grouped in honeycomb structure, part of instrument for soft X-ray radiation. *14* detector. *15* gas-feed system for large X-ray detector. *16* reaction wheel for *z*-axis. *17* horizon sensor. *18* balance weight. *19* yo-yo ring. *20* aerial.

The nature of the experiments, the observation of a large number of very faint stars, requires that the satellite should be accurately oriented and that it should be possible to alter its attitude easily. This is best done by three-axis stabilization, but the high directional accuracy required (1′) is difficult to achieve in a satellite of low weight and therefore low moment of inertia. An acceptable solution that has been found to this problem is to make the satellite describe a polar orbit. For pointing the satellite, carrying out the measurement programmes and processing and storing the data obtained, it was found necessary to include a small computer in the satellite. Since this computer could only have a permitted weight of 16 mg per bit and a volume of 20 mm^3 per bit, it required technology then in advance of existing developments. The required pointing accuracy obviously imposed very difficult requirements on the sensors and actuators that would have to be developed for the control functions.

The limited space in the nose cone of the rocket (*fig. 4*) and the spin stabilization of the last stage require deployable solar-energy panels, while a system is also required that will stop the rotation of the satellite after it has separated from the propelling vehicle.

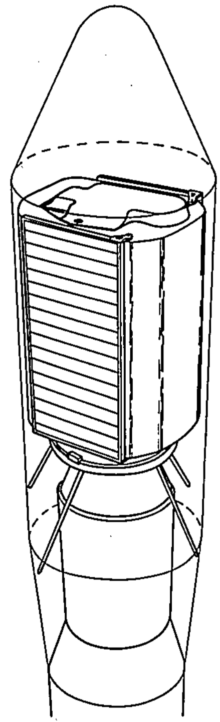


Fig. 4. The satellite, as it will be mounted on the fourth stage of the Scout vehicle in the nose cone. The solar panels are then folded in, and the openings at the top of the satellite (see fig. 2) are covered by an ejectable dust cover.

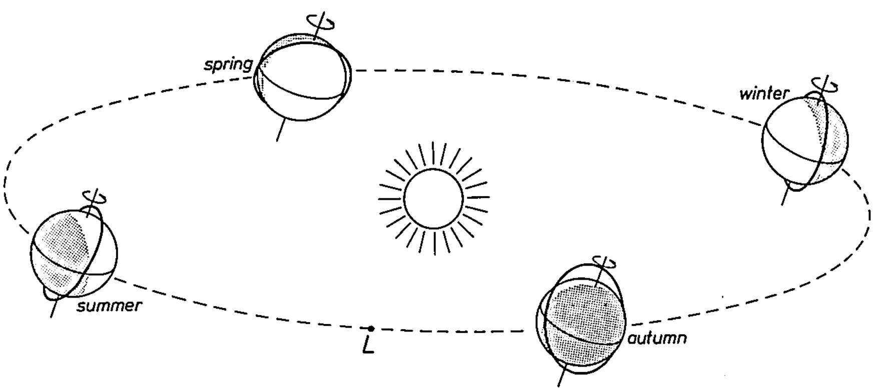


Fig. 5. The orbital plane of the satellite follows the movement of the Earth around the Sun, so that its normal always points towards the Sun. This keeps the satellite permanently in sunlight. The situation at the beginning of the four seasons is shown. The launch will be made in the summer (point L).

Finally, the vibrational forces that arise during launching are largest of all in small rockets. This imposed particularly difficult mechanical requirements on a small satellite of light construction that would have to carry delicate instruments.

Choice of orbit; attitude control

As has already been pointed out, the pointing of the observation equipment entails difficult requirements for the attitude control of the satellite. The Earth cannot be used as the stable platform, as in a terrestrial telescope, and the satellite must be pointed with the aid of optical references and using equipment for producing control torques [2].

The reference most easy to find from an orbit round the Earth is the Sun. An attitude-control system has therefore been chosen in which one axis is continuously directed towards the Sun. Then not only is there a clear attitude reference, but the solar cells are used in the optimum way. A disadvantage is that objects can only be observed if they are located in a plane perpendicular to the connecting line with the Sun. However, because of the annual rotation of the Earth around the Sun this plane rotates once per year, so that any object can be observed within a period of six months.

It is clear that the attitude-control system adopted can only operate if the satellite is in fact in sunlight and does not lie in the shadow of the Earth. By choosing an orbit that lies above the poles of the Earth, it is possible initially to remain outside the cone of shadow of the Earth. If the orbit is exactly polar, however, the attitude of its orbital plane is invariant with respect to the fixed stars. Then, with the passage of time, the satellite would arrive in the Earth's shadow because of the orbital movement of the Earth around the Sun. An chance of running into eclipse; and on the other hand it is desirable to make the height as small as possible to give the maximum launched weight and the least background interference from charged particles.

Once the satellite has been placed in orbit and aligned on the Sun, another reference object is necessary to enable the satellite to be rotated about the axis

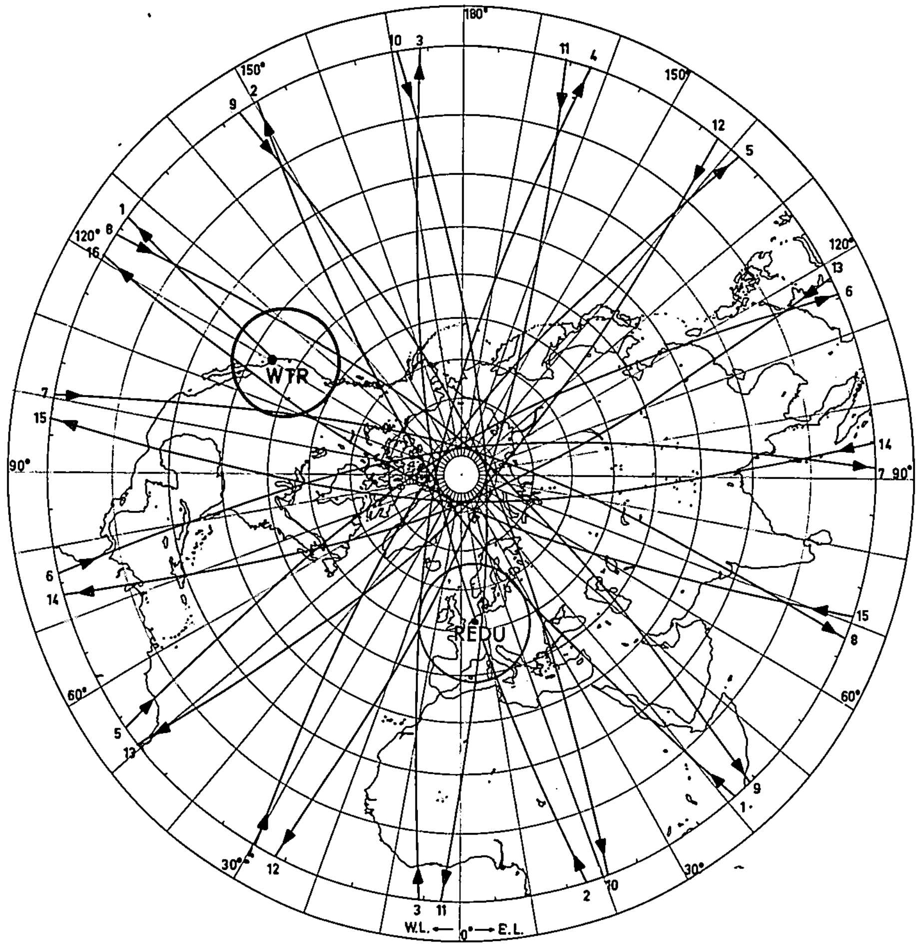


Fig. 6. Projection on the Earth's surface of the ground path of the satellite on the first day immediately after launching. As seen from the Earth, the orbital plane rotates with the Sun. WTR the Western Test Range launching site in California. REDU the ground station (see figs. 7 and 9). The circles indicate the region inside which radio contact is possible.

orbit is therefore chosen whose plane follows the movement of the Earth around the Sun (*figs. 5* and *6*). This is possible since the flattening of the Earth at the poles causes a certain amount of rotation of the plane of orbits that do not pass exactly over the poles. A suitable choice of the inclination of the orbital plane will give a situation in which the satellite remains outside the Earth's shadow for longer than six months at a time.

The height of the satellite in its orbit has been set at 500 kilometres. This value is a compromise. On one hand it is desirable to make the height as large as possible, to give as long an orbital life as possible, a large available time for ground contact, and a smaller

directed towards the Sun and into the correct attitude. This is done by making use of the infrared radiation from the Earth. A sensor with a small field of view scans the plane perpendicular to the direction of the Sun with a mirror rotating at 1 rev/s. In this way the angle is determined between the direction in which the telescopes are pointing and the two directions in which the sensor sees the horizon — 'rising' and 'falling'; these data are fed to the onboard computer.

The satellite can be pointed with an accuracy better than one degree with the horizon sensor. However, for

[2] A more detailed treatment of the attitude-control system is given in: P. van Otterloo, Attitude control for the Netherlands astronomical satellite (ANS); to appear shortly in Philips Technical Review.

pointing at stars this accuracy is not sufficient. A more accurate attitude control is not possible with a horizon sensor because the infrared horizon does not coincide with the optical horizon, but is located at a variable height in the atmosphere (30 $\pm$ 3 km), and also because the location of the satellite in its orbit is not known in advance sufficiently accurately for this purpose.

After the satellite has been pointed as well as possible with the horizon sensor, further attitude information is therefore obtained from a television camera tube of the image-dissector type located at the focal plane of the ultraviolet telescope. With this device the satellite can be pointed at a reference point, the 'guide-star', to the desired accuracy. An advantage of this method is that only those pointing errors arising in equipment directly related to the star sensor are of significance, whereas such effects as distortion in the telescope are largely eliminated because they have a similar effect on the guide-star and the object to be measured.

The attitude of the satellite is varied with the aid of the reaction torques of three reaction wheels mounted at right angles to one another and driven by motors. All the data from the attitude sensors for fine control are suppled to a computer, which calculates the torques required from these data and from an observation program stored in the computer [3]. Attitude control with the aid of a computer has the advantage of considerable flexibility. Not only can control laws be applied that would otherwise require the development of special circuits, but corrections can also be made at a very late stage, even during the flight itself, from the results presented.

To prevent information stored in the computer from being lost in the case of a temporary loss of power, the memory is of the core-store type.

Processing the data

Regular radio contact with the satellite is necessary both for supplying in turn the measurement program blocks and also for retrieving the results of the measurements. The time that elapses between successive contacts with ground control is determined by the orbit selected and the number of ground stations. Except in the immediate surroundings of the north or south poles, there is no single location on the Earth from which contact with the satellite would be possible during each orbit. However, since the poles are not the most suitable places for a ground station, in practice it is only possible to make contact from a single station at intervals of about twelve hours. This means that the satellite must be able to carry the measurement programs for a period of at least twelve hours as well as the results obtained in that period. *Fig. 7* gives a schematic diagram of the way in which the information flows between the satellite and the observers on the ground.

The procedure is broadly as follows. For every period of twelve hours a program suited to the opportunities available to the equipment, the attitude and the position of the satellite in its orbit is made at Utrecht, with consultation between the three astronomical groups. This program is transmitted to the European Satellite Operation Centre (ESOC) at Darmstadt (*fig. 8*). This is the centre from which the satellite will be controlled, via a ground station located near the village of Redu in the south of Belgium (*fig. 9*). At Darmstadt the program is checked and coded so that it can be entered into the memory of the onboard computer, and real-time command instructions can be added. Transmission between Darmstadt and Redu is by cable data link, and the transmitter at Redu operates on a frequency of 148 MHz (wavelength about 2 m). When the satellite is passing over Redu it is possible to transmit instructions that have to be carried out by the satellite in real time in addition to the instructions for storage in the computer. The satellite transmits verification information back to the ground about the signals it has received.

While the satellite is out of sight of the ground station, its own transmitter sends out a 0.15 W signal at a frequency of 137 MHz. This signal, which can also be used for tracking the orbit, is modulated by a signal of 128 bits/second that provides data about the state of the satellite. At the same time the information coming from the observation systems and the attitude-control system is entered into the memory of the onboard computer. Six blocks of 4096 words of 16 bits are available for this function. A seventh block serves as an operating memory and also contains the measurement program. A cross-connection between the onboard computer and the telemetry equipment allows a small part of the 'housekeeping' information to be stored in the computer, and allows a small part of the results obtained to be transmitted. When the satellite comes into direct view of the ground station, the transmitting power is increased to 1.5 W and the information rate to 4096 bits per second. The information stored in the memories can then be transmitted to the ground. The housekeeping information and the command-instruction verification are interleaved with the memory read-out data. The quality of the signal is checked immediately at the ground station, so that the satellite

[3] A more detailed treatment of the onboard computer will be given in: G. J. A. Arink, The onboard computer for the Netherlands astronomical satellite; to appear shortly in Philips Technical Review.

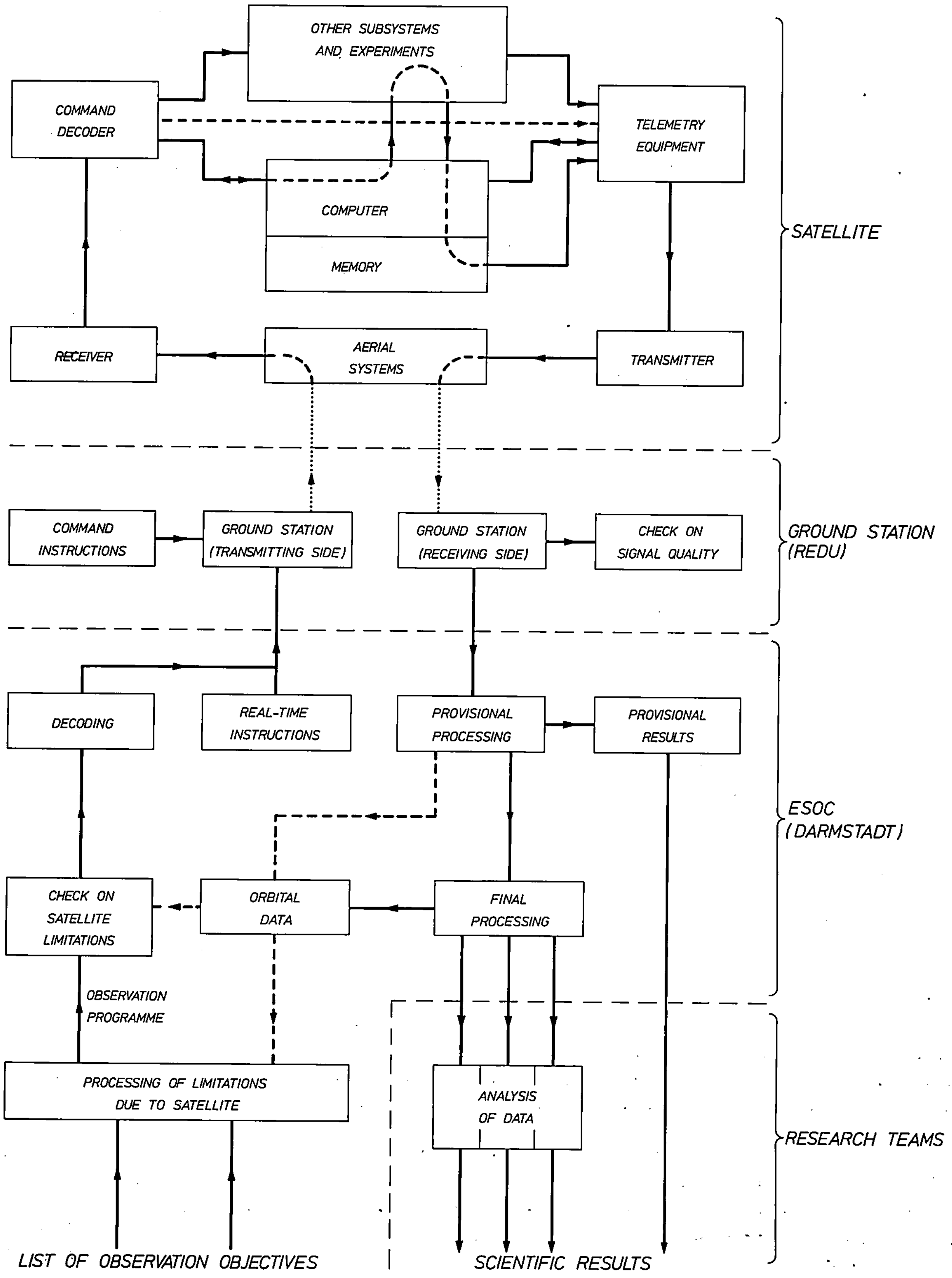


Fig. 7. Schematic representation of the way in which information flows between 'Earth' and the satellite. The programs to be carried out by the three observation systems in the next 12 hours are written at Utrecht and transmitted to the European Satellite Operation Centre (ESOC) at Darmstadt (West Germany). Here they are checked and coded, and the command instructions are added. The transmitter and receiver that maintain radio contact with the satellite are located at Redu (Belgium). Communication between Darmstadt and Redu is by cable.

Photo ESOC

Fig. 8. The control room of the European Satellite Operation Centre (ESOC) at Darmstadt (West Germany). The satellite will be controlled from here.

can be asked for example to retransmit a part of the information. The verification of the commands and the housekeeping information are processed during the ground contact. A provisional processing of the measurement data is then carried out, to obtain a rapid assessment before the next ground contact; this can be useful in deciding whether or not to transmit an alternative measurement program.

The final processing of the data is carried out after the exact orbital data have been obtained. The results obtained from this final processing are offered to the astronomers whose equipment is on board the satellite for scientific analysis.

Power supply and temperature control

The solar cells mounted on the deployable panels can produce between them a total power of more than 70 W. An NiCd battery (6 Ah) is also provided for use in periods when the panels cannot be used or can only be partially used (acquisition of Sun, aiming, periods of eclipse). The power-supply circuit provides two d.c. voltages, 20 V and 5 V; the 5 V supply is mainly used for digital integrated circuits.

The temperature control is passive, which means that the internal temperature of the satellite is determined by the equilibrium between the internal heat dissipation and the radiated heat. The thermal insulation is arranged in such a way that this radiation is emitted almost entirely by the upper and lower surfaces of the satellite. This is done to reduce as far as possible the temperature gradient in the transverse direction, which can cause mechanical distortion of the instruments that have to be aligned very accurately. For proper operation of the onboard systems the average internal temperature should lie between 0 and 30 °C. To keep the temperature within this range when some of the equipment has to be switched off extra heating elements are provided; these can be switched on from the ground.

The scheduling of the project

As was noted earlier, a start was made with the work of the project in early 1970 (*fig. 10*). In addition to setting up a sufficiently strong technical group a start was made with laying down the specifications and the

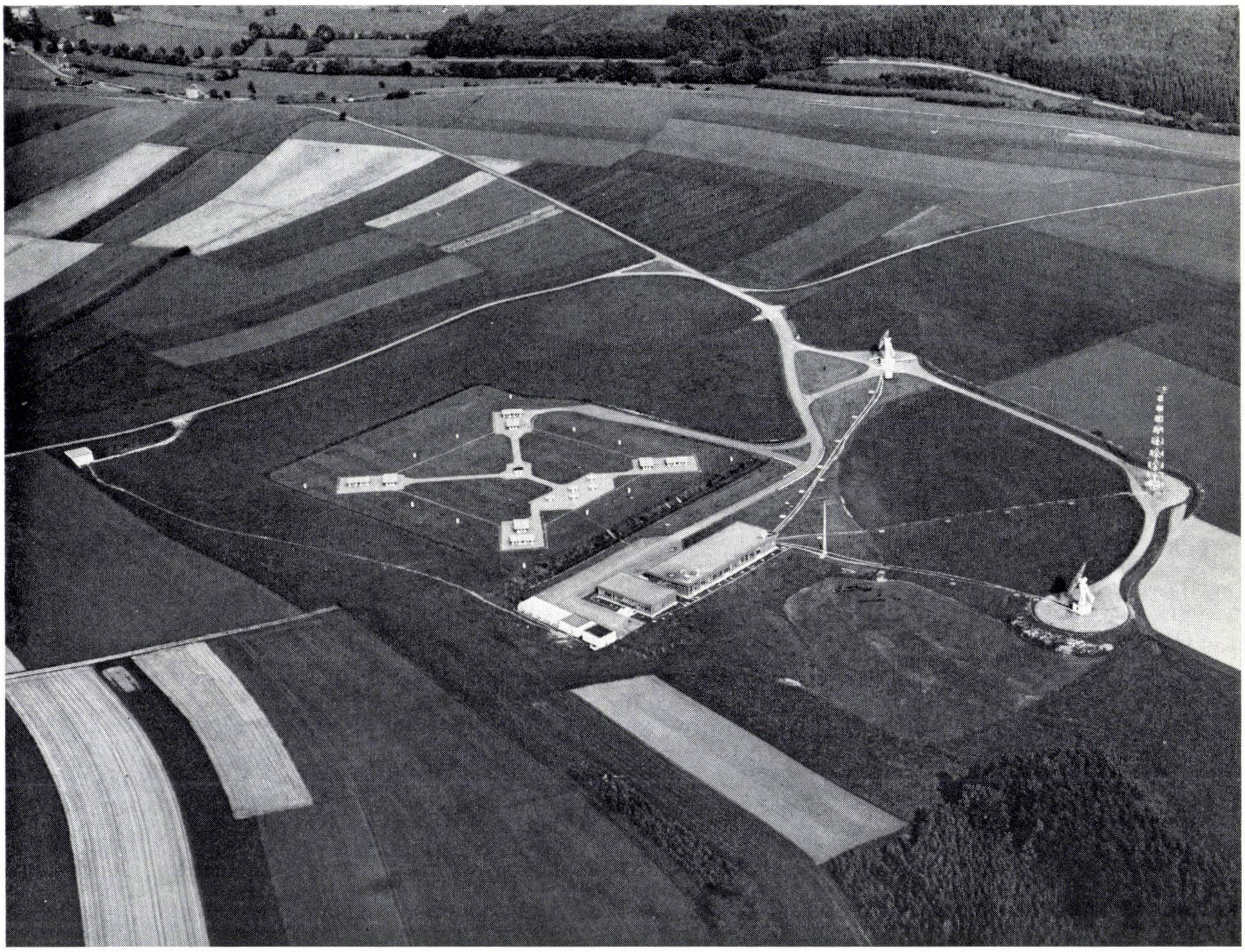


Fig. 9. The ground station at Redu (Belgium). ESOC will maintain radio contact of 10 minutes in every 12 hours via this station. The aerials with which the satellite will be tracked can be seen on the right.

development of the subsystems. The mechanical layout was checked with the aid of a dimensional model, with particular attention to the relative positions and ease of access of the various components. A 'prestructural' model was also made and used in vibration tests to check the main mechanical features of the satellite. Polar diagrams of the aerials were measured on a scale model and on a full-size mock-up.

At about the end of 1971 a start was made with the assembly — the 'integration' — of structural, thermal and electrical models of the satellite. The structural model was subjected to a static load test and to vibration tests, all intended to simulate the stresses that would be experienced on launching. The thermal model was mounted in a large vacuum chamber and exposed to simulated sunlight and to the low temperatures to be expected in space, to verify the thermal design of the satellite. The electrical model was first assembled on the bench and was then mounted in a satellite frame. In this way the interaction of the subsystems was checked in all possible operational situations.

At the start of 1972 a critical design review was carried out for each subsystem. After putting right inadequacies that had come to light in this review, a start was made on the construction of the equipment for the satellite proper. This will be integrated during 1973 and will put through an extensive test programme.

When this has all been completed the satellite will be sent to the launching site, checked there once again, and finally launched. After the launch the satellite will be checked and calibrated for one or two weeks in orbit. The phase in which the astronomical measurements are carried out then follows; this phase will have to be one of at least six months.

Organization

It is clear that good organization is necessary in the running of a development project of such complexity and with such a large number of participating groups (*fig. 11*). The day-to-day management of the project is the responsibility of the Executive Coordination Committee (ECC). The two executive members of the ICANS board both have seats on this committee, as Project Manager and Chief Engineer, and so do the two Dutch Experiment Managers. The meetings are presided over by the Project Manager. The interests of the Netherlands Government in the project are represented by the Netherlands Agency for Aerospace Programmes (NIVR); the programme is supervised by the ANS Supervising Director. Supervision of the scientific side of the project is the responsibility of a Project Scientist representing the Dutch astronomers. Both the Supervising Director and the Project Scientist attend the meetings of the ECC.

Within the ICANS organization the work is divided up into a number of activities that coincide in general with the subdivision of the satellite into subsystems. These activities are shared among the cooperating companies with each company producing one or more subsystems. In each company, one man — the Local Project Manager — is responsible for the coordination of all the activities for ANS within that company. The technical responsibility for this work is delegated to Subsystem Managers at the company.

The most important lines of communication are those from the Project Manager to the Local Project Managers for planning and financial accounting, and from the Chief Engineer to the Subsystem Managers for technical problems.

The progress of the project is monitored by the Project Control Group, on which each company has one of its planners as a representative. In a similar way, reliability and quality control of the satellite are the responsibility of the Product Assurance Group, which again includes a representative from each company. The chairmen of these two groups report directly to the Project Manager, and the representatives to the Local Project Manager at their company.

It is of course impossible to include all the relationships within such a complex organization in a simple scheme. Activities such as 'integration' and 'operations' require some modification to the general approach, but we cannot enter into a detailed discussion here.

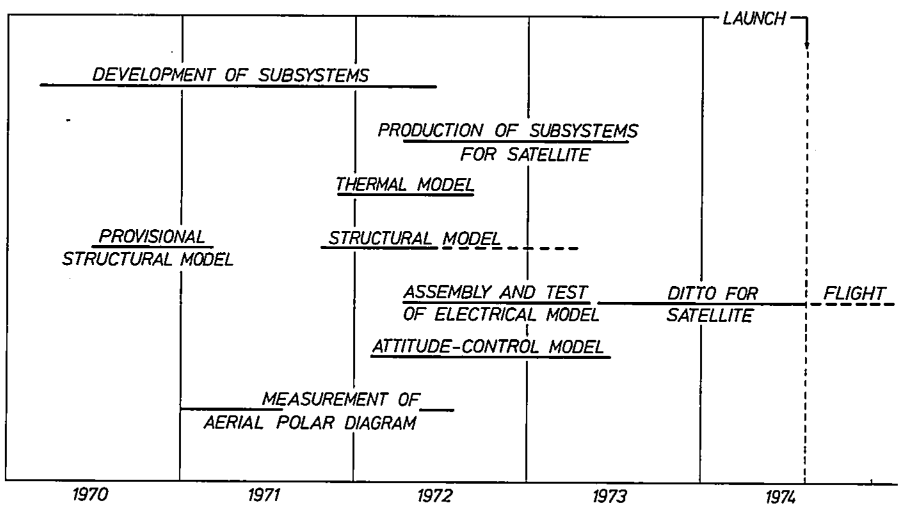
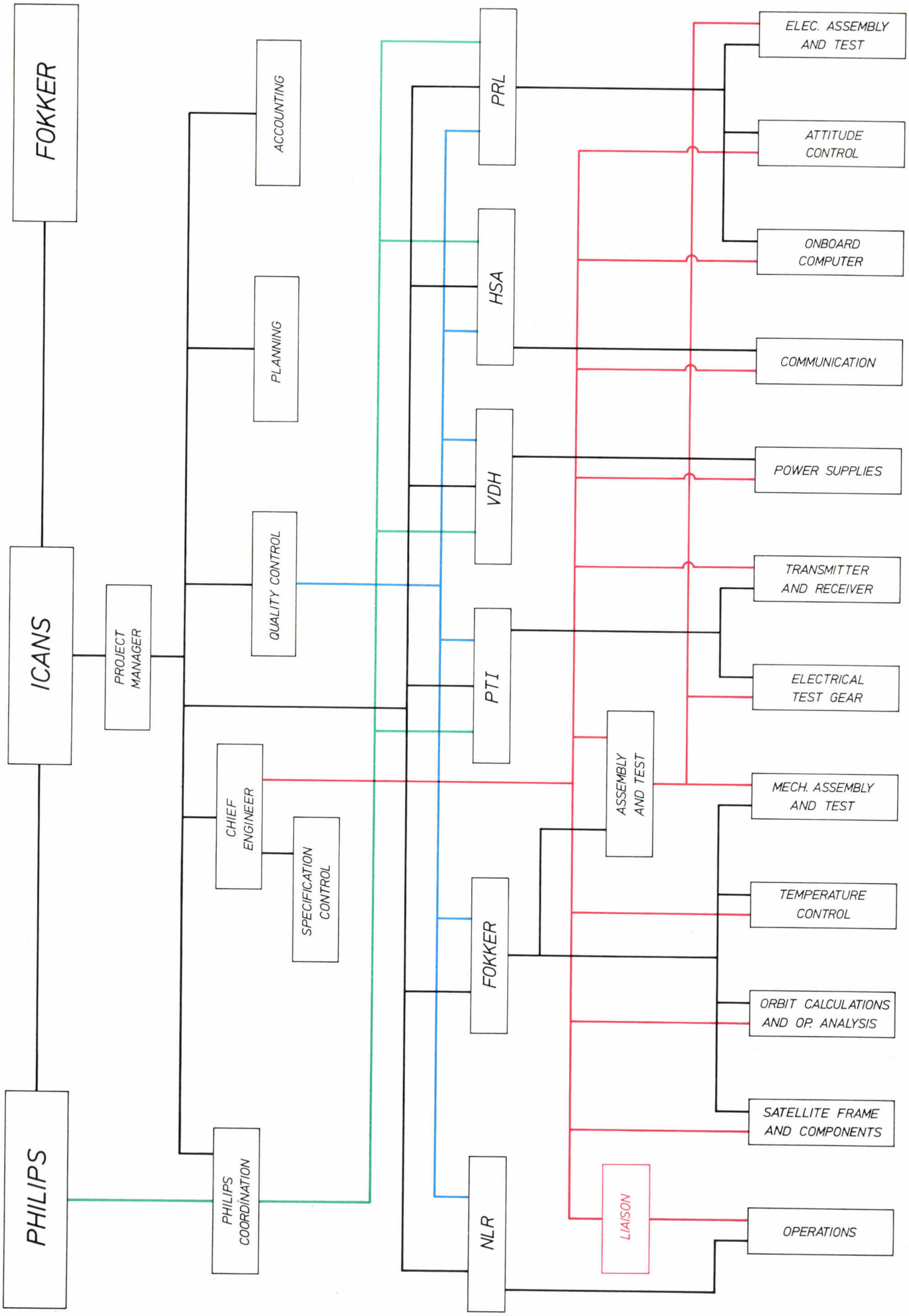


Fig. 10. Planning schedule for the complete programme of the project. The phase in which investigations are made on models and the subsystems are developed and constructed is now nearly completed.

Summary. In August 1974 a Scout space vehicle will be launched, from the Western Test Range launching site in California, which will put into orbit around the Earth a satellite made in the Netherlands and intended to carry out astronomical research. This Netherlands astronomical satellite (ANS) has been designed and is being constructed by the ANS Industrial Consortium (ICANS), a partnership between Fokker-VFW and Philips, at the request of the Netherlands Government. The satellite will carry three observation systems, from the Universities of Groningen (measurements on 'very blue' stars between 1500 and 3300 Å) and Utrecht (X-radiation from stars, 2-55 Å), and also from AS & E and MIT (Cambridge, Massachusetts; similar measurements, 0.3-6 Å). A polar orbit will be used such that the satellite will remain in continuous sunlight for at least six months. One of the axes of the satellite will be permanently directed at the Sun; searching for the objects to be measured will be done by rotating the satellite about this axis. Contact with the ground will only be possible once in 12 hours; this contact will be made from the European Satellite Operation Centre (ESOC) at Darmstadt via a station at Redu (Belgium). The instructions for the following 12 hours will then be fed into the memory of the onboard computer, which directs the operations from then onwards, and if required will send back the measured results at the next ground contact.

Fig. 11. The organization linking the various groups participating in the ANS project through the ANS Industrial Consortium (ICANS). The significance of the abbreviations is as follows:

FOKKER: Fokker-VFW B.V., Amsterdam.
PRL: Philips Research Laboratories, Eindhoven.
PTI: Philips Telecommunication Industries, Hilversum.
HSA: Hollandse Signaalapparaten B.V., Hengelo.
VDH: Van der Heem Electronics B.V., Voorburg.
NLR: The Netherlands Aerospace Laboratory.


FOKKER
ICANS
PHILIPS
PROJECT MANAGER
ACCOUNTING
PLANNING
QUALITY CONTROL
CHIEF ENGINEER
SPECIFICATION CONTROL
PHILIPS COORDINATION
PRL
HSA
VDH
PTI
FOKKER
NLR
ASSEMBLY AND TEST
LIAISON
ELEC. ASSEMBLY AND TEST
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COMMUNICATION
POWER SUPPLIES
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