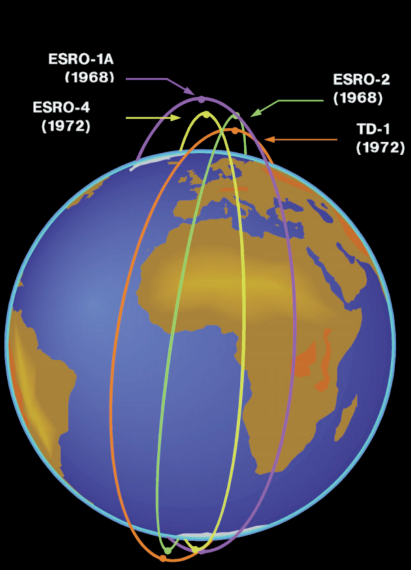
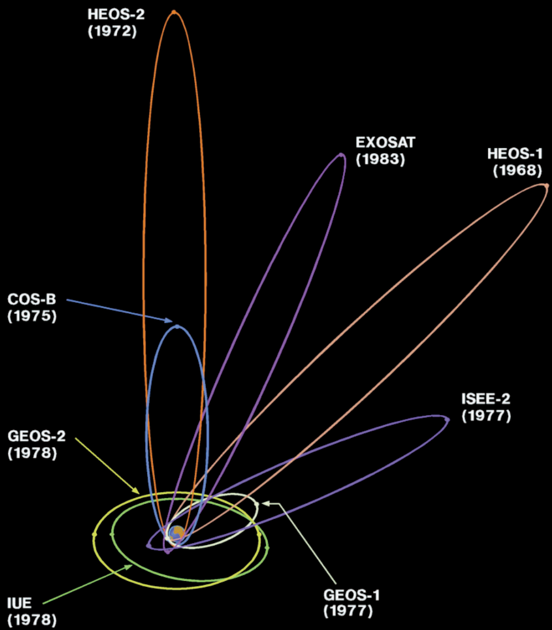
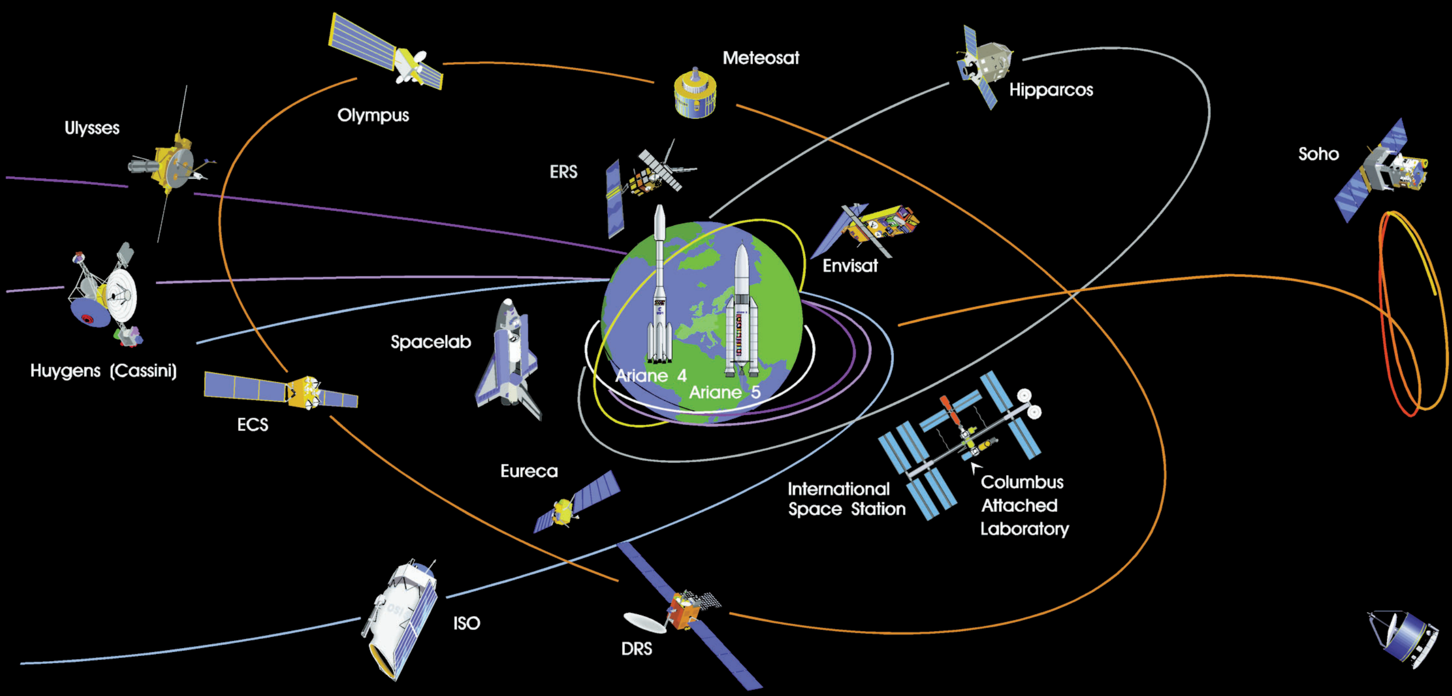
HSR-27

November 2002

An Overview of Space Activities in the Netherlands







European Space Agency
Agence spatiale européenne

HSR-27
November 2002

An Overview of Space Activities in the Netherlands

by
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European Space Agency
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Short Title: ***Netherlands Space Activities***

Published by: ESA Publications Division
ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands

Editor: R.A. Harris
Price: €10
ISSN: 1683-4704
ISBN: 92-9092-353-3

Printed in: The Netherlands

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1 Prologue

In June 1655 Christiaan Huygens, the great Dutch mathematician, astronomer and physician, sent an anagram to John Wallis in London consisting of a verse of Ovidius and the letters *uuuuuuu ccc rr h n b q x.* The verse was *Admovere oculis distantia sidera nostris*, meaning 'distant stars move towards our eyes'. Both verse and letters combined into: *Saturno luna sua circumducitur diebus sexdecim horis quatuor* meaning 'around Saturn its moon circles in sixteen days and four hours'. With this anagram Huygens claimed his discovery of Titan, the largest moon in our solar system.

As a seafaring nation the Republic of the Netherlands showed great interest in the movement of celestial bodies, mainly for position determination. In the 17th Century there were already several instruments (telescope, sextant) which could be used to 'shoot a star', but in order to derive your position from that you needed to know the positions of the stars. This practical need formed the basis of the long-standing tradition of astronomical research in the Netherlands of which Huygens was a shining example.

1.1 Mapping the Universe

An important Dutch astronomer is Jacob Kapteyn who derived a model of the Universe from pictures taken at the Cape of Good Hope in South Africa. Although in the end it proved to be wrong, the model played an important role in the astronomical debate in the 1920s, a debate that led to our modern insights in the structure of the Galaxy. One of his pupils was Hendrik Jan Oort who mapped the spiral structure of the Galaxy with the help of the then newly discovered radio wave detector. He also discovered the Oort Cloud at the edge of the solar system where comets reside. Gerard Kuiper, a Dutch-born American astronomer gives his name to the Kuiper Belt, a zone past Neptune which is considered the source of short period comets.

The mapping work of Oort would not have been possible without the use of radio emission. Another Dutch astronomer, Henk van de Hulst, suggested the use of the 21 cm spectral line of atomic hydrogen as tool for the mapping of the Universe. In 1957 a radio telescope was built in Dwingeloo and in 1970 an array of 14 radio telescopes was built in Westerbork, 25 km from the first one. In 1990 the Westerbork array became part of a European network for Very Long Baseline Interferometry, which makes it possible to pick up radio signals from the end of the Universe. The headquarters of the European network for VLBI are in Dwingeloo.

1.2 Looking at Earth Itself

Astronomy research was an important driving force behind the first space activities in the Netherlands, but not the only one. From the end of the 19th century onward the Netherlands was also involved in geophysical research, especially the First (1882-1883) and Second (1932-1933) Polar Year and the International Geophysical Year (1957-1958). It was the Dutchman Vening Meinesz who, based on his measurement of the Earth's gravitational field, suggested that convection flows in the outer layers of the Earth's mantle were responsible for the movement of the continental shelves thus supporting Alfred Wegener's theory of plate tectonics. Other research areas that enhanced the interest in space were meteorology, oceanography and research into the upper layers of the atmosphere, the ionosphere.

The suggestion to set up an international sounding rocket programme as part of the International Geophysical Year was hence welcomed by the Netherlands research community. The programme included the launch of a satellite to gather data from the upper layers of the atmosphere. The US Vanguard had been developed for that purpose and was supposed to be put into orbit in the spring of 1958. On 4 October 1957, however, everyone, including the geophysicists, was surprised by the launch of Sputnik-1 by the USSR, exactly 40 years after the October Revolution of 1917. The first Vanguard satellite was launched in March 1958, only a few months after Sputnik-1, but in the tense cold War period of the 1950s and 1960s Sputnik-1 was enough to start the 'Space Race' that resulted in the Apollo-programme for manned space flights and the first steps on the Moon in 1969.

1.3 Peaceful use

As already indicated, the impact of the launch was enormous, not only among politicians and the military but also among scientists. They already had presumed that satellites would greatly enhance their means of exploring space, but the successful launch of Sputnik and shortly afterwards the first Vanguard (which still is orbiting Earth) really opened up space, at first mainly for research, but later also for commercial purposes.

Scientists in the Netherlands were very keen on the peaceful use of space. In November 1958, Van de Hulst – at the instigation of Oort – attended a meeting in London of the International Council of Scientific Unions (ICSU). A week later he came home as the first president of COSPAR, the Committee for Space Research of ICSU, aimed at the peaceful exploitation of space. The ICSU was worried that, in the upcoming rivalry between the USA and the Soviet Union, the military aspects of space studies would take priority over the scientific ones. The fact that this did not happen (even though the military importance remained great) must have been at least partly due to COSPAR. At a COSPAR congress Van de Hulst presented a Dutch wooden shoe (clog), cut from wood of the same tree, to two astronauts (Glenn from the USA and Titov from the Soviet Union). The symbolism was understood by everybody.

1.4 Embryonic organisation

In 1959 Van de Hulst took the initiative to form the Netherlands Geophysics and Space Research Committee (GROC) as part of the Royal Netherlands Academy of Sciences (KNAW). This committee was to co-ordinate the space research carried out by the astronomers and geophysicists in the Netherlands. It managed to get government funding for space research and it represented the Netherlands in several international organisations. Van de Hulst remained the Chairman of GROC until it was superseded by SRON (Space Research Organisation of the Netherlands) in 1983.

GROC consisted mainly of the Astronomy Departments of the University of Utrecht (Solar and Stellar Space Research); the University of Leiden (Cosmic Rays); the University of Groningen (Photometry) and the research group on Satellite Geodesy of the University of Technology Delft. The GROC research groups took part in several rocket and balloon experiments. The instruments used were designed and developed by the university groups themselves, assisted by industry and technical laboratories.

Although small-scale rocket tests were performed at the island of Texel in the 1950s and 1960s (mainly for ballistics research) the Netherlands did not until then have a tradition in rocket research and development, except for one notable exemption: in 1946 J.M.J. Kooy and J.W.H. Uytenbogaert published 'Ballistics of the Future' a now classic book on space flight dynamics. The book was for a large part written during the Second World War when Kooy observed the launch of V-2 rockets near his home in The Hague. Kooy became professor at the Royal Military Academy in Breda in 1967 and was Chairman of the Netherlands Astronautical Society. For many years he published articles on space flight, specifically on the stability of lunar orbits. A fund that carries his name supports research on ballistics and related fields to this day.

2 First Steps

From the start it was clear that the Netherlands' contribution to space exploration could only take place through cooperation. The country just did not have the capacity to go its own way. Apart from the superpowers, the USA and the USSR, other countries were in the same position, so European cooperation seemed the obvious choice. The Dutch already were avid supporters of European cooperation in general, which was beginning to emerge in the 1950s. In 1951 the Netherlands had been one of the six countries that signed the ECSC Treaty (European Coal and Steel Community) and in 1957 the EEC Treaty of Rome (European Economic Community) was signed. It was thus no wonder that Dutch space enthusiasts turned to their European colleagues.

2.1 Founding father

The signing of the Meyrin Treaty in 1961, named after the Swiss town of Meyrin, was a result of discussions and meetings held since 1958 and it led to the founding of the Commission Préparatoire Européenne de Recherche Spatiale (COPERS). The committee's brief was to prepare a European Space Research Programme. In that same year GROC, together with the Netherlands Agency for Aircraft Development (NIV) addressed the Netherlands government with a plea to take part in the European space cooperation. They found a sympathetic ear and consequently the Netherlands became one of the founding fathers of the European Space Research Organisation (ESRO), founded in June 1962. The Netherlands' share amounted to 4.24 percent.

A few months before the official signing of the ESRO Treaty, in April 1962 it was decided that the technology centre of the organisation, ESTEC, would be based in the Netherlands. ESTEC is responsible for managing space projects and the preparation of future projects, supporting (ESA-) project teams and the development of new space technology. In 1962 the organisation was temporarily housed in buildings of the University of Technology in Delft, but these soon proved to be too small for the increasing number of people that came to work for ESTEC. Furthermore the ground in the polder where the University was located was too unstable to build test facilities. At a meeting of the ESRO Council in June 1964 it was decided that ESTEC would be based somewhere else.

The Netherlands government proposed the coastal town of Noordwijk and construction there started in 1965. Two years later, in April 1967, Princess Beatrix (now Queen of the Netherlands) officially opened the buildings. Scientists from the Netherlands were from the start actively involved in ESRO-projects and scientific instruments were delivered for ESRO satellites like ESRO-2 and 4 and TD-1 (1968-1972).

Nowadays about 1600 people are working in Noordwijk; 1000 staff of ESA and 600 people employed by various other agencies and industries. The exhibition 'Space Expo', also housed in Noordwijk close to ESTEC, is a popular destination for family outings.

At the same time ESRO was being formed (1960) the United Kingdom and France had started to discuss the possibilities regarding the development of a satellite launching system. Both countries were already developing such a system (Blue Streak in the UK and Coralie in France, while Germany was building Astris) but the burden for each of them became too heavy. Other countries got involved and in March 1962 the Netherlands was one of the seven countries to sign a convention with the aim of designing, constructing and launching rockets for spacecraft. The new organisation was named ELDO, European Launcher Development Organisation and the Netherlands' share was 2.6 percent.

2.2 Attitude control

The work within ELDO was roughly divided between the participating countries. The Netherlands had to develop and manufacture equipment for long-distance telemetry and to test the Attitude Reference and Programme Unit (ARPU) and, later on, the inertial guidance system. The latter task was done by the National Aerospace Laboratory (NLR), which also carried out wind tunnel tests. The development of long distance telemetry was assigned to Philips Telecommunications Industry (PTI) in Hilversum.

The ARPU used a gyroscopically stabilised platform, which provided a reference point for deriving the attitude of the rocket in space. It was tested on a hydraulically controlled rocking table with three degrees of motion, with which the rotational motions of the rocket could be simulated. The hydraulic cylinders were controlled by an analogue computer on which the equations of motion and the characteristics of the rocket steering mechanism were simulated.

Fully analogue computation was needed because in those days the speed of digital computers was not sufficient to process the equations of motion and control equations in real time. In later versions of the ELDO rockets the gyroscopically stabilised platform was replaced by an inertial system using accelerometers. These were also tested by NLR by providing them with signals from the computations that simulated accelerations during actual flight.

Apart from the attitude control system for the rocket, NLR, Philips and Fokker were also responsible for developing a similar system for the ELDO-PAS project (Perigee-Apogee Satellite) whereby a payload was to be carried into an elliptical orbit with its highest point (apogee) at the altitude for a geostationary orbit. At this point the satellite would be released into that orbit. The project was cancelled, but the experience gained was valuable for the emerging Dutch space-related industry.

2.3 Useful experience

It can be said that, although ELDO was not very successful with respect to its launches (according to some it was an expensive experiment in international cooperation that did not work out very well) it laid the grounds for the development of Ariane. Further on it provided Dutch participants like Philips, NLR, TUD, TNO and Fokker with a lot of technical and operational expertise that has also been used for Ariane. The experience gained in international cooperation – although quite frustrating at times – also proved to be very useful, especially when the Netherlands began to think about building its own satellite.

3 Growing Up

By the mid-1960s it was becoming clear that the Netherlands commercial sector was not very successful in obtaining orders for European space projects, at least not the orders that were technologically challenging. Under the ESRO/ELDO agreements the contribution of each country to the budget of the European organisation determined the value of the contracts awarded to this country so the money spent came back anyway. The problem was that it did not do very much for the building of technical and operational capacity.

3.1 Space plan

The obvious solution was to build your own satellite, thus showing to the world that the Netherlands had the technical and managerial capacity needed for space exploration. A working group, spontaneously formed by representatives from Fokker, Van der Heem Electronics and Philips submitted a proposal to develop such a satellite in 1966: the Netherlands Astronomy Satellite. With the proposal the industries involved in space research and development reacted to a call from the Department of Economic Affairs regarding suggestions for a national space plan. An Interdepartmental Commission for Space Research and Technology (ICR) had been set up in March 1966 to co-ordinate activities in the Netherlands. A first plan was presented in September a year later.

Not only was the ICR presented with a plan for a Netherlands Astronomy Satellite, but the commercial sector together with the PTT (the Netherlands' mail and telephone company, at that time still government-owned and operated) submitted a proposal to build an experimental ground station for satellite communication. The ground station was opened in 1973 by the then Queen Juliana near the village of Burum in Friesland in the north of the Netherlands, not on an experimental basis but as the first operational ground station for Intelsat-1, which had been launched in 1965. Burum is still the main ground station for satellite communications. The 25 hectare area with its dozen dishes is aptly called 'it Greate Earen' (the great ears) in the local Frisian language.

3.2 National enthusiasm

As the proposed satellite and ground station would lead to a substantial increase in spending on space the government sought the advice of the Science Policy Council (RAWB). In 1968 the Council recommended to go ahead with both projects and to stay involved in European programmes. In 1969 a second advice of the Science Policy council was published as a reaction to the preliminary study for the Netherlands Astronomy Satellite or ANS (Astronomische Nederlandse Satelliet). In this document the RAWB proposed to improve the situation of the Dutch space industry. An astronomical satellite would be an excellent object for a national space plan. There were several arguments.

First of all Dutch astronomers had a reputation to uphold; a satellite would further boost that reputation. Secondly, space is so enormously vast that the overlap with other space research initiatives would be limited. A third reason for choosing an astronomical satellite was that astronomical research was quite popular among the public. A satellite could possibly lead to some 'national enthusiasm'. Last but not least, an astronomical satellite would give ample opportunity to show Dutch ingenuity without the complications that arise from international cooperation.

3.3 Scientific interest

Dutch astronomers were asked to develop research experiments that could be carried out with this not too heavy satellite (<112 kg), which also should not be too expensive. The scientists suggested to measure the following:

- ultraviolet radiation of hot stars, between 1500 and 3300 Å;
- weak stellar X-rays, between 44 and 55 Å;
- hard solar X-rays between 0,3 and 6 Å;
- hard stellar X-rays, between 2 and 34 Å.

Scientific interest was enormous. Earlier attempts like the Uhuru satellite from NASA had revealed that there were quite a few X-ray sources in the Universe. The suggested X-ray telescope on the Netherlands satellite was supposed to reveal many more, but also to provide more information on these sources, for instance their periodicity. The monitoring of the far ultraviolet was expected to reveal information on the process of star formation. A special feature of the proposed satellite was a programmable onboard computer that could be reprogrammed every 12 hours for optimal measurement of ultraviolet and X-ray sources in space.

3.4 Deadline

After a preliminary study, the Netherlands government decided in December 1970 to build the Netherlands Astronomy Satellite or ANS (Astronomische Nederlandse Satelliet) with the Netherlands Agency for Aerospace Programmes (NIVR) as the supervisor. Fokker and Philips established the Industrial Consortium Netherlands Astronomy Satellite (ICANS) which worked closely with the Laboratories for Space Research of the Universities of Groningen and Utrecht. Together they succeeded in building the satellite within the five-year deadline. With the proverbial Dutch thriftiness the costs were kept to a minimum. The whole operation would cost a mere 36 million Euro.

The instruments on ANS consisted of an ultraviolet telescope designed by the Space Research Group of the University of Groningen and built by Ball Brothers Research Corporation in the USA, two X-ray detectors built by the Space Exploration Laboratory of the University of Utrecht for measuring soft and hard X-rays and an X-ray detector built by a US consortium which included MIT (the Massachusetts Institute of Technology) and the Centre for Astrophysics. The ANS was tested by NIVR with help from ESTEC in Noordwijk, NLR and the German DFVLR.

3.5 Out of orbit

On the 30th of August 1974 ANS was launched from the Western Test Range in California. During the launch there was a deviation in the launch path of the SCOUT-rocket, which resulted in an alteration in the orbit of the ANS. Instead of an almost circular orbit between 510 and 560 kilometres the satellite went into an elliptical orbit between 260 and 1160 kilometres high. At first it looked like a disaster but, thanks to the programmable computer on board, the attitude control system could be adjusted to give the desired observation programme, even in these extreme circumstances. The only thing was that a group of staff and students at Delft University of Technology (TUD), had to work overtime to calculate the exact attitude and position of the satellite.

Almost three years later, in July 1977, ANS returned into the Earth's atmosphere. It was kept in operation between September 1974 and December 1975 and turned on again shortly in March and April 1976. ANS is still considered a great success. First of all because of the scientific results that were obtained. Both the X-ray and ultraviolet measurements have produced a lot of data, amounting to years of work. Three new types of X-ray sources were identified and the ultraviolet spectrometer proved the existence of very hot stars in our galaxy.

3.6 Capability

Apart from the scientific results ANS also demonstrated the technological capability of the Netherlands. Although the different systems on board were designed for a six months lifetime they lasted for nearly three years. The attitude control worked better than expected; the aiming accuracy was designed to be one arc minute but turned out to be 30 arc seconds.

The scientific, technological and operational success of the ANS-mission established the Netherlands as a space-faring nation. Add to that the fact that, compared with other space projects, the ANS was carried out on a shoestring then it is no wonder that it invited some technologically challenging orders from ESA, NASA and others for years to come, not only for advanced instrumentation but also for solar arrays, robotics and attitude control systems. An evaluation study revealed that ANS had fulfilled its expectations with respect to its scientific and technological goals and the increased competitiveness of Dutch industry.

3.7 Education

Around the time that the government decided to go ahead with ANS, TUD started with a new course on space technology within the Department of Aeronautics, at that time still part of the Faculty of Mechanical Engineering. The establishment of this course followed a suggestion by Henk van de Hulst, who around 1965 had gathered a few university staff members to discuss the need for academic training in space technology.

In 1970 the number of new students entering the Department increased dramatically, following the successful flight of Apollo-11 in 1969, which put Armstrong and Aldrin on the Moon. In 1975 the Department of Aeronautics became a full-fledged Faculty of Aerospace Engineering, illustrating the importance of space technology for industry and society as a whole.

In 1996 the university started a post-graduate course in space systems management. This SpaceTech course is developed in cooperation with the commercial sector, scientific organisations and ESA and leads to the degree of Master of Space Systems Engineering. By 2001 about 80 people had taken part in the course.

3.8 Satellite laser ranging

As ANS was launched another event took place, which attracted a lot less publicity; the start of satellite laser ranging at a new Observatory for Satellite Geodesy, in Kootwijk, a village located on the edge of the Veluwe National Park. The start of the Observatory marked the importance of space for geophysics. Even before 1957 geophysicists had realised the importance of satellites for triangulation, the measuring of distances on Earth. By using a satellite's position, triangulation points hundreds of miles apart, could be connected.

Geoscientists from TUD started using satellites for triangulation in 1961. At first existing satellites were used by photographing them against the night sky. Comparing the photographs of several stations gave a very precise triangulation and hence a good estimate of distance between the stations. Later on, in the beginning of the 1970's, the technique of satellite laser ranging was used. A laser beam is emitted towards a special reflecting satellite (LAGEOS), reflected and received again by a telescope. By sending (and receiving) laser beams from separate stations at exactly the same time, distances can be measured on the Earth's surface with an accuracy of 5 centimetres. To avoid difficulties with timing, an innovative method was developed in Delft to calculate exactly the distance the satellite had covered in between two laser beams.

Among other things the satellite laser ranging system has been used to measure the movement of continental plates in the Mediterranean and to verify the position of the satellites used for the United States Global Positioning System. Early in the 1990s the observatory in Kootwijk was closed; triangulation is now done by radio telescopes using quasars as their reference point.

3.9 Another satellite plan

ANS qualified the Netherlands as a fully-fledged space nation. Although this led to some very interesting assignments, the size of the Netherlands contribution in ESA (which was formed in 1975 as a successor of ESRO/ELDO) remained small – too small to earn overall systems responsibility for one of the ESA projects. Therefore it was no surprise that after the successful ANS mission the Dutch astronomy community and space industry submitted a proposal for a new national satellite, this time much larger than ANS.

As with ANS the question was, what kind of satellite would boost astronomical research in the Netherlands without duplicating other initiatives. One of the areas that proved interesting was the infrared wavelength between 8 and 100 μm. At that wavelength radiation is emitted from so-called 'cool' objects, cool meaning a temperature between 10 and 2000K. Planets are cool objects, but so are dust clouds in the farther regions of space. It was thought that by exploring these objects, information could be obtained on the formation and death of stars and the formation of planetary systems.

No such survey had been carried out at that time and – as previous endeavours had shown – unexplored regions of the electromagnetic spectrum could reveal quite exciting phenomena. Exploration of infrared sources is impossible from Earth, due to obscuration of the signal by thermal radiation from the telescope and its surroundings. An infrared telescope on a space platform was very attractive to astronomers. The objective of the Infrared Astronomy Satellite (IRAS) was to survey at least 95% of the sky for sources of infrared radiation, but mainly in the Milky Way region.

3.10 Benefits

In 1975 a preliminary study for IRAS was made, resulting in a proposal from the NIVR to build such a satellite. The proposal was supported by a study on the 'Potential benefits to the Netherlands from the IRAS-project', carried out by a British consultancy firm. They advised the Netherlands government to increase spending on space activities so that industry and society as a whole would benefit from the strengthening of the technological capacity. At that time the Netherlands were spending about 0.03% of the Gross National Income on space-related activities. According to the British consultants this had to more than double to 0.08% to keep up with other nations. IRAS was an excellent object to spend this extra money on.

In 1976 the government gave IRAS the green light. The project began with an agreement, between the NIVR and NASA, for the Netherlands to provide the spacecraft and be responsible for the testing, the system integration and the operation. NASA would provide the telescope, the launcher and the data processing equipment. The Space Exploration Group of Groningen University would build a series of spectrometers, together called DAX, short for Dutch Additional Experiment. As the Netherlands did not have in-house capacity for operating the satellite, the UK Science and Engineering Research Council got involved. They would provide the necessary facilities in exchange for a piece of the pie, i.e. the participation of British astronomers in the survey.

3.11 Commercial involvement

As with ANS the Netherlands commercial sector was heavily involved in IRAS via an industrial consortium (ICIRAS). The ICIRAS consisting of Fokker and Hollandse Signaal Apparaten was responsible for the project management in the Netherlands. In the USA project management was allocated to the Jet Propulsion Laboratory (JPL) and in the UK the Rutherford Appleton Laboratory managed the British part of the project. Overall project management was put in the hands of the Joint IRAS Project Executive Group (JIPEG) which consisted of the representatives of the different institutes involved and of the Joint IRAS Science Working Group.

IRAS was a much heavier (1080 kg) and much more complicated satellite than ANS (140 kg). It was a cylindrical structure, the base of which housed the spacecraft platform with all the necessary housekeeping and control tasks, like power distribution, attitude control, data storage and communication. The remainder of the cylinder housed the telescope, consisting of an optical system with two mirrors in a tank filled with liquid helium. Several detectors were mounted in the focal plane.

The helium was used to cool the detectors to a temperature of about 2K and to keep the inner walls of the telescope at a temperature of about 10K to obtain the desired sensitivity for the observations. These low temperatures were a technological challenge in the sense that electronics and materials behave quite differently. IRAS had 75 kg of helium which would last for about 300 days of operation.

3.12 Spectacular

After being postponed a number of times, due to problems with the cryogenic system, IRAS was launched with a Delta rocket on 25 January 1983 from the Western Test Range in California. Once in its Sun-synchronous near polar orbit the satellite operated smoothly until 22 November 1983 when it ran out of helium. The results of the IRAS mission were spectacular. For instance it was discovered that in some galaxies the infrared radiation is about 500 times larger than in our own galaxy, meaning that a lot of new stars are being formed in these galaxies. Its infrared map of the Galaxy is still in use. IRAS also showed that planets are forming around other stars in the Universe. Or, to quote from the US National Commission on Space: ‘The Infrared Astronomy Satellite discovered that dozens of stars have clouds of particles surrounding them, emitting infrared radiation; astrophysicists believe that such clouds represent an early stage in the formation of planets.’

4 Coming of Age

The IRAS mission marked the coming of age of space activities in the Netherlands – a shift from the pioneering stage, with its emphasis on scientific research, to a situation in which space activities have become 'normal'. At the same time space activity has broadened to include practical applications, such as telecommunications, earth observation (including weather forecasting) and the use of microgravity for biological and material science experiments.

4.1 Dwindling

This change in both position and scope was marked by a White Paper published by the Netherlands government in 1982 called: 'De ruimtevaart in de jaren '80' ('Space in the eighties'). It stated that up to that point the Netherlands' space policy had merely been an extrapolation of developments that had started in the late 1950s. It also stated that the time had come to formulate a long-term policy, based on strategic choices. These choices were necessary because of the limited financial means of the Netherlands government, but also because spaceflight had to prove its worth, not only for scientists but for society as a whole.

This proof was needed because after the spectacular successes of manned space flight, the public support for space activities was beginning to dwindle. This downward trend was reinforced by a very critical attitude towards technology in those days, ignited by the incident at the Three Mile Island nuclear power plant in the USA and fed by bleak stories of environmental deterioration. According to some, the mood of the day was very anti-technology. Being a spearhead of technological development space activities hence came under fire. They seemed a luxury; a lot of money spent on the hobbies of some 'space addicts'.

The White Paper on Space in the eighties had already been announced in 1977 by the then Minister for Science Policy. It took almost five years to complete because a radical change in attitude towards space activities was required. Instead of going with the flow, policy makers had to evaluate in detail the economical, environmental and technological effects of space exploration. An additional problem was that the Netherlands, being a relatively small space nation, could not formulate its own strategy without knowing the future plans of ESA. However it took ESA until 1980 to formulate a long-term strategy for its activities, the process being complicated because the large member states of ESA had their own national programmes and hence their own agendas.

4.2 Practical use

The policy document analysed the importance of space for the Netherlands. It pointed out that telecommunications was the most developed space application at the beginning of the 1980s. Communication satellites were already being exploited on a commercial basis. Taking part in the L-Sat programme (later, Olympus) opened up the possibility for the Netherlands industry to gain a share of the satellite market. Less developed but still quite interesting were the emerging possibilities with respect to the observation of the Earth or 'teledetection' as it was called in those days. It was deemed especially useful for the monitoring of environmental and ecological trends and agricultural development. This would not just be useful for the Low Countries themselves but also as a means to instigate development in the Third World. With the International Institute for Aerospace and Earth Sciences (ITC) in Enschede, established in 1950, the Netherlands would have a strong position in the transfer of knowledge of geosciences to Third World countries.

With regards to space-related science the Netherlands traditionally had a strong position in the field of astronomy, a position that had been further strengthened by the ANS and IRAS missions. Spacelab provided the opportunity for other disciplines to do new and fundamental research in space, in particular biological and materials research.

4.3 No third satellite

Considering these developments and considering the limited financial resources for space activities the Netherlands government decided that there was no room for a third Netherlands scientific satellite. Netherlands industry and institutions had made their mark internationally with ANS and IRAS. The added value of designing and building such a satellite would be too small to justify the costs of – at that time – 90 million Euro. More practical satellite systems, for instance for telecommunications or Earth observation, required investments that went well beyond the Netherlands space budget.

It was decided that the relatively modest amount of money available (40 million Euro per year) would be better spent by taking part in international projects. The projects of choice would mainly be ESA projects, with an emphasis on applications, such as telecommunications (L-Sat at that time) and Earth observation (ERS). The space policy would also attempt to stimulate bilateral projects and the participation of the Netherlands industry in commercial projects. The application to other fields of the knowledge and experience gained in space projects would also be stimulated.

4.4 Dismay

The Netherlands space community – including astronomers – reacted with dismay to the government's decision. Several people in industry and university pointed out that without a Netherlands satellite project the experience with systems integration and management of complex technological projects would be lost. Instead of being the main contractor on such projects, the Netherlands industry would be demoted to the role of subcontractor, dependent on the whims of foreign companies and organisations.

Several studies had already been performed on possible satellite projects. One such project was a broadcasting satellite, NETSAT. It never got beyond the discussion stage, because in 1979 the L-Sat programme was launched by ESA. In that same year a feasibility study was undertaken regarding a successor to ANS, the TIXTE (Timing and Imaging X-ray Transient Explorer) which would carry an Imaging Wide Angle Camera for X-ray Sources (IWACXS). NASA was interested and the British SERC also wanted to join in. The NIVR, in co-operation with NASA's Goddard Space Flight Center, conducted a feasibility study. But as the political climate in the Netherlands was changing and the support for a national satellite diminished the TIXTE project was abandoned before it had even begun.

Another project that was shelved around that time was TERS, the Tropical Earth Resources Satellite, an Earth observation satellite to be developed together with Indonesia, a former Dutch colony and a partner in development. Discussions between the Netherlands and Indonesian Aerospace Agency started in 1978 and in 1979 a workshop was held in Jakarta. While the Netherlands industry started work on a provisional definition study, the enthusiasm in Indonesia appeared to be waning. In 1981 though the Indonesians announced that they wanted to become involved again and in 1984 the definition study was concluded. A year later a proposal was made for a systems study. At that time Belgium was also interested in joining because of the satellite's potential application in Equatorial Africa. However, no agreement could be reached on the financing of the project. It was discontinued.

4.5 New objectives

At the beginning of the 1980s, when the new Netherlands space policy was formulated, its main aim had been to use the unique possibilities of space for social and economic well-being and scientific progress. This objective consisted of several sub-objectives, which can be grouped in three categories; political objectives, user objectives and industrial/technological objectives.

The **political** objectives were and still are:

- to maintain independent European access to space;
- effective international technological cooperation;
- participation in the building of a European space capacity;
- to contribute to solving global problems.

The **user** objectives are divided into scientific, institutional and industrial/technological use. *Scientifically* the aim of the Netherlands is to perform ground-breaking research in and on space. *Institutionally* this means that the necessary infrastructure should remain available both in space and on Earth, including a user infrastructure to guarantee the availability of data and data products. On the *industrial/ technological* level private companies should be stimulated to either take part in building this type of infrastructure and/or to use the data generated.

The industrial/technological objectives are:

- to improve technological innovation and competitiveness of the Netherlands industry, by allowing access to space technology;

- to help use the knowledge and experience gained in developing commercial products and services;
- to promote co-operation between companies and public institutes at both national and international levels.

Since then these objectives have led to a space policy in which the focus lies on European co-operation through ESA, Eumetsat and the EU. The Netherlands contribution in the optional part of these programmes was defined by priorities set by users and by industry. These priorities were supported by activities at a national level, e.g. the use of Earth observation data and the development of advanced technology. Apart from that, the government aims at developing a market for institutional and commercial use of space and for the transfer of knowledge to small and medium-sized companies.

4.6 Formalisation

Together with the formulation of a space policy the institutions became more formalised. In the early days space policy and funding of space activities was the responsibility of the Minister of Economic Affairs and the Minister of Science Policy. As it became clear that space activities were also important for other areas of government, more ministers gradually became involved.

As mentioned before, in 1966 an Interdepartmental Commission for Space Research and Technology (ICR) was established to formulate the Netherlands Space policy, advise the government on participation in international programmes and co-ordinate the Netherlands position in ESA (then still ESRO/ELDO). This ICR was given a more formal role in the policy document of 1982. The number of participating departments increased to nine and the tasks and competences of each of these were formulated. At first the Minister of Science Policy held the presidency of the ICR. Later on the Minister of Economic Affairs held this post; another illustration of the switch from a pioneering, research-oriented space community to a more established and application-oriented organisation.

Some people regret that the days of pioneering are now over and are of the opinion that space is now being controlled by bureaucrats. Other people, for instance the young space professionals that took part in the Vision 2020 project of the International Space University in 1995, want to use space and space technology for the benefit of all mankind and want to be held accountable for that.

4.7 From GROC to SRON

Not only the ICR but also the positions of its advisory bodies were evaluated and consequently updated. One of these was the GROC of the Royal Netherlands Academy of Science. Since its start in 1959 it had operated on an *ad hoc* basis, working on a project basis, both internationally as well as at national level. This *ad hoc* character also had an effect on the organisational structure of the committee and on the financing of projects.

In 1982 when the space policy document was published, the first steps had been taken towards the creation of a more formal institution. The GROC was discussing with the Netherlands Organisation for Scientific Research (NWO) about becoming a foundation within the framework of this parent-organisation, which was mainly government-financed. This would be identical to the way other sciences, such as physics were structured. One of the underlying thoughts was that by embedding GROC in the regular science institutions it would become easier for other scientists to get access to space. This was the more urgent because of the Space Research Module Spacelab with its possibility for research on fluid dynamics, physiology and other interesting research areas. For researchers in these fields the step into space was still quite big. It was thought that a ‘new’ GROC could bridge this gap more easily.

Hence in 1983 the acronym GROC was changed into SRON, a foundation within the framework of NWO with a more formal organisation and – although still based on projects – a bit less *ad hoc* regarding its financing.

4.8 National Space Agency

In 1970, at the time the Netherlands government gave the go-ahead for ANS, it was also decided that the NIV would co-ordinate space activities in the Netherlands. As with all the other projects, a working group was set up. In July 1970 it presented its proposal to include spaceflight in the agenda of the Agency. In 1971 the name of the agency was changed into the Netherlands Agency for Aerospace Programmes (NIVR).

In those days, the space activities of NIVR were primarily concerned with the management of the ANS project. Apart from that studies were made on space activities and on the development of space technology in the United States, the Soviet Union and Europe. These included the potential value of space and space technology for the economy and for society as a whole. Following these studies the NIVR started in 1979 with its – government financed – NIVR Space Technology programme (NRT) aimed at funding research on promising space technology and products.

4.9 Technology development

Over the years the Space Technology programme has been important in strengthening the position of Netherlands industry and research institutes, both as part of ESA programmes and in commercial space activities. One of the successful products developed within the Space Technology programme was a solar panel, the Advanced Rigid Array (ARA) developed by Fokker Space & Systems (now Fokker Space). The ARA, completed in 1988, was later superseded by the Retractable and Retrievable Array (RARA), a solar panel that could be retracted, retrieved and returned to Earth. This RARA was used on the European Retrievable Carrier (Eureca) that was launched (1992) and retrieved (1993) by the Space Shuttle.

Another successful product developed under the NRT programme was PHARUS, an acronym for Phased Array Universal Synthetic aperture radar, a radar system for collecting all kinds of surface information, ranging from cartographic information to measuring wave heights at sea. The project was carried out by the TNO Physics and Electronics Laboratory, the NLR and TUD. PHARUS was tested in November 1990.

Under the NRT programme (and the ESA technology programme) a small satellite, Sloshsat-FLEVO, had been developed to study the dynamics of sloshing liquids in space. The behaviour of water in an instrumented tank in the satellite is to be monitored, to help understand how sloshing affects the attitude and orbit control of space vehicles. Sloshsat FLEVO will be launched in 2003 from the Space Shuttle, and operated from the ground. The main contractor for Sloshat-FLEVO is NLR. Fokker Space (NL), Verhaert (B), Newtec (B), Rafael (Israel) and NASA (USA) are also participating in the project.

4.10 National Remote Sensing Board

Having participated in ESA programmes since the late 1970s, scientists and policy makers in the Netherlands became more and more aware of the importance of satellite remote sensing for monitoring changes in the Earth’s environment. In the Space Policy document of 1982 the government announced the establishment of a National Remote Sensing Programme.

In 1986 the National Remote Sensing Board (BCRS) was founded, consisting of representatives from six ministries: Transport, Public Works and Water Management, Education and Science, Economic Affairs, Agriculture and Fisheries, Development Co-operation, Defence. The major technical institutes and the Netherlands industry were represented by the NIVR. The Netherlands Engineering Consultants (NEDECO) were part of the board to represent the Netherlands engineering consultants and SRON represented the space research community. The BCRS was discontinued in 2001 and several tasks were transferred to the NIVR.

The main task of the BCRS was the execution of the National Remote Sensing Programme and – since 1993 – part of the National User Support programme. These programmes are intended to promote the adoption of remote sensing techniques and the use of data by potential clients in the public and private sector. Among these are (local) government agencies, research institutes and commercial users. The BCRS has also been involved in processing and using the data of the ERS-1 and ERS-2 satellites developed by ESA. Subsequently the Netherlands government decided to take part in the new remote sensing programmes of ESA and Eumetsat.

4.11 Commercial interests

In 1989 the Netherlands Industrial Space Organisation (NISO) was founded as a permanent forum for the country's space industry and as a sounding board for the Netherlands space authorities. NISO brings together almost all industries active in space, as well as institutes supporting research and (pre-) development. About 40 Dutch companies are involved in space activities, of which a dozen or so are engaged in systems engineering. Apart from the direct involvement of companies, space activities have also led to new products and processes in industry through transfer of technology. An example of ‘bringing aerospace technology down to Earth’ is the lightweight tank for Liquid Petroleum Gas (LPG), developed by Advanced Lightweight Engineering. The tank is produced from a new fibre (M5) invented by Akzo Nobel with spinning techniques used in space and its weight is 30 percent of that of a comparable steel tank. Another example is a system, developed by Stork Product Engineering and TNO for the suppression of dust explosions. This is based on the ignition system for Ariane-5. A more general spin-off of space activities is the added value gained by companies in terms of quality assurance, organisation and marketing.

5 Focus

A direct result of the space policy, of which the foundations were laid in 1981/82, is the shift of Netherlands activities from national projects to participation in projects of ESA. Since then, about three quarters of the annual budget is used for ESA's mandatory activities and optional projects. In addition the Netherlands were and are still involved in a number of international space organisations such as Eumetsat (meteorology), Inmarsat (navigation) and Intelsat and Eutelsat (satellite communication). A number of national supporting activities were developed to allow industry and user communities to get involved in space activities and in the use of data generated in Space studies.

The main aim of Netherlands space policy is the deployment and utilisation of a global space infrastructure to the best possible effect, for social, economic and scientific progress.

5.1 Spacelab

One of ESA's main projects has been Spacelab, a manned space module for microgravity research. In November 1983 Spacelab was taken into space for the first time by the US Space Shuttle. On that first flight an experiment of the NLR was carried out in Spacelab to study the behaviour of fluids in partially filled containers under conditions of microgravity. Up to 1997 Spacelab flew on numerous missions, carrying out hundreds of experiments on a whole range of topics, such as properties of fluids, crystal growth, alloy formation and the influence of gravity on a range of physiological processes, such as circulatory disorders, osteoporosis (decalcifying of bones) and loss of balance. Researchers from the Hubrecht Laboratory in Utrecht for example have studied the impregnation of toads (*Xenopus laevis*) in space and a group of researchers from Amsterdam studied the development of mouse embryos in space in order to gain insight into (de-) mineralisation processes of bone. In 1985 Wubbo Ockels, a physicist from the University of Groningen, flew with Spacelab and thus became the first, and at present only, Dutchman who has been in space. Since 1999 André Kuipers has been a member of the European Astronaut corps and is training for his first flight.

Dutch industry also contributed to the success of Spacelab by developing new equipment. One piece of equipment used in Spacelab (and elsewhere) was the Glovebox, a closed cabinet used to carry out experiments. Access to the box is possible using rubber gloves, which form an integral part of the box. Gloveboxes are commonly used on Earth, but whilst terrestrial glove boxes are often used to conduct experiments on air-sensitive or highly toxic compounds, the space glovebox was designed to protect the living environment of the astronauts from the experiments and to prevent cross-contamination between experiments. The Netherlands have played a leading role in the development of glove boxes for the manned space programme. The Space Glovebox was conceived by ESA in the late 1970s and was used in Spacelab's Biorack on several missions and in the space station Mir in 1996-1998. While Fokker Space & Systems was the main contractor for the Biorack, the Dutch company Bradford Engineering BV developed the Glovebox. Bradford also built a large part of the successor: the Microgravity Science Glovebox (MSG) which ESA recently (October 2001) shipped to NASA to be launched to the International Space Station (ISS).

5.2 Robotic Arm

In the 1980s plans were made for a European space shuttle, Hermes. As part of the Hermes programme, Fokker Space designed a robotic arm (HERA), to be used as a cargo crane and for the maintenance of the space vehicle. In the early 1990s the plans for Hermes were abandoned, but ESA found another use for the European Robotic Arm (ERA). It would become part of the Russian contribution to the International Space Station and is due to be launched by Space Shuttle in 2005.

Its main purpose is to minimise the amount of time astronauts have to spend outside the space station. Walking in space generally is quite strenuous and not without its hazards. The robotic arm has two limbs, each five metres long and connected with an elbow hinge. Both ends are fitted with grippers, which it can use to hold on to the vehicle or grasp other objects to move them from one place to another. With its grippers the arm can 'walk' along the outside of the space station by grabbing hold of one attachment after another. The robotic arm can be controlled in real-time or it can be pre-programmed. It is capable of determining its own position. From the start Fokker Space has been the main contractor for the European Robotic Arm, but other Dutch companies have been involved as well, including Stork Product Engineering, TNO, Bradford and NLR. The ERA is the largest space project in the Netherlands since ANS and IRAS. Other components for the International Space Station in which organisations from the Netherlands are involved, are the Data Management System for the Russian Service Module (DMS-R) and the rudders for the Crew Return Vehicle (CRV) meant for evacuation of the crew in case of an emergency.

5.3 Transportation

The Netherlands was one of the founding fathers of ELDO, developing the attitude reference system and the instruments for telemetry in the 1960s. ELDO's attempts at developing a rocket to bring payloads into space were not very successful so in 1973 a new French programme, Ariane, was created and later handed over to ESA. In 1979 the first Ariane rocket was launched from Kourou in French Guyana. The Netherlands contribution consisted of testing Ariane in the wind tunnel. In 1980 it was decided to hand over the production, marketing and launch of Ariane rockets to a French privately owned company Arianespace. ESA would limit itself to the design and development of new versions of Ariane.

Companies and research institutes from the Netherlands have been rewarded with increasingly interesting contracts on the successive Ariane models. The Netherlands contribution to the latest model, Ariane-5, is 2 percent. This contribution consists of an aluminium engine frame that transfers the thrust of the engine to the rocket itself. Fokker Space is the main contractor for this part of the project. Another Dutch company, Stork Products Engineering is the contractor for the ignition system of Ariane-5. This system consists of three pyrotechnic components (turbine pump starter, thrust chamber igniter and gas generator igniter), which perform their task in just over one second. Other Dutch components are the booster recovery system, a parachute that enables the spent booster to make a soft landing, the transport containers and a specially adapted ship to transport the rocket parts to the launch site in French Guyana.

5.4 Space research

Although the days of Dutch scientific satellites are over, this has not stopped scientists and industry from taking part in space research projects, in particular research into the X-ray and gamma-ray wavelength range and the infrared and sub-millimetre part of the spectrum. The Netherlands and more specifically SRON, have acquired considerable expertise in developing and building advanced radiation detectors and often functioned as the main contractor for such instruments.

Between 1975 and 1982, three quarters of the gamma sky was plotted by the European satellite COS-B. The gamma-ray detector on this satellite had been designed and built by a consortium of several laboratories known as the 'Caravane Consortium'. The Space Laboratory of the University of Leiden was part of this consortium. COS-B provided the first complete map of gamma ray sources. Another European satellite, which was operational from 1983 to 1986, was Exosat. The instruments on board, which were used for the mapping of X-ray sources, were partly designed and built by SRON. It also developed a coded mask camera, which was installed on board the space station Mir in 1987.

In 1984 The Netherlands got involved in the SAX-project. This was a satellite to be built together with Italy for the mapping of the X-ray universe and as such can be considered as a successor to ANS. SRON designed and built two wide angle X-ray cameras. Fokker Space made the attitude control system and the solar panels. Several other institutes were also involved. The initial plan was to launch SAX near the end of the 1980s, using a Space Shuttle. However, due to the accident with the Space shuttle 'Challenger' in 1986, the launch was postponed and another launch vehicle had to be considered. At the same time the Italian Space Agency underwent considerable reorganisations, which together with various modifications to the satellite resulted in a considerable delay. SAX was eventually launched by an Atlas Centaur rocket on 30 April 1996.

The Netherlands' involvement in X-ray space research was continued with ESA's XMM and NASA's Chandra, both launched in 1999.

The Netherlands-American IRAS satellite for mapping infrared sources was superseded in 1995 by ISO, the Infrared Space Observatory of ESA. ISO has given us a detailed view of chemical processes occurring at the birth of stars and at their time of death. Compared to IRAS the operational life of ISO was longer (two and a half years) and a broader spectrum was covered. SRON, together with the Max Planck Institute in Munich and TNO Physical Laboratory (TPD) developed a spectrophotometer for ISO covering the shorter wave part of the spectrum.

5.5 Earth observation

From 1986 onward the Netherlands became more and more involved in Earth observation activities. An infrastructure was also developed to use the data from Earth observations for agriculture, environmental monitoring and development cooperation. The use of satellites for monitoring processes on Earth served scientific, technological, social and industrial goals and in the beginning of the 1990s Earth observation became one of the spearheads of Dutch space policy.

The Netherlands took part in the development of ERS-1. Its data were used for monitoring ocean currents and the rise in sea level. The mapping of the seabed for mining proved to be a commercially interesting application. ERS-2 was launched in 1995 and had an instrument on board to monitor the ozone concentration in the upper layers of the atmosphere. The Netherlands were involved in the development of this instrument named GOME (Global Ozone Monitoring Experiment) and the data have been used in climate research.

Early in 2002 the European Space Agency launched Envisat, an advanced polar-orbiting Earth observation satellite that will provide measurements of the atmosphere, ocean, land, and ice over a five-year period. The Envisat satellite has a payload that will ensure the continuity of the data measurements of the ERS satellites. The Envisat data will support Earth science research and allow monitoring of the evolution of environmental and climatic changes. One of the instruments on board is the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (Sciamachy). This can be used to map concentrations of trace gases in the atmosphere, such as carbon monoxide and dioxide, nitrogen oxides, methane and ozone. These are all trace gases that are believed to play a role in climate change.

Sciamachy is a joint project of the Netherlands and Germany, with Belgium also contributing. The Dutch Nobel laureate Paul Crutzen has been involved in the development of the instrument. NIVR is responsible for managing the project; leading Dutch participants are Fokker Space, SRON and TPD. The data will be used by a wide range of institutes, including the Netherlands Climate Research Centre.

In 1997 the Netherlands were invited by NASA to develop and build a new instrument, the Ozone Monitoring Instrument (OMI) for the Aura (EOS CHEM) mission, planned for 2003. The aim of the mission is to study the chemistry and dynamics of the Earth's atmosphere, with emphasis on the upper troposphere and lower stratosphere (5-20 km). The mission will measure ozone, aerosols and other atmospheric constituents that play an important role in atmospheric chemistry, air quality, and climate. OMI is unique in its detail, while every day the whole of the Earth's atmosphere is mapped. The mission, led by the Royal Netherlands Meteorological Institute (KNMI) will help in evaluating the environmental policies and international agreements on the phasing out of chlorofluorocarbons (CFCs).

5.6 Eumetsat

In 1977 ESA launched its first weather satellite, Meteosat, which sent images of the atmosphere back to Earth until 1979. In 1981 a second Meteosat was launched, still under the ESA umbrella. In 1986 Eumetsat came into being and assumed formal responsibility for the Meteosat system in January 1987. In 1991 it initiated a new programme, the Meteosat Second Generation (MSG), to ensure the continuity of observations from the geostationary orbit until the period 2015 to 2020. The first MSG satellite will be launched in 2002. A Meteosat Transition Programme will ensure continuity between the current Meteosat Operational Programme and MSG.

The Netherlands is one of the 17 nations that are now members of Eumetsat. Pictures of several satellites are shown every night on television during the weather forecast. It is safe to say that we can now predict the weather with reasonable certainty up to five days ahead, although a local low pressure zone may play havoc with the forecast once in a while.

Apart from weather forecasting, data from Eumetsat's and other satellites are increasingly being used in one of the most exciting new research areas that goes under the name 'global change'. The Netherlands plays an important part in this field, which connects phenomena at a local level, for instance water temperature in the North Sea, to long term changes in the Earth's hydro-, bio- and atmospheres. What started as climatic modelling has thus widened into research on land use and land cover, land-ocean interactions, ocean fluxes and ecosystem dynamics. These new fields of research would not have been possible without the use of both low-orbiting and geostationary satellites.

5.7 Telecommunications and navigation

In the early 1970s ESA decided to develop telecommunications satellites. The initial test satellites were followed by the European Communication Satellites. In 1977 the operational responsibility of these satellites was transferred to a new organisation, Eutelsat, of which the Netherlands was one of the founding fathers. Telecommunications through space is now a global commercial operation. It continues to grow rapidly both in terms of channels and access to broad- and narrow-casting. The government involvement in the Netherlands has, as a result, decreased considerably. Netherlands industry supplies solar panels (Fokker Space) and advanced attitude sensors (TNO) for communication satellites.

Satellites are becoming more and more important for navigation purposes. As the precision has increased, other applications beside the traditional navigation (ships, airplanes) have become possible. In the Netherlands, work is being done on satellite tracking of cars, not only for navigation, but also – experimentally – for road pricing. Another application is precision agriculture – in which fertiliser, pesticides and other inputs such as water are not spread evenly over a field but only applied in places where they are really needed. In this way Dutch farmers hope to increase the productivity of their lands and at the same time decrease the burden on the environment. TUD has developed the LAMDA-method for very precise navigation based on satellites.

6 Conclusion

In the 45 years that have elapsed since Sputnik-1 circled the Earth, space has become an integral and utterly normal part of every day life in the Netherlands and other industrialised countries. Satellite images of weather systems appear on our televisions and the pages of our newspapers and we don't even blink. Our voices travel to and from space when we make a telephone call and the fact that we can receive TV-programmes from all over the world has ceased to amaze us.

As a relatively small country the Netherlands has never had the funds nor the capacity to become an independent 'space nation', competing with the USA and the USSR. Still it was one of the first countries to recognise the importance of space, not only for the promotion of science or just for commercial purposes, but also as a tool for forging peace among nations and stimulating international cooperation. This remains an important driving force behind Netherlands space policy.

It began with scientists who had a great interest in space; astronomers who wanted a space platform to look at the sky undisturbed by the Earth' atmosphere and geophysicists who wanted to study the Earth from 'outside'. To realise these platforms, advanced technology was needed together with large investments in space projects. Commercial interest grew as the money became available, thanks to an unprecedented economic growth in the second half of the 1960s.

In the Netherlands this was illustrated by the development and operation of two satellites: ANS and IRAS. The aims of their missions were not solely scientific. Although they set out to map the X-ray, ultraviolet and infrared sources in the Universe, they also had a commercial and political goal. Developing, building and operating these satellites made the Netherlands a space-going nation and demonstrated the capability of the Dutch commercial sector to the rest of the world.

In the beginning of the 1980s there was a definite change in space policy. As public support dwindled – partly due to an economic recession – the objectives of Dutch space policy had to be (re-)formulated. Spending large sums of money just to satisfy scientific curiosity was no longer accepted. The practical use of space, for communications, weather forecasting, Earth observation and microgravity research and development became the most important driving force for development. At the same time the organisation of space activities was formalised.

In the twenty years that have passed since then, the Netherlands space sector has become an integral part of society. Space research is still an important driving force, but so are Earth observation, new production processes, biological research and the more commercial sectors of weather forecasting and telecommunications. Dutch companies and research institutes form a strong network capable of developing and building complicated subsystems for satellites, rockets and for the international space station that is now being built.

Looking back though, the exploration and use of space has never been 'normal'. It has only developed thanks to people who had a vision and the drive to turn that vision into reality: the astronomers who wanted to know more about our universe; the geophysicists who wanted to know more about our remarkable planet; the engineers who stretched their creativity beyond its limits; the companies that were willing to put their money on, sometimes shaky, projects; the civil servants who searched every nook and cranny for money to fund these endeavours; the diplomats who constructed the treaties and conventions to ensure the peaceful use of space and the cooperation among the erstwhile so divided nations. Without denying the importance of the knowledge and experience gained, this peaceful co-operation might well have been the most important result of space exploration.

7 Sources

Concretisering ruimtevaartbeleid en Nederlandse inzet voor ESA Ministerconferentie 2001, Letter from the Minister of Economic Affairs to Parliament, October 2001, 24 446/12.

Evaluatie ruimtevaartbeleid, Letter from the Minister of Economic Affairs to Parliament, July 2001, 24 446/11 .

Learning in space, earning in industry, spin-off van ruimtevaart in Nederland, NISO, 2001.

Ruimtevaart in het nieuwe millennium, Letter from the Minister of Economic Affairs to Parliament, May 1999, 24 446/7.

The Netherlands Agency for Aerospace Programmes – 50 years, NIVR, 1997.

Ruimteonderzoek in Nederland, SRON, 1997.

Ruimtevaart: terug op aarde, Fokker Space BV, 1997.

The Netherlands in space, Minister of Economic Affairs, 1996.

Een visie op de toekomst, Ruimtevaart, April 1996.

Ministerconferentie ESA 1995: *Ruimtevaart onderweg naar 2000*, Letter from the Minister of Economic Affairs to Parliament, October 1995, 24 446/1.

75 Years of aerospace research in the Netherlands, NLR 1919-1994, NLR, 1994.

Space technology in the Netherlands, Ruimtevaart, August 1993.

Van ANS naar Leiden, Fokker Space Systems BV, 1993.

Space activities in the Netherlands, Ruimtevaart, June 1990.

Europe: stepping stones to space, Lacoste, 1990.

Ruimtevaart in de samenleving, Ruimtevaart, April/June 1986.

Ruimte Technologie, Ruimtevaart, April/June 1985.

Tien jaar na de ANS-lancering, Ruimtevaart, August/October 1984.

Infra-red astronomical satellite, J. British Interplanetary Society, January 1983.

De ruimtevaart in de jaren '80', Letter from the Minister of Education and Research to Parliament, May 1982, 17 294/2-3.

Krige. J & A. Russo, *Europe in space 1960-1973*, ESA SP-1172.

Voorstel tot ontwikkeling van een Nederlandse Astronomische Satelliet, Fokker et al., 1966.

Acronyms and Abbreviations

ANS	Astronomische Nederlandse Satelliet
ARA	Advanced Rigid Array
ARPU	Attitude Reference and Programme Unit
BCRS	National Remote Sensing Board
COPERS	Commission Préparatoire Européenne de Recherche Spatiale
COS-B	ESRO/ESA Gamma Ray Satellite
COSPAR	Committee for Space Research (of ICSU)
CRV	Crew Return Vehicle (ISS)
DAX	Dutch Additional Experiment. (on IRAS)
DFVLR	Deutsche Forschungs- und Versuchsanstalt für Luft und Raumfahrt (now DLR)
DMS-R	Data Management System for the Russian Service Module (ISS)
TUD	Delft University of Technology
ELDO	European Launcher Development Organisation
ELDO-PAS	ELDO Perigee-Apogee Satellite
EOS CHEM	Earth Observing System Chemistry Mission (now EOS AURA) (NASA)
ERA	European Robotic Arm
ERS	European Remote sensing satellites
ESRO-2	ESRO's first satellite
ESTEC	European Space Research and Technology Centre
EU	European Union
Eureca	European Retrievable Carrier
GOME	Global Ozone Monitoring Experiment
GROC	(Netherlands) Geophysics and Space Research Committee
HERA	Hermes External Robotic Arm (now ERA)
ICANS	Industrial Consortium Netherlands Astronomy Satellite
ICIRAS	Industrial Consortium IRAS
ICR	Interdepartmental Commission for Space Research and Technology
ICSU	International Council of Scientific Unions
IRAS	Infrared Astronomy Satellite
ISO	Infrared Space Observatory (ESA)
ISS	International Space Station
ITC	International Institute for Aerospace and Earth Sciences
IWACXS	Imaging Wide Angle Camera for X-ray Sources
JIPEG	Joint IRAS Project Executive Group
JPL	Jet Propulsion Laboratory (NASA)
KNAW	Royal Netherlands Academy of Sciences
KNMI	Royal Netherlands Meteorological Institute
LPG	Liquid Petroleum Gas
L-Sat	Large (telecommunications) Satellite (ESA)
MIT	Massachusetts Institute of Technology
MSG	Microgravity Science Glovebox
MSG	Meteosat Second Generation

NETSAT	Netherlands Satellite
NISO	Netherlands Industrial Space Organisation
NIV	Netherlands Agency for Aircraft Development
NIVR	Netherlands Agency for Aerospace Programmes
NLR	National Aerospace Laboratory
NRT	NIVR Space Technology programme
NWO	Netherlands Organisation for Scientific Research
OMI	Ozone Monitoring Instrument
PHARUS	Phased Array Universal Synthetic aperture radar
PTI	Philips Telecommunications Industry
PTT	Post, Telegraph and Telecommunications
RARA	Retractable and Retrievable Array
RAWB	(Netherlands) Science Policy Council
SAX	Satellite per Astronomia in raggi-X (now BeppoSAX)
SERC	Science and Engineering Research Council (UK)
SRON	Space Research Organisation of the Netherlands
TERS	Tropical Earth Resources Satellite
TIXTE	Timing and Imaging X-ray Transient Explorer
TNO	Netherlands Organisation for Applied Scientific Research
TPD	TNO Physical Laboratory
TUD	Delft University of Technology
XMM	X-ray Multi-Mirror Observatory (now XMM-Newton) (ESA)

Appendix I: Netherlands expenditure on space activities: 1972-2001 (million Euros)

year	*72*	*75*	*78*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*
ESA	4	10	12	22	25	28	36	42	41	42	46	39	43	53
Eumetsat											2	2	3	2
Bilateral												1	1	3
National	8	5	19	14	16	14	12	11	11	12	12	13	15	17
Total	**12**	**15**	**31**	**36**	**41**	**42**	**48**	**53**	**52**	**54**	**60**	**55**	**62**	**75**

Year	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*00*	*01*
ESA	59	68	71	70	80	91	85	74	82	69	(59)
Eumetsat	2	2	3	4	4	7	6	10	12	12	(12)
Bilateral	7	9	5	2	16	3	5	11	5	2	(10)
National	15	16	17	16	17	17	20	20	27	18	(21)
Total	**83**	**95**	**96**	**92**	**117**	**118**	**116**	**115**	**126**	**101**	**(102)**

Appendix II: Milestones in Netherlands Space History

1957 A radio telescope is built in Dwingeloo.

1958 Dutch astronomer Henk van de Hulst becomes the first president of COSPAR, the Committee on Space Research of ICSU. Also in 1958, Amsterdam hosted for the first time the yearly Congress of the International Astronautical Federation (IAF).

1959 The Netherlands Geophysics and Space Research Committee (GROC) is formed as part of the Royal Netherlands Academy of Science.

1960 Geoscientists from the Technical University of Delft start using (existing) satellites for triangulation. Later on, satellite laser ranging was introduced.

1962 The Netherlands becomes one of the founding fathers of ESRO, the European Space Research Organisation and ELDO, the European Launcher Development Organisation. In that same year it is decided that the ESRO Technology Centre ESTEC will be based in the Netherlands.

1966 Netherlands space industry submits a proposal to build a Netherlands Astronomy Satellite. In that same year the Interdepartmental Commission for Space Research and Technology (ICR) is formed to co-ordinate government space efforts.

1967 Princess (now Queen) Beatrix officially opens ESTEC in Noordwijk.

1970 The government gives ANS, the Netherlands Astronomy Satellite the go-ahead. In that same year Delft University of Technology starts a course on space technology and NIV (Netherlands Agency for Aircraft Development) is transformed into NIVR (Netherlands Agency for Aerospace Programmes.

1973 A ground station for satellite communication is opened in Burum by Queen Juliana.

1974 On 30 August ANS is launched from the Western Test Range in California by a SCOUT-rocket.

1975 The government gives the green light for the building of IRAS, the Infra Red Astronomical Satellite.

1982 The government publishes a White Paper on space in the 1980s ('De ruimtevaart in de jaren '80'). No third satellite but an emphasis on the practical use of space and space technology.

1983 On 25 January IRAS is launched from the Western Test Range and operates smoothly until 22 November when it runs out of coolant (liquid helium). In the same year GROC becomes the Space Research Organisation of the Netherlands (SRON) under the umbrella of the Netherlands Organisation for Scientific Research (NWO).

1985 Wubbo Ockels, a physicist from the University of Groningen flies with Spacelab and becomes the first and at present only Dutch astronaut. On the same flight the Glovebox flies for the first time in Spacelab's Biorack.

1986 Foundation of the National Remote Sensing Board (BCRS) which existed until 2001.

1987 ESA Ministerial Conference in The Hague: Establishing the space activities for the 1990s (incl. approval of Ariane-5 and Columbus, Europe's main ISS element).

1989 The Netherlands Industrial Space Organisation (NISO) is founded as a forum for the space industry and a sounding board for the government.

1995 The ESA Infrared Space Observatory (ISO) is launched carrying a spectrophotometer designed and built by SRON. In the same year the Dutch designed Global Ozone Monitoring Experiment (GOME) is launched aboard ERS-2

1996 The Italian-Dutch satellite SAX is launched for mapping the X-ray universe with two wide angle X-ray cameras built by SRON on board.

1999 NASA's advanced X-ray research satellite Chandra and ESA’s X-ray Multi-Mirror satellite Newton are launched with SRON instruments.

2001 Government policy on space is evaluated and its goals are re-established.

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