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AN OVERVIEW OF DUTCH PARTICIPATION IN THE SPACELAB D1 MISSION AND THE COLUMBUS SPACE STATION PROJECT

Netherlands Aerospace Agency

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16. Abstract

This paper contains articles and a few short descriptions of recent developments in the field of space travel. It provides information on research and technology in space and to facilitate contact between these two fields. A description is given of the successful Spacelab D-1 flight and the standard instrument package. The Netherlands experiments in the D-1 mission, the next Spacelaf flights, and the Columbus program are discussed.

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SPACE SHUTTLE, SPACELAB AND SPACE STATIONS

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The NVR, a member of the International Astronautical Federation (IAF), was established in 1951 to provide information on research and technology in space and to facilitate contact between these two fields.

The NVR has developed a large scope of activity to further these goals. This includes the publication of the bimonthly journal RUIMTEVAART (in Dutch) and the organization of lecture tours, excursions, presentations, etc.

Lectures have been presented by national and international experts in the field. These have been subdivided into two categories:

- afternoon meetings for specialists
- evening meetings designed for a wider public interested in space travel.

Symposia, excursions and film presentations at regular intervals have also been organized.

The journal RUIMTEVAART normally contains four major articles and a few short descriptions of recent developments in the field of space travel. In addition, issues dedicated to a special theme are published regularly. These volumes can be ordered separately from the NVR in Utrecht. The volumes which have appeared so far are: Remote Sensing (Feb 1980, 124 pages), Telecommunication Satellites, L-Sat (Jun 1982, 80 pages), IRAS (Jun 1983, 72 pages), Space Shuttle/Spacelab (Mar 1984, 100 pages), Perspectives in Space Travel (Oct 1984, 72 pages), and Space Technology (Apr 1985).

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* Numbers in margin indicate foreign pagination.

THE SUCCESSFUL SPACELAB D-1 FLIGHT

The Spacelab D-1 mission, which ran from October 30 to November 6, 1985 was /23 more than 100% successful. The nearly 80 experiments, nine of them from the Netherlands, were carried out to the satisfaction of the researchers. At first there were a few problems, mostly with the furnaces, but these could be corrected to a great extent by the astronauts. Wubbo Ockels, who can reflect back on an excellent flight, snipped the correct red wire in one of the furnaces and that solved one of the problems. At first these difficulties caused delays numbering in the tens of hours, but eventually all experiments could be carried out during the seven-day flight. An experiment from the University of Delft (TH-Delft), the second-last task scheduled in the mission, on the solidification of cast iron was successfully completed. Unfortunately the results of the Netherlands' experiment on frog's eggs were not ideal. Only the German experiment on the mixing of salt solutions failed. Because several experiments, including two from the Netherlands on fluid state physics, were able to collect data during an additional cycle, and the fact that new additional tests could be inserted, the flight direction declared that the mission was more than 100% successful. This flight was largely dedicated to research in the fields of material science, physics, chemistry, biology and related fields, where use could be made of the microgravity conditions (10^{-3} to 10^{-5}g) on board.

THE STANDARD INSTRUMENT PACKAGE /24

Most of the experiments were carried out with the standard instrument package. As well the astronauts were able to carry out small experiments on their own. These included the Netherlands' experiment on the connection between speech and expression, and the experiments shown many times on television where a rod held firmly in the hands of one of the astronauts suddenly shot free from his grasp. The Materials Science Double Rack consisted of a reflecting furnace, a gradient furnace and an isothermal furnace, a cryostat, a thermostat for high temperatures and the well-known Fluid Physics Module. This rack was also on board the first Spacelab flight at the end of 1983. Experiments were carried out in these various multipurpose subunits on the solidification of metals, the growth of crystals and on fluid physics properties. In the Process Chamber physical processes were studied using the optical diagonistic apparatus. The instruments used were the Holographic Interferometric Apparatus, Interdiffusion in Salt Melt and the Marangoni Convection Boot. In the MEDEA double rack, just as in the material science double rack experiments mentioned above, second generation experiments were carried out using improved furnaces and thermostats. Metals and semiconductors were melted and solidified here as well. The Biorack (an ESA contribution) consisted of three parts: two incubators with specific temperature ranges, a freezer/cooler unit, and a sealed unit for sample preparation. This last apparatus, the so-called glove box, was developed and built by Fokker and it functioned perfectly.

The experiments themselves took place in one of two standard units placed in the Biorack by the astronauts. The fourteen experiments had different goals but the effect of microgravity conditions on the growth of biological materials was /25
important in many of the experiments. Rails on which a space sled could be moved back and forth were laid down in the central corridor of Spacelab. The astronauts were buckled onto this sled and a helmet with instrumentation was placed on the head of the astronaut. These instruments measured eye movement and the temperatures in the inner ear where the equilibrium organs are located. The most important function of the tests with the sled was to obtain more insight into the phenomenon of space sickness. A few biological experiments were also carried out with instruments located in the system rack. Two instruments were also attached to the frame outside the module (in vacuum). These were the MEA facility containing apparatus for materials research and the NAVEX experimental packet for navigational tests.

THE NETHERLANDS EXPERIMENTS IN THE D-1 MISSION /29

The Netherlands' contribution to the Spacelab D-1 program was relatively large. Nine experiments proposed by the Netherlands were carried out. Dr. Wubbo Ockels also did some other experiments which included those proposed by students. The Netherlands' D-1 experiments will be described in this section.

Three experiments in the fields of material science and physics were carried out: two in the ESA Fluid Physics Module and one in the isothermal furnace. An experiment from the Technical Chemistry laboratory of the University of Groningen (Rijksuniversiteit Groningen) involved mass transport from the liquid to the gaseous state. Here the effects of density variations and of surface tension on the mass transport were determined. Two containers, filled with a mixture of water and acetone, were placed in the module. This research is important for the determination of the sizes of apparatus used in the chemical industry in processes such as distillation. The Marangoni convection which produces a circulatory motion of the liquid was clearly visible. This experiment was given as an example of the successful nature of the mission during a press conference in the flight direction centre in Oberpfaffenhoven. On the following day a third measuring cycle was carried out on this experiment.

The second experiment in the Fluid Physics Module, from the National Air and Space Laboratory (Nationaal Lucht- en Ruimtevaartlaboratorium) in Amsterdam, involved research on the dynamic behaviour of liquids. In this experiment the behaviour of liquids in various types of small containers was recorded on film. The motion of the liquid in the container as well as the effect of this motion on the container itself was measured. This research is important for the development of space travel systems which have containers with liquids on board. This experiment also received extra measuring time. The video pictures displayed were of good quality. At the last moment, the experiment from the material science division of the University of Delft (TH-Delft) on the effects of sulphur and phosphorus on the solidification of cast iron was carried out. This experiment, the second-last one of the entire mission, succeeded perfectly.

Six of the Netherlands' experiments in the D-1 mission were carried out in the field of the life sciences. These were: one biological experiment with frogs' eggs and five experiments in which the astronauts were involved. The experiment with frogs' eggs, from the Hubrecht Laboratory of the University of Utrecht (Rijksuniversiteit Utrecht) was carried out in the standard biorack facility. The purpose was to investigate how a tri-axially symmetric embryo develops from a mono-axial egg of a klauwpad under conditions of microgravity. One hoped here to obtain a better insight into the complex processes occurring during embryonic development. It appeared later that this experiment did not succeed. The experiment has received an additional opportunity for success on the IML-1 Spacelab flight in 1987.

The experiment from the Institute of the Physiology of the Sense Organs/TNO /30 (Instituut voor Zintuigfysiologie/TNO) concerned the modification of sense organ information in space originating from the effect of gravity on those organs which influence equilibrium. The astronauts carried out experiments both before and after the flight in the 'tilt chamber'. This experiment is important for investigations in the fields of sea, air and space sickness. Blood samples were collected from the astronauts before, during and after the flight. The University of Limburg (Rijksuniversiteit Limburg) received 1 ml of blood from these samples and determined the presence of osteocalcine in protein. This protein is manufactured in the bones and comes into play during the regulation of calcium loss from the bones. Ockels, on a request from the laboratory for animal physiology of the University of Groningen, carried out several tests on the effect of gravity on arm positioning. In this experiment he was blindfolded and was required to indicate specific distances using a scanning pen and a special ruler equipped with a device producing audible tones. Finally, two psychological tests proposed by the Max Planck Institute for Psycholinguistics in Nijmegen were carried out. Here the relation between speech and behaviour were investigated under gravity-free conditions and the spatial orientation of objects was described. The video pictures which were simultaneously transmitted on national television will be analyzed further.

THE NEXT SPACELAB FLIGHTS /31

At the present time there are six Spacelab flights planned up to 1989. The Earth Observation Mission (EOM) and the SL-4 mission have been planned for 1987/88.

The EOM flight is dedicated to atmospheric research and earth observation. Here, some of the European experiments already pretested in the first Spacelab flight will be carried out under better flight conditions. The SL-4 flight is dedicated to research in the life sciences. In 1988 and 1989 there will be a few Spacelab missions using the International Microgravity Laboratory (IML). Finally, a German/European D-2 mission dedicated to microgravity research has been planned for 1989. Researchers from the Netherlands will also take part in these missions. Already, scientists from the Universities of Groningen, Delft and Eindhoven, the City University and the Free University of Amsterdam, the University of Limburg, the TNO, the NLR and several other institutions have indicated interest in the facilities planned for these flights. The following instruments will certainly be included in either the IML or the D-2 (or both) flights: the new fluid physics laboratory, the critical point facility, the Biorack, various kinds of furnaces and the space sled. New proposals for experiments can be submitted to the SRON or the NIVR. Any experiment appropriate to these facilities is heartily welcome. One could think of proposals for the production of new materials, such as immiscible alloys, large crystals and pharmaceuticals. Experiments can also be submitted which require gravity-free conditions. Results could be important for the determination of the dimensions of apparatus on earth. Enterprises such as Philips, AKZO, Duphar, Gist-Brocades, Unilever and similar companies are expected to carry out research in space now that the possibilities offered by the Spacelab, rocket flights and, eventually, space stations are better known.

SOME BACKGROUND ON MICROGRAVITY RESEARCH CARRIED OUT BY THE NETHERLANDS DURING D-1

Interest has already been shown in the Netherlands in various fields of science and technology for experiments in Spacelab. Since 1974 the Netherlands Institute for Aircraft Development and Space Travel (NIVR - Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart) has encouraged research in the use of Spacelab. It has done this through the organization of several symposia. Some preliminary experimental studies were carried out before the first Spacelab flight. Eventually five well-defined proposals were submitted by the ESA for the first Spacelab flight. Three of these experiments were selected. One experiment from the NLR, one proposed by the University of Delft and one from the Catholic University of Nijmegen were carried out. These experiments were financed from existing budgets. The first Spacelab flight took place just before the end of 1983. In the early 1980's several proposals were made to the NIVR for future Spacelab and rocket flights. A Netherlands' program for microgravity research was begun by the NIVR in 1980. In this program instrumentation which would fit into the ESA standard facility was developed. In general this research was funded by the /32 scientific institutions involved. In 1986 the Foundation for Netherlands Space Research (SRON - Stichting Ruimte Onderzoek Nederland) in Utrecht took over the scientific responsibilities of the NIVR. The NIVR now concerns itself with the industrial and other applied aspects.

Since the Netherlands participates in the various ESA programs on microgravity its experiments can be placed on board the ESA flights. These include the Spacelab, TEXUS rocket flights and the EURECA space platform flights. In phases 1 and 2 of the ESA microgravity experimentstandard facilities, including Biorack, Anthrorack and liquid physics laboratoria, were developed which could be placed in the various flights of Spacelab (D-1, D-2, IML, etc.). The Netherlands provides 4% of the total budget and, as a result, its experiments are able to be placed on board. The Netherlands also participates in the EURECA space platform program. Three experiments from the Netherlands have already been selected for the first EURECA flight in 1988. These experiments also obtain financial support from the Netherlands microgravity program mentioned above.

THE COLUMBUS PROGRAM

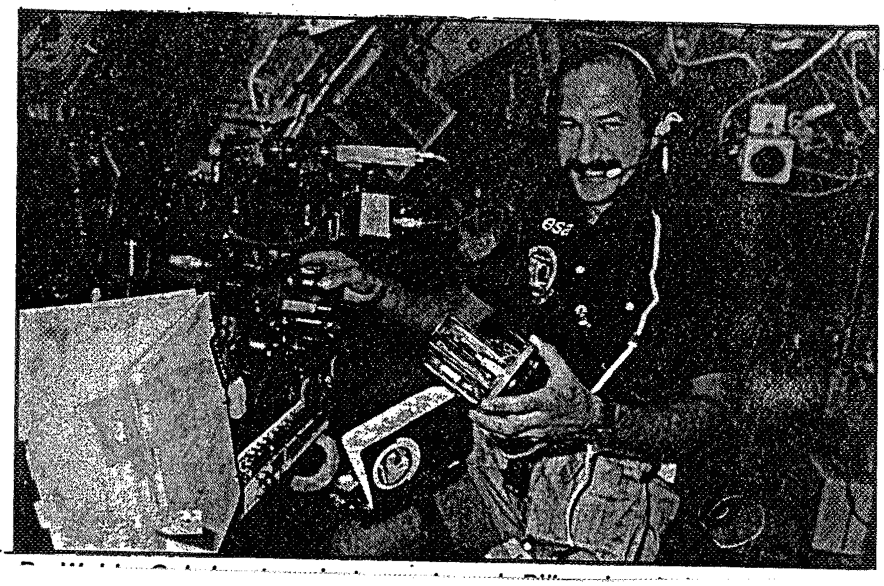
Europe is about to construct the Columbus space station. The eleven countries which are members of the European Space Agency (ESA) approved this program during a ministerial conference in Rome at the end of January 1985. The Netherlands participated in this conference. In the next two years the scope of this program will be more clearly defined. This phase B study will last for some time after 1987 since the president of the USA has announced, at the start of 1986, a delay of about two years in the space station program. It is possible that the Challenger catastrophe in January 1986 will affect the timing as well. Only toward the end of the 1980's will the construction of the elements of the American and European space stations be able to begin. In the middle of the 1990's Columbus will be connected to the American space platform, 500 years after Columbus, a European, first set foot on American soil. With this program Europe will maintain its contact with world-wide events in the field of space travel. With its own carrier rockets and its own space station , Europe can guarantee its position as a space power. One of the important reasons for the construction of Columbus was the fear that Europe would fall behind the USA, USSR and Japan in the fields of space technology, fabrication of materials, biotechnology and similar fields and in the commercial spin-off from this research. The Columbus space station contains many elements including a habitable module which besides serving as a laboratory can also be used for the storage of materials and as living quarters. It will also contain space platforms and several instruments for research. At the same time, systems, in space and on the ground, will be developed which will determine the precise evolution of the use of space stations. These systems will include ground-bases communication systems among other things. /35

At first, plans call for close co-operation with the United States. The European module will be coupled to the NASA station. But it is possible that in the years 1990/2000 Columbus will fly independently. Then, perhaps, components put into orbit with the future European launching system, or with Space Shuttles, will be coupled to the European space station. It is possible that a European Space Shuttle based on the French Hermes or on the British Hotol system will be in operation. The current Columbus program is based on co-operation with the United States because the costs of an independent system are very high and because Europe does not yet have the infrastructure (ground facilities, telecommunication satellites, etc.) to be able to use efficiently the space station.

The Columbus module mentioned above is based on the European Spacelab. This module which will be coupled to the American space station in the 1990's will get its electrical energy and other power from the American station. A further Columbus module will be able to fly independently and will use the European solar panels which will be connected to the module for its electrical energy. The European space platforms which form part of the Columbus project are based on the existing systems such as the Spacelab pallet and the EURECA platform.

THE NETHERLANDS INTEREST IN COLUMBUS

The Netherlands has agreed to a 4 to 5% participation in the ESA definition study for Columbus. Industries and institutes in the Netherlands such as Fokker, NLR and BSO will carry out studies on the solar panels, hybrid heat pipe radiators, two-phase heating systems, subsystems for controls, parts for robot arms, data collection systems, air locks, robot test facilities, operational aspects and instrumentation for the use of space stations. Industry and laboratories in the Netherlands will be involved actively in the definition of the space station. In this way advanced subsystems will be developed by Netherlands' industry and the competitive position of the Netherlands will be improved. Even small and medium-sized companies will be involved in these various activities. Philips, perhaps, will develop a new compact disc system for the storage of data. Researchers in the Netherlands are already involved in the definition of the facilities for the space station. Scientists at the Universities of Nijmegen, Utrecht, Groningen and Limburg are defining the biomedical facilities while colleagues at the NLR, Fokker and the Universities of Groningen and Amsterdam are actively involved in the development of instrumentation for fluid physics. Eventually astronauts and experts from the Netherlands will use the various facilities for space and earth observation.

 /23

Dr. Wubbo Ockels placing an instrument from the University of Groningen in the Fluid Physics Module

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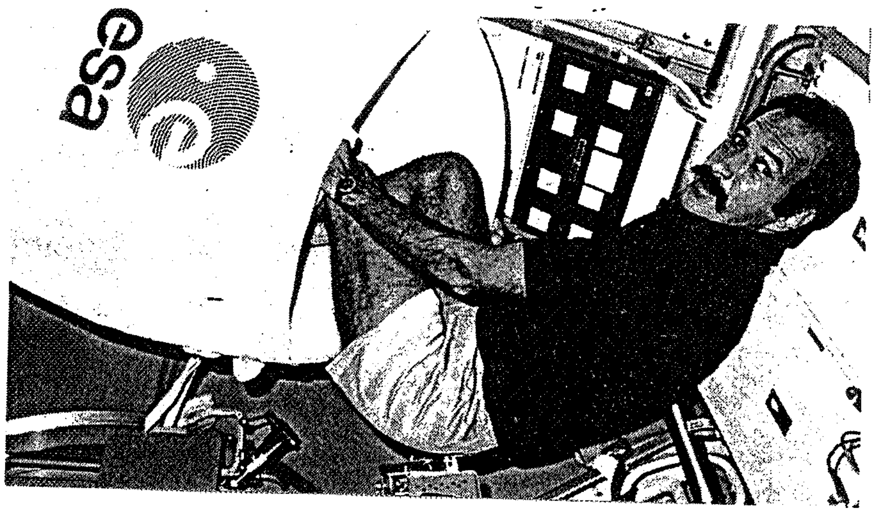
The crew of the Spacelab D-1 Mission

 /30

Wubbo Ockels in his 'own' sleeping bag

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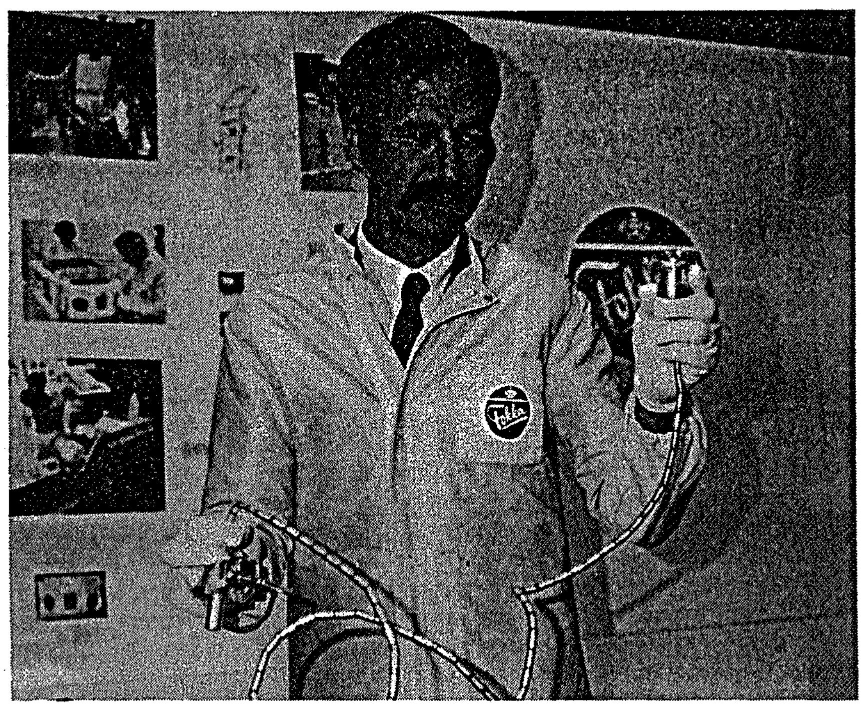 /32

Wubbo Ockels carried out various experiments during the mission. This is a test of a cable constructed out of cylindrical and spherical links. Such cable could make possible better docking procedures. This cable was his own idea and was developed by Fokker and the TNO

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ii